The Effectiveness of iPad in Enhancing Instruction in Mathematics Teaching and Learning for Secondary Schools in Saudi Arabia

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Abstract

Tablet devices, such as the iPad, have emerged among the most essential educational tools due to features that facilitate the learning and teaching process without the limitations of time or location. Tablet devices and their range of applications (apps) can potentially improve both the teaching and learning processes and the communication between teachers and students. However, there are concerns about the benefits of using tablet devices and their different apps in the learning process, including the extent to which students actually use them for educational purposes. Therefore, this study sought to evaluate the effectiveness of iPad usage, including various applications, in terms of improving students' mathematics achievement and motivation based on accomplishing the goals of mathematics lessons in a 10th grade secondary school in Saudi Arabia (SA). To achieve this, iPad devices were deliberately introduced to support teachers and students in the teaching and learning of mathematics. The study also sought to evaluate the impact that iPad usage and the various applications would have on mathematics teachers' perspectives regarding the teaching of mathematics concepts in the same secondary school in SA.

While there are now many opportunities for technology to be used in the education sector, there is still a need for a better understanding of how and to what extent iPad devices and the various dedicated education apps can be integrated in teaching and learning in secondary schools in SA, particularly with regard to mathematics education. This is an important matter, as it has several wider implications for curriculum design, classroom practice, teacher and student education, and the development of greater understanding of learning and cognition in technology-enhanced learning settings.

To generate insights into the effectiveness of introducing iPad devices and various apps related to teaching and learning mathematics in Saudi secondary schools, the study used a logical model design for program evaluation based on a mixed-method approach. A quasi-experimental design was applied as the primary quantitative approach, while the secondary qualitative approach was carried out simultaneously. The quasi-experimental period stretched over two months. In the first month, class A was the treatment group and pupils in that group used iPads and relevant apps to learn mathematics, while class B was the control group, with the pupils using traditional methods based on using books, paper, and pencils. The treatment was switched between the two classes in the second month. Data were collected from a pre-test and two post-tests (quantitative data), semi-structured interviews,

and a focus group interview (qualitative data). The participants in this quasi-experimental study included 50 students from two classes in the 10th grade (25 participants in each class), as well as four teachers who took part in the interviews. The focus groups comprised eight groups of six students, four groups from each class. The quantitative data were analysed using a multi-statistical method in IBM SPSS and the qualitative data were analysed using thematic analysis.

The study uncovered a wide range of evidence indicating encouraging results for the integration of the iPad and relevant applications in the process of teaching and learning mathematics in educational systems, particularly in Saudi Arabian secondary schools. The findings of the quantitative data showed that the iPad devices and the applications used significantly improved students' achievement in the period during which they were encouraged to use these devices to learn mathematics, with better results than when they used the traditional methods (books, paper, and pencils). However, this improvement might not occur if the students or teacher are not trained to use the device and the various educational apps employed in this quasi-experimental study.

The findings of the students' focus group interviews revealed largely positive views towards the use of the iPad device and its apps, such as education platform apps and various communication apps. This device and its apps promoted students' performance in mathematics by providing immediate feedback, improving their mathematical skills, helping them to prepare for tests, and assisting them to search for information, thus equipping them with a better understanding of the content. The majority of students also found the use of these devices to be a source of motivation and they encouraged them to learn mathematics and achieve the goals of the lesson plans to a greater degree than when working with conventional methods. Moreover, the students were dependent on this device and its apps for their learning and viewed is as a useful and supportive educational tool for facilitating their communication and enhancing their collaboration, as well as organising their time and studies. However, while most of the students believed that the iPad and its apps encourage them to study mathematics, some students reported that they were not inclined to use this device to learn mathematics. They stated that their preference was to handwrite notes or complete mathematics activities using paper and pencil because they found it difficult to write certain symbols on the device. They also reported encountering several obstacles, such as interrupted or slow internet connection, low battery level, difficulty recharging the battery, some apps hanging during use, and the iPad screen breaking easily.

The findings of the teacher interviews showed that, in general, the perception was that both teachers and students benefitted from the use of the iPad, and the apps were deemed useful tools for facilitating and improving the in-class teaching and learning processes. They believed that this device assisted them in achieving the lesson objectives faster than previous teaching methods. It also helped them to immediately ascertain their students' academic level, improve their students' performance, motivate their students to learn mathematics, and provide instant feedback for their students. The findings also demonstrate that iPads facilitated collaboration and communication among students, as well as developing their creativity, critical thinking, and self-reliance skills.

However, the results also illustrated that there are several elements that make both teachers and students in SA public schools unwilling or unable to use the device and its apps. For instance, the infrastructure of schools may not be equipped to integrate the technology, especially so in the case of iPads. In addition, teachers were afraid to integrate iPad use in the classroom because they lacked the knowledge to use this device and its apps for educational purposes. They also faced continuing obstacles and limitations in using the iPad and its apps in the classroom environment. These obstacles were mainly associated with technical issues, such as lack of connection to the internet or battery problems. Other issues included students forgetting to bring their iPad device or using non-instructional apps in the classroom. The study, therefore, proposes some solutions to these obstacles, which could be beneficial for schools to consider before deciding whether to integrate iPad devices and their various apps in the classroom.

Therefore, this study helps provide insights and evidence regarding iPad usage with various educational apps in the classroom. The implications of these findings are considered in relation to students' development, teachers' development, and the educational technology and school development curricula in SA secondary schools. Some suggestions regarding future research based on this are also offered.

Dedication

I would like to dedicate this work to my beloved parents, who have always supported and encouraged me throughout my PhD studies. Their support and prayers have given me the inspiration to achieve my goals. I feel they are always with me, guiding me to do the right thing, even though they are far away.

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Author's Declaration

I declare that, except where explicit reference is made to the contribution of others, this dissertation is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution.

I used some of the content from the following publications in this thesis.

Journal Articles

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Aldossry, B. and Lally, V. (2019). Assessing the Impact of Using iPad in Teaching and Learning Mathematics within Saudi Arabian Secondary Schools. *INTED2019 Proceedings*, pp. 1423-1428.

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Aldossry, B. (2020). The Impact of Using an Ipad on the Achievements of Secondary School Students in Saudi Arabia, *INTED2020 Proceedings*, pp. 1412-1416.

Name: Badi Shara F Aldossry

Signature

List of Abbreviations

CA	Continuous assessment
ESD	Educational Services Department
ETEC	Education and Training Evaluation Commission
Future Gate	Digital portal website
GAS	General Authority for Statistics
GAT	General Aptitude Test
GE	General education
IBM	International Business Machines
ICMI	The International Commission on Mathematics Instruction
ICT	Information and communication technology
iEN	National Education Portal
MoE	Ministry of Education
MoHE	Ministry of Higher Education
MoGE	Ministry of General Education
MNSCD	Mathematics and Natural Science Curriculum Development
NCTM	National Council of Teachers of Mathematics
NMSI	National Math and Science Initiative
NTP	National Transformation Programme
PC	Personal computer
PISA	Program for International Student Assessment
QIYAS	General abilities tests
RCJY	Royal Commission for Jubail and Yanbu administration
SA	Saudi Arabia
SAR	Saudi Arabian Riyal
SPSS	Statistical Package for the Social Sciences
Tatweer	King Abdullah bin Abdul-Aziz Project for Public Education Development
TI	Texas Instrument
TIMSS	Trends in International Mathematics and Science Study
US	United States
USB	Universal serial bus

Chapter 1 Introduction

1.1 Introduction

In secondary schools in Saudi Arabia (SA), some students encounter difficulties with mathematics, which negatively impacts their achievement and discourages them from learning. In particular, students find that they are unable to understand and solve mathematics problems, deal with numbers, and accomplish the mathematical operations expected of them (Alafaleq & Fan, 2014; Chan, 2009). Mathematics, as an academic subject, is one of the most complex and challenging subjects for teachers and students in SA to teach and learn, particularly in terms of mathematics concepts such as equations and logic (Aldossry & Lally, 2019a). It is not surprising that students typically feel that mathematics is a hard subject that encompasses many complex areas (Wendling & Mather, 2008). Thus, the Ministry of Education (MoE) in SA aims to improve students' values, performance, and skills. Another MoE aim is to develop the philosophy, policy, and goals of learner-focused educational curricula by developing teaching methods in line with both teachers' views and Saudi Vision 2030 (MoE, 2020; for more details about Saudi Vision 2030, see section 2.11). Another key point is to promote positive attitudes towards mathematics learning among secondary school students as this will foster the development of strong capabilities in this area, which can be carried forward to their future university education and careers.

The MoE established the Saudi Mathematics and Natural Science Curriculum Development (MNSCD) project, which is one of the most significant educational projects in SA. Its purpose was to improve the mathematics curriculum in schools and ultimately enhance the level of students' achievement in mathematics (Almaleki, 2010). However, students' lack of willingness to learn mathematics and their low achievement levels were – and continue to be – a significant problem (Almaleki, 2010). As noted in the Trends in International Mathematics and Science Study (TIMSS), it is evident that SA students' achievement is substantially lower than the international average scores in all exams over the years in mathematics for the fourth and eighth grades (Mullis et al., 2020). For example, in the most recent mathematics rankings (TIMSS, 2019), SA was ranked 53rd out of 64 nations and 37th out of 46 nations for the 4th and 8th grades, respectively. This placed Saudi students' achievement in mathematics at the bottom end of the TIMSS rankings. Additionally, in the 2018 Program for International Student Assessment (PISA), of the participating nations, Saudi male students performed worst (Organisation for Economic Cooperation and Development [OECD], 2020).

The SA government allocated SAR 202 billion in the educational budget for development in 2019 and it made significant efforts to develop the educational system (Ministry of Finance [MoF], 2020), with one of the primary aims being to establish effective technology usage in the mathematics classroom. In line with global trends, this integration of technology in education is a component of the National Transformation Programme (NTP) for the education sector, initiated by the MoE in 2016 under Saudi Vision 2030. The MoE entered into a contract with the King Abdullah bin Abdul-Aziz Project for public education development (Tatweer; a large company discussed in greater detail in Chapter two) to provide high-quality solutions and implement the use of technology, technological solutions, and digital transformation in the education sector in accordance with Saudi Vision 2030 and international growth (MoE, 2020). Consequently, teachers and schools have become focused on improving learning and teaching methods through the new technology tools to achieve the goals of lessons (Barrett-Greenly, 2013).

Over the years, attempts have been made in the SA education system to address the problem of the low achievements in mathematics by developing the mathematics curriculum. Despite this, it is an ongoing issue that has become a serious concern to educational stakeholders, with the results of TIMSS and other international assessments such as PISA further illuminating the problem. One issue is that Saudi students still depend heavily on their teachers for their learning and find it difficult to be more independent in a teacher-centred educational context (Albadry, 2018). Although the MoE has tried to implement student-centred strategies in recent years, the teacher-centred approach is still prevalent and can affect students' performance in mathematics and cause the classes themselves to feel boring and unappealing.

Several studies have examined the use of technology in education and concluded that employing technology in teaching and learning enhances the capacity of students to solve mathematics equations and confirm their answers (Gadanidis & Geiger, 2010; Kastberg & Leatham, 2005; Pierce & Stacey, 2010). According to Regan (2014), technology supports students in the mathematics classroom, as it is a learning tool that can be used in a variety of creative ways to better understand mathematics processes and activities, thereby improving students' skills. Blackwell (2014) has expressed positivity about the significant role of technology in the classroom. It is believed that technology provides a stimulus for the educational transformation that positively impacts student achievement.

The most recent technological phenomenon is the iPad and other tablet devices, which have made potential changes to the means of learning and become the focus of teachers at all levels and sectors of the educational system (Culén & Gasperini, 2011; McNaughton & Light, 2013; Murray & Olcese, 2011). Furthermore, most of the existing research on tablet devices has focused on the iPad. Given the popularity of this device for educational purposes compared to others, this study also focuses on the iPad. However, this research is concerned with the use of tablet computers in general; thus, what is learned from this research could be applied to the use of other tablet devices in teaching and learning. Blackwell (2014) contends that iPad or tablet use provides opportunities for individualised learning. Furthermore, the portable nature of this technology allows teachers to provide differentiated activities and go from one place to another. Thus, iPads and other tablet devices can support students in relating well to mathematics content by enabling them to learn and engage in practise activities through different mathematics applications (Preciado-Babb, 2012). It is critical that the education sector understands the effectiveness of iPad devices in mathematics teaching and learning in secondary schools in SA. Thus, this study aims to evaluate the effectiveness of iPad use on students' achievement, students' motivation, and teachers' perceptions. To facilitate and draw out optimal performance in mathematics among students, it is essential that the effect of iPad usage is fully understood by teachers and educators. The literature shows that only a few researchers have specifically explored the effect of using iPads on students' achievement in kindergarten and elementary schools in SA.

The integration of technology, such as tablet devices, in education systems is a strategy adopted by the majority of countries in the world to deliver optimal education for the 21st century. However, there are still some students and teachers who face obstacles in using these technologies and although some successfully manage to overcome such obstacles, others fail to adapt to the use of new devices. Such problems of integration that have been observed in SA are specific instances of problems observed more widely. A major obstacle for most education systems worldwide is the availability of funding for such projects. In contrast, SA provides an interesting context for observing the integration of the iPad in teaching and learning mathematics because the Saudi government supports the education sector by allotting a large part of its budget for developing education, as mentioned above. An additional reason for focusing on SA is that the MoE prioritises the introduction of new technology (e.g. Internet, smartboards, PCs, laptops, tablet devices) to public schools by providing technology for students and teachers under the Saudi Vision 2030 (for more detail see section 2.11). Thus, this investigation will help the Saudi government, as well as the education systems of other countries, to achieve the successful integration of technology.

The research that has previously been conducted incorporates studies in SA that are focused on the use of technology, such as computers, digital cameras, overhead projectors, and smartboards (Alelaiwi et al., 2015; Al-Jabri, 1996; Almalki et al., 2012; Al Shammari, 2017; Chan, 2004). Other research has examined the use of smartphones and tablets at different educational levels (Al-Bogami, 2017; Alfawareh et al., 2017; Alhazmi et al., 2018; Alzannan, 2015; Dhir, 2013; LaBelle et al., 2016). Most studies have focused on students' achievement and positive effects on attainment have been found from use of iPads (Zhang et al., 2015). However, other studies have found no differences between using tablet devices and the traditional method (paper and pencil) in terms of students' performance in mathematics or other subjects. Studies focusing on students' motivation and engagement have reported that compared to other learning methods, iPad use significantly improved students’ learning motivation. Other studies have reported that iPad use either did not motivate students substantially or had a negative effect. For example, Karsenti and Fievez (2013) found that iPads had a negative effect on learning and teaching processes for different reasons, such as being a source of distraction for students, reducing the amount of attention students paid to the teacher, and encouraging the use of social networking sites.

A few studies have focused on teaching mathematics using iPads or other tablet devices in the secondary school context, with most investigating the effect of tablet devices on students’ learning. However, no studies have considered the effectiveness of iPad use on both students' achievement and motivation, as well as teachers' perceptions; most studies have looked at them separately. This research considers them in combination in the context of a secondary school in SA with a view to improving understanding of learning and cognition in technology-enhanced learning settings. Moreover, to the best of my knowledge, this study is the first to attempt a treatment switch (iPad use) between two different classes in SA. This switch design will ensure that all students receive an equivalent experience of using the iPad device and its apps and none will be disadvantaged. This will also make it possible to determine the statistical significance of the results after each experimental period. Hence, the significance of the exploration of this area is justified, particularly in SA, which is the context of this study. This study aims to encourage greater support for iPad use to accomplish the goals of mathematics lessons at all school levels throughout SA, as well as in other education systems worldwide. It is also hoped that the findings of this research will support the Saudi MoE regarding the implementation of the iPad and its applications as teaching and learning tools in the education sector.

1.2 Aims and Objectives of the Research

The overarching aim of this study is to evaluate and understand how and to what extent the use of tablets such as the iPad in the classroom can support the development and achievement of students in mathematics and enhance motivation. Such understanding, in turn, can support the practice of teaching mathematics concepts in secondary school settings, both in SA and beyond.

I contribute to this general aim through fulfilling five specific objectives:

1. Objective: Identify research frontier. Activity: Conduct literature review.
2. Objective: Identify whether and to what extent use of the iPad affects student achievement and motivation levels in 10th grade secondary classrooms in SA. Activity: Field experiment and students' focus group interview.
3. Objective: Explore teachers' perceptions of factors that influence the adoption of iPads and applications in teaching mathematics in secondary school in SA. Activity: Interview.
4. Objective: Identify key challenges facing students and teachers when using the iPad in the classroom, with the aim of exploring possible solutions.
   Activity: Teachers' interview and students' focus group.

1.3 Conceptual Framework

The conceptual underpinning for this study was the need to evaluate the programme through which iPads and other tablet devices are introduced in the Al-Rowad Secondary School in SA. An embedded mixed methods design was used in this study to evaluate the use of iPads in the 10th grade. The embedded design is particularly useful when the researcher intends to embed a qualitative component within a quantitative research design, such as an experimental design. For instance, the researcher includes qualitative data for examination and follows up with an intervention process (Creswell & Plano Clark, 2011). In this research, the design was a logic model for program evaluation, which facilitated assessment of the effectiveness of the iPad intervention. Programme evaluation aims to determine if inputs or activities produce results that are in line with the expected or planned goals (Kellogg, 2004).

1.3.1 Programme Evaluation

The MoE and educational stakeholders must understand the needs of teachers and students sufficiently to be fully cognisant of the interventions that will guarantee the success of education. It is essential that any educational intervention is thoroughly planned and proficiently implemented (Johnson et al., 2009). Furthermore, precise assessment is key to successful school programmes (Sanders & Sullins, 2006). Although many organisations pour substantial resources and energy into the planning and implementation of an intervention, most disregard the subsequent assessment of its impact (Royse et al., 2006). The fact that in many schools there is a lack of programme evaluation shows the weakness of the intervention programmes. Schools cannot accurately evaluate programmes and subsequently the progress of students if the impacts of the interventions are not quantified. A key point is that schools must develop evaluation strategies that encompass the programme activities, their desired results, and measurable data to assess the impact of the intervention.

This study employs a logic model for programme evaluation as the basis for establishing the effectiveness of introducing iPads and other tablet devices in achieving the intended results for this school. Logic models offer a practical and simple guide for checking and confirming that a programme is working to achieve its intended results. The logic model included a flow chart style representation of the iPad intervention programme and the available resources, inputs, planned activities, and outputs, making it possible to determine and structure pertinent evaluation questions that would accurately reflect the impact of the programme. Figure 1-1 presents a simple graphic logic model that shows the elements used to plan and implement an intervention. The subsequent sections discuss the various elements of the iPad intervention programme.

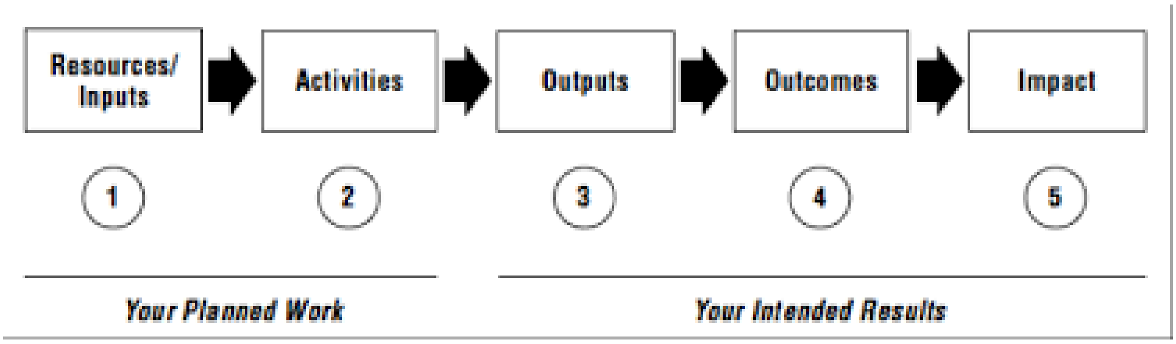

Figure 1-1 Basic logic model for evaluation (adapted from Kellogg, 2004, Logic Model Development Guide).

1.3.1.1 Programme inputs or resources

Arguably, financial support is the most important resource for the preliminary stages of an intervention programme (including the planning, implementation, and evaluation). Other significant resources include the mathematics curricula, participants, and professional development. The stakeholders of the Educational Services Department in Al Jubail City have provided substantial financial support to the Al-Rowad Secondary School, providing iPad devices for all students at the school. The resources in terms of participants included four mathematics teachers and 50 students from two classes in the 10th grade. The mathematics curriculum resources included lessons that covered the duration of this quasi-experimental study. Finally, the school, in cooperation with the Educational Services Department, oversaw the teachers' professional development by providing training courses on the use of the iPad and its various educational apps.

1.3.1.2 Planned activities

The iPad intervention could include certain planned activities by accessing the abovementioned resources. Planned pre-service activities took place in the months prior to the implementation, which included identifying, selecting, and inviting the two 10th grade classes to participate, reviewing the curriculum, and selecting the teachers with experience of iPads and other tablet devices. Planned instructional classes were incorporated into the mathematics curriculum and the planned implementation activities took place over a two-month period. These activities were separated into two phases, each lasting a month. In the first month, students in class A had access to the iPad devices for mathematics learning. They were also permitted to communicate with their classmates at any time via the iPads regarding their studies at school or at home to support their attainment and enhance their motivation. In this period, the students in class B used the conventional methods (mathematics books, pencils and paper) for their learning. In the second month of the implementation, the iPads were taken away from the students in class A, who then reverted to learning via traditional methods, and the students in class B started using the iPads for learning and communication in the same way as class A had in the previous month.

The school management supported the teachers' professional development via training courses. Thus, the teacher participating in the classroom intervention was well-trained in the use of the iPad and its various applications. The teacher subsequently trained his students in the use of the iPad and its apps to cover the lessons in the quasi-experimental period.

1.3.1.3 Programme outputs

Various programme outputs were identified to evaluate the intervention using iPads and associated apps in the education process (see section 4.7.2. During the first two months of the second semester of the 2018/2019 academic year, a total of 50 students participated in the intervention programme. They used the iPad for at least one mathematics lesson every school day on which they studied the curriculum. They were allowed to use the iPads and the apps, especially mathematics apps, at school, and were also permitted to take the devices home. Furthermore, the students could use social media apps to communicate with their classmates and share their knowledge.

Over the period of the intervention, the students were assessed three times (pre-test, first post-test, and second post-test) to evaluate its impact on their mathematics achievement. (The tests are reported in more detail in Chapter 5 and discussed in depth in Chapter 7.) In addition, the students were invited to participate in a focus group interview to evaluate the effect of the intervention on their motivation to achieve the goals of the lessons.

1.3.1.4 Programme outcomes

Programme outcomes can be measured if the planned activities are implemented using techniques that produce expected outputs. The iPad intervention outcomes included: (1) increasing students' achievement in mathematics by improving their performance; (2) improving students' motivation to achieve the goals of the lessons plans; (3) fostering higher levels of student engagement in the classroom; (4) encouraging communication and collaboration by developing relationships among the students, and among the students and teachers; (5) developing students' creative and critical thinking skills through mathematics activities; (6) developing students' self-reliance by encouraging them to study independently; (7) changing and enhancing teachers' perceptions regarding the teaching of mathematics concepts using the iPad device; (8) minimising obstacles for students; (9) reducing the potential obstacles to the use of iPads for teachers.

1.3.1.5 Programme impact

The iPad intervention operated under the assumption of the logic model that if inputs or resources could be assured and expended, the planned activities could successfully be implemented. This facilitated specific collection of the outputs produced by the programme. Likewise, the desired programme outcomes could be achieved if the outputs were generated at the required levels. Finally, to the extent that the desired programme outcomes were achieved, there was an impact on learning and teaching. Essentially, the specific impacts of the intervention were: first, that the teaching and learning process was significantly improved; second, the curriculum was designed more effectively; third, that classroom practices were fundamentally altered.

1.4 Research Questions

The study aims to investigate the effectiveness of the use of iPads and associated applications in enhancing students' mathematics achievement and motivation for learning in terms of accomplishing the goals of their mathematics lessons at a secondary school in SA. In addition, it aims to explore the effect of using iPads and the applications on the secondary school teachers' perspectives relating to the teaching of mathematics concepts in SA. It seeks to answer the following three research questions:

1. What are the effects of iPad use on students' mathematics achievement?
2. How does iPad use affect the motivation of students in learning mathematics?
3. What are teachers' perceptions of the effectiveness of using iPads for teaching and learning mathematics concepts?

1.5 Contributions of the Research

The research findings contribute to knowledge of how a comparatively new type of technology-enhanced learning, using tablet devices and apps, can contribute to learning and teaching processes and systems in education. Research is a core element of general education (GE) and therefore it is important to develop an understanding of the contribution of modern technology in the form of tablet devices to research. Most previous studies in the area have investigated the use of tablet devices in the general learning environment at different educational levels in SA (Al-Bogami, 2017; Alfawareh et al., 2017; Alhazmi et al., 2018; Alzannan, 2015; Dhir, 2013; LaBelle et al., 2016). This study contributes to the literature by evaluating the issue from a research perspective. The study is sensitive to the contextual and cultural issues of the evaluation study and draws out those findings that have wider relevance, as well as those that are specifically pertinent to Saudi GE. The findings of the study also offer notable insights that are beneficial to practice and policy in the Saudi GE system.

A significant impact of this study is the increased understanding it offers of the use of tablet devices and apps within a GE environment that has been enhanced with broader technology. Furthermore, it offers valuable insights into how such devices and apps can aid both students and teachers in educational processes. The study also contributes to the development of the logic model by facilitating an understanding of the factors that influence an intervention using tablet devices and their apps in the education sector in the particular context of GE in SA.

A quasi-experimental study consisting of a primary quantitative approach and a secondary qualitative approach was conducted at one secondary school in SA over a period of two months. Thus, an embedded design was used combining quantitative data (pre-test and two post-tests for 50 students from two 10th grade classes) and qualitative data (semi-structured interviews with four teachers and student focus group interviews with eight groups, each group comprising six students). During the first month of the quasi-experimental phase, class A was designated the treatment group (learning mathematics using iPads) and class B was the control group (learning mathematics using traditional methods). The traditional approach involved students learning mathematics based on teacher instruction and materials such as mathematics textbooks, worksheets, and pens or pencils. Subsequently, in the second month, the intervention was switched between the two classes, with class A becoming the control group and class B becoming the treatment group. Teachers, schools, and other researchers might implement this methodology to improve students' achievement and motivation in a similar field in SA or other countries seeking to integrate iPads in their education systems. The study will provide useful insights into the development of the educational process, as well as teachers' perceptions of teaching mathematical concepts and their pedagogical knowledge.

Furthermore, before the treatment, quantitative data were collected from both classes to gain pre-test measures, thus making it possible to determine whether or not there was a statistically significant difference between the two classes prior to treatment. Following the first treatment, i.e. after one month, data were collected through the first post-test from both classes to compare the results of the treatment. At the end of data collection, i.e. after the second month, data were collected through the second post-test from both classes to compare the results after switching the treatment.

A few studies have been undertaken on switching treatment groups, but no research has specifically evaluated how tablet devices and apps contribute to learning systems at secondary school level in GE in SA among two different classes. For instance, Stattel (2015) investigated the use of the iPad as an educational tool by switching treatment between two groups in one class at an elementary school, finding no significant difference between the class during the treatment week when using iPads and the non-treatment week when using traditional methods. Alzannan (2015) conducted a study that investigated the impact of using iPads on students' achievement in Arabic at kindergarten in SA. The researcher divided the class into two groups, one experimental group taught using iPads and the other the control group taught using traditional methods (textbooks, real objects, and flash cards). He found that students who used iPads achieved better than students who employed the traditional method.

To address the first research question, the quantitative data were analysed using multiple statistical methods in the Statistical Package for the Social Sciences (SPSS) software program. The second and third research questions were addressed by subjecting the qualitative data collected during the quasi-experimental phase to thematic analysis.

This research was designed to produce data that can be used as evidence to help counsel secondary school management in SA about the effectiveness of iPad use for teaching and learning mathematics, thus supporting their decisions regarding pedagogical needs. Furthermore, this research will be of relevance to researchers, contributing to their discussions about how tablet devices could make a difference in teaching and learning mathematics. There are still concerns about investing in the classroom use of tablet devices and this research provides evidence that can be employed to either support or reject their use in secondary schools.

By reviewing the current use of tablet devices and apps for teaching and learning in GE, this research presents students, teachers, school administrations, stakeholders, and other researchers with an overview of the factors that shape the perceptions affecting their implementation in an education environment. In addition, it illustrates the perceived obstacles to integrating tablet devices and apps and details possible solutions to address and overcome them, thereby informing better use of such technology.

The findings of this research also show that, overall, tablet devices and apps enhance learning and teaching in GE in terms of providing more opportunities to address different concepts. The results may accelerate the implementation of such technology in GE. Tablet devices and apps also clearly offer a range of pedagogical benefits in GE. This research reveals some of these benefits in terms of improving levels of student achievement and motivation. Tablet devices and apps are also perceived to develop engagement, communication, collaboration, critical thinking, creative skills, and self-reliance for students, together with offering convenience in pedagogical approach. The findings of this research will also be valuable for teachers, helping to illustrate how tablet devices can be used to enhance teaching and learning processes.

Despite the research being conducted meticulously, there were some limitations. First, this research involved only one secondary school in SA and the intervention was restricted to two months' duration. Therefore, the findings are not generalisable to all secondary schools in SA. However, the school is classified as a smart school in the country and the students' parents are highly educated, making it an excellent choice for the intervention. Nonetheless, the findings are limited to this context and it would be beneficial for future studies to extend not only the scope, but also to lengthen the duration of the intervention to at least four months, which would cover a full semester in the SA education system; alternatively a different duration could be chosen to cover a similar educational period in other countries. Second, the research explored the perceptions of four teachers who experienced using the iPad as a teaching tool, including the teacher who taught the two classes in this quasi-experimental study. All the teachers were male because the selected school was a boys' school. Under the education system in SA, the initial three years of education can be integrated and are taught by female teachers only; however, when this has been completed, the children are separated by gender and are only permitted to be taught by a teacher of the same gender. Thus, it is not possible for male researchers to access female schools for the purposes of conducting research.

1.6 Positionality

Growing up in SA, I have had experiences both as a student and as a teacher and I noticed that despite the availability of technological devices (e.g. smartboard, projector, computer/laptop) in most schools, classroom use of technology was minimal. When I was a secondary school student, the only teacher who used the computer was the computer science teacher in the computer lab, which I found the most interesting class. Furthermore, when I was a mathematics teacher, my attempts to integrate technology (e.g. smartboard connected to the Internet) in the mathematics classroom met with a positive response. Most of my colleagues attended my class at different times to gain experience of technology use. Indeed, the school management asked me to organise a workshop for all the teachers in the school on how to use technology in the classroom.

I believe that integrating technology, especially tablet devices such as the iPad, in the classroom is a way to improve teaching and learning. This gives students a chance to be active participants in all aspects of the lesson, rather than just passive recipients listening to the teacher's instruction. From my perspective, the use of tablet devices can have a positive effect not only on students' mathematics achievement and motivation, but also on the teachers' attitudes towards mathematics instruction, thus making the teaching and learning process more interactive.

I believe that the immediate feedback that tablet devices and related applications can provide enhance secondary school students' learning because it offers them a sense of accomplishment in their tasks and increases their motivation and self-confidence. Use of tablet devices can also benefit teachers, helping them to identify differences between students quicker than other strategies, as well as increasing students' learning autonomy and reducing their dependence on teachers.

In terms of my background, I have been working as an elementary teacher in my home town, which is located south of Riyadh city, since 2007. The school is a small government school with low potential. However, I created a mathematics lab with necessary materials and technological tools to serve all students in the school. There was great interest in this lab and most of the students asked their teachers to join this lab rather than study in a regular class.

Furthermore, I made use of technology to deliver the objective of the lesson in an easy way, as well as to support students during mathematics tasks, especially those struggling with some of the tasks. I observed that when students used technology during class activities, they became more interested in and interacted better with the tasks and activities. This has convinced me that the use of the iPad and its applications in the teaching of mathematics or other subjects can improve students’ performance and motivation to achieve the lesson goals.

While working as a mathematics teacher, I decided to complete my education by pursuing a Master’s degree in Mathematics Education at the University of the Incarnate Word in the US. The Master’s degree included a final project, which involved programming a website to support mathematics educators and learners. For that project, I created an online calculator for addition, subtraction, multiplication, and division of fractions, as well as a unit converter and regular calculator.

Upon completion of my Master’s degree, I began working again at my school and started using the iPad as a teaching tool in the mathematics class by connecting my device to the projector. It was interesting for me as well as for my students. I became very keen to develop a deeper understanding of the integration of tablet devices in teaching and learning mathematics. In addition, I was interested in the effect that tablet use might have on teachers and students in terms of obstacles and the solutions to those obstacles. At that time, I started exploring the literature to find out more about the effectiveness of iPad use in teaching and learning mathematics. I decided to do an experiment in a secondary school rather than an elementary school because secondary school students were likely to be better at following instructions from a teacher or researcher. Thus, the results of the research would have more validity and would be able to support teachers in making informed decisions about whether or not to use iPads and other tablet devices in the secondary school classroom.

Furthermore, as far as I am aware, there is no available research on the effect of using iPads or other tablet devices on teaching and learning mathematics at the secondary school level in SA, especially in terms of students' performance and motivation for learning mathematics and teachers' perceptions of using technology for mathematics instruction. I conducted two pilot studies before I started collecting my primary research data and I presented the results of those pilot studies at international conferences. When collecting the data for the primary research, I tried to minimise bias by using several strategies, such as having the two classes taught by the same instructor over the same period, at the same level, and in the same school. Moreover, to further improve the credibility of the research, the interview and focus group transcripts were submitted for verification to the teacher involved in the experiment. In addition, as the researcher, I did not have any connection to the participants, either students or teachers.

1.7 Thesis Structure

This thesis comprises eight chapters. Chapter 1 has presented the research problem, the purpose statement, and the significance of the study, the aim and objectives, the research questions, the contributions of the research, and the limitations of the study.

Chapter 2 presents a brief overview of the SA context, which includes general information about SA, such as its location, population, and religion. It briefly discusses the education system and the history of education, focusing especially on the history of the integration of technology and the development of educational projects in SA.

Chapter 3 presents a review of the literature, providing an overview of the history of mathematics education, especially the development of the Saudi mathematics curriculum. Also, it provides an overview of the history of the integration of technology in the education system, focusing heavily on the integration of computers, smartphones, and iPads. It also evaluates the potential effects of the use of iPads and associated applications on students' learning. Furthermore, it evaluates teachers' perceptions of using technology such as iPads or other tablet devices for teaching and learning in the classroom. It also examines the barriers to integrating the iPad in the classroom, which potentially hamper their effectiveness and prevalence in the educational environment. Finally, it discusses a comprehensive understanding of how different learning theories and models respond to the aims of this study and how they apply to the use of the iPad and its apps. Therefore, it is important to select relevant theoretical perspectives and conceptual models that lay a sound foundation for any research study.

Chapter 4 presents the methodology and methods. It explains the research paradigm in terms of the ontology and epistemology. Also, it discusses paradigms in educational research, focusing on both positivism and interpretivism. As this research adopted a mixed-methods approach (quantitative and qualitative), the underpinning frame was pragmatism. This chapter also describes the sampling approach and the quasi-experimental research design used to collect quantitative data through a pre-test and two post-tests. Moreover, it presents a single case study used to collect qualitative data through a student focus group and semi-structured interviews with the participating teachers. It also provides an overview of the methods of data analysis and ensuring validity and reliability in mixed methods research. Finally, it addresses the research ethics.

Chapter 5 analyses the data gathered from the quantitative phase (the pre-test, first post-test, and second post-test) to examine the effectiveness of iPad use on students' achievement (first research question), and then presents the results of statistical testing.

Chapter 6 presents the qualitative findings, i.e. the results of the students' focus groups (first part) and teachers' interview (second part). Thus, it examines the effectiveness of iPad use on students' motivation to achieve the planned mathematics goals and the teachers' perceptions regarding the teaching of mathematics concepts via iPads.

Chapter 7 provides an in-depth discussion of the findings obtained from both the quantitative and qualitative parts of the research set out in Chapters 5 and 6, relating the discussion to the theoretical framework guiding this research.

Chapter 8 presents the major results for the research questions and outlines the contributions to knowledge and the implications of the study. Also, it provides a section about the connection of the research problem with the general findings of the study. It also provides recommendations for further research based on the findings obtained.

Chapter 2 Saudi Context

2.1 Introduction

This study examines the effectiveness of using iPads in enhancing mathematics teaching and learning for secondary schools in SA. This chapter is important in setting out the context to understand the positions and implications of this study. It presents wide-ranging information about the SA in terms of its location, religion, and general foundations. Also, it provides more specific information about the education system in SA, describing aspects such as educational objectives and aims, and student assessments. It also details the most significant educational project in SA in 2008, the Mathematics and Natural Science Curriculum Development (MNSCD) project, which aimed to enhance the level of student achievement in mathematics and science.

In addition, it discusses the integration of technology in the education system in SA over the years since the establishment of the MoE, aimed at enhancing learning and teaching through the intervention of technological devices. It covers Tatweer, which aims to improve curricula in the SA by fulfilling today's requirements for technological use and enhancing teachers' professional development via specialised training to equip them with the skills necessary to use technology in a classroom context. Furthermore, it addresses the National Education Portal (iEN), one of the primary objectives of which is to improve the effectiveness of technology and enhance performance levels in Saudi education. Finally, it outlines the Digital Transformation programme (Future Gate), which is a platform launched by the MoE to enhance students' learning. An app is provided for students to use this platform via their devices, anywhere and at any time.

2.2 General Information about Saudi Arabia (SA)

2.2.1 Location and Population

SA is located in the Middle East and occupies circa 80% of the Arab Peninsula, as depicted in the map shown in Figure 2-1. The total area is approximately 2,000,000 km^2. SA has a diverse topography, including mountains, coastal areas, sands, and plateaus. The Empty Quarter, situated in the south-east of the country, is the largest region, encompassing 640,000 km^2. It is composed of sand hills and lava fields. The climate in SA is ordinarily hot in summer and cold in winter (General Authority for Statistics [GAS], 2018). The total population in mid-2019 was 34,218,169, of which 21,112,611 were Saudi nationals and

13,105,558 were non-Saudi nationals (GAS, 2021a). Arabic and English are the official and second languages, respectively.

Figure 2-1. Map of Saudi Arabia
(https://es.wikipedia.org/wiki/Jubail#/media/File:Jubail,_Saudi_Arabia_locator_map.png)

As can be seen, SA is surrounded by Jordan and Iraq to the north, Oman and Yemen to the south, the Red Sea to the west, and the United Arab Emirates (UAE), Qatar, Bahrain, Kuwait, and the Arabian Gulf to the east. In 1991, SA was divided into 13 administrative regions, each of which is further divided into different governorates (cities). Each of these has various centres (small towns), which are individually linked to the governorate. The 13 regions are Riyadh, the Eastern Province, Makkah Al Mokaramah, Qaseem, Madinah Al-Monawrah, Asser, Tabuk, Jouf, Hail, Northern Borders, Jazan, Baha, and Najran (GAS, 2018). The capital city is Riyadh, located in the Riyadh region. In the Eastern Province is the city of Jubail, which is the location used in the study.

In this evaluative research, the school involved was located in Jubail Industrial City, which is under the Royal Commission for Jubail and Yanbu (RCJY) administration in the city of Jubail. Jubail is situated on the Arabian Gulf in the Eastern Province of SA (see Figure 2-1). For 7,000 years, the people of Dilmun have inhabited the area and they built their civilisation on the Arabian Gulf. In 1933, Jubail was the initial location in which the first team of geologists began the search for oil. Jubail gained fame as an industrial city in 1983 (Jubail Industrial City) due to the Guinness Book of Records citing it as the city with the most construction and engineering projects in the world. The population of Jubail is 378,946, comprised of 181,320 and 197,626 Saudi and non-Saudi citizens, respectively. The city is divided into two parts, Jubail Town and Jubail Industrial City.

Jubail Industrial City is under the Royal Commission for Jubail (RCJ). The RCJ has an Educational Services Department (ESD) to service educational needs. There are 68 schools under the ESD in Jubail Industrial City: 24 boys' schools, 22 girls' schools, and 22 kindergartens. (For further details about the Policy and Aims of the ESD, see section 2.5.4.) As mentioned above, this quasi-experimental evaluation was undertaken at Alrowad Secondary School, which is located in Jubail Industrial City. The reasons for choosing this particular school were that its technological infrastructure is excellent and it is classified as a smart school. Moreover, the school has 600 students and all those from the 10th to 12th grades received an iPad device as part of a 2015 initiative supported by the RCJ aimed at developing the city's educational services. (For further details, see section 4.6.1 and 4.7).

2.2.2 Religion

SA is a monarchy with a system of government based on the Holy Book (Quran) and Sharia Law (Islamic Law). The King is the Chair of the Council of Ministers and the Head of the Executive and Administrative branches of the SA government (Oyaid, 2009). For the Saudi people, Islam and their religious identity are the core of their cultural and social principles, and form the primary driving factor in any of their decisions. In addition, people in Saudi have religious morals which control their lives within their communities and spread from personal relations to tribal relations in the extended family system, which is part of a complex grid related to individuals in the Quran (Oyaid, 2009). Islam is embedded in all aspects of the daily lives of Saudi nationals and is particularly prevalent in their education; as such, education in SA is considered a religious duty and is highly respected by all citizens (Oyaid, 2009).

According to Al-Salloom (1989), every Saudi Arabian citizen is entitled to an education. This entitlement, which elevates education to the level of religious duty, is the cornerstone upon which Saudi Arabian education is built. It is the foundation of the country's educational responsibilities, according to which Saudi men and women fulfil their duties to themselves, their society, and their faith. Thus, education in Saudi Arabia is inextricably linked to Islamic education, which originated in mosques and progressed to schools and universities. Indeed, religious beliefs and the Islamic code of conduct are so pervasive in Saudi Arabia that it is impossible to interpret educational issues without referring to them. It is important to recognise that Islam places a high value on education in Saudi Arabia. Indeed, religion and education are seen as inseparable and the aim of education and the respect for the participants in it are based in religion. Due to religious and cultural conventions, there is a strict separation of genders across all levels of education in SA, which also extends to school buildings and staff (Alotabi, 2014; Oyaid, 2009).

2.3 Educational System in Saudi Arabia (SA)

Each year, 23 September is the National Day of SA, which commemorates the founding of the kingdom by King Abdul Aziz bin Abdul Rahman Al Saud in 1923 (GAS, 2018). One of the most important aims of the Saudi government since its establishment has been the development of the education system. In 1925, the Directorate of Knowledge was introduced as the first educational system in SA and was for boys only (MoE, 2018c).

In 1927, the first Council of Knowledge was established, a major aim of which was to develop the educational system in the Hijaz Region (Makkah Al Mokaramah region). Initially it monitored only four specific schools, but this was subsequently extended to beyond the Hijaz district, encompassing 323 schools throughout the whole of SA (MoE, 2018c). In 1951, during the reign of King Saud bin Abdulaziz, the Directorate of Knowledge was developed and became the Ministry of Knowledge, monitoring boys' government schools at all education levels. At that time, the first minister was King Fahd bin Abdulaziz (MoE, 2018c). In 1960, during the reign of King Faisal bin Abdulaziz, the General Presidency for Girls' Education was established. The budget for girls' education was USD 4.4 million and was to cover 15 primary schools and one female trainer teacher in an intermediate institute. The girls' and boys' educational systems are kept separate. In 2002, the General Presidency for Girls' Education became the responsibility of the Ministry of Knowledge. In 2003, the Ministry of Knowledge was renamed the Ministry of Education (MoE, 2018c). Table 2-1 provides a historical timeline of the development of the MoE.

Table 2-1. Historical timeline of the development of the Ministry of Education (MOE, 2018c).

Year	Established/Expanded
1925	Directorate of Knowledge
1927	Council of Knowledge
1951	Ministry of Knowledge
1960	General Presidency for Girls' Education
1975	Ministry of Higher Education
2002	General Presidency for Girls' Education under the responsibility of the Ministry of Knowledge
2003	Ministry of Knowledge renamed the Ministry of General Education (MoGE)
2015	Merger of the Ministry of General Education (MoGE) and Ministry of Higher Education (MoHE) as Ministry of Education (MoE)

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2.4 General Foundations of Saudi Education

As mentioned, the educational system in SA is primarily based on Islam. Some of the general foundations of education are as follows:

- Believing in Allah as the only God, with Islam as the one religion, and Mohammed the messenger and prophet from Allah.
- Establishing human civilisation, which is inspired by the message of the Prophet Mohammed.
- Believing in human dignity and being honest on the earth, as described in the Holy Quran.
- Providing students with the opportunity to build their communities and reap the benefits of their contribution to the successful development of society.
- Searching for new knowledge is the community's task as presented in Islam.
- Islamic religious knowledge is required for all educational stages and is to be taught at every level from primary to higher education.
- The National Development Plan is connected with all educational levels.
- Dealing rationally with global developments, especially in science, literature, and culture, by participating in, directing and following activities to attain their benefits. (MoE, 2018a)

2.5 Ministry of General Education (MoGE)

In terms of general education (GE), there are two different types of schools: (i) government (a total of 26,248 schools), and (ii) private (a total of 4,377 schools) (see Table 2-2) (GAS, 2018, cited in MoE, 2018a). The school in this evaluation study is considered a government school operated by the ESD under the RCJY in Jubail Industrial City.

There are also different school levels: nursery and kindergarten, primary, intermediate, and secondary. Students attend school from pre-school (aged 3 years) to K12 (aged 18 years). In the pre-school stage (nursery and kindergarten), nursery is optional for children at age 3, but by age 5, the child should be enrolled in kindergarten. Nursery and kindergarten are taught by female teachers and the genders are mixed. From the primary stage, 6–12 years, and onwards, the schools are segregated by gender. At the primary level, assessment is continuous and the students are required to pass the required levels to move on to the intermediate stage. In intermediate school, the students are aged 13–15 years. There is an examination in each of the three academic years and students need to pass all these to progress to high school. High school, or secondary school, is for students aged 16–18 years and students can opt to take either a science or literature programme. Those participating in both classes in this study were following the science programme. Again, assessment is through examinations and students must pass all examinations in each of the three academic years.

Table 2-2. Schools in Saudi Arabia by type and stage of education 1437/1438 A., 2017/2018.

Stages of Education	Private تعليم اهلي			Government تعليم حكومي			راحل التعليم العام
	المجموع Total	إناث Female	ذكور Male	المجموع Total	إناث Female	ذكور Male	
Kindergarten	1259	1259	0	2013	2013	0	رياض أطفال
Primary	1392	779	613	12661	6322	6339	ابتدائي
Intermediate	996	456	540	7580	3683	3897	متوسط
Secondary	730	302	428	3994	2028	1966	ثانوي عام
Total	4377	2796	1581	26248	14046	12202	المجموع
Adult Education	1	1	0	1955	1260	695	مراكز محو الأميه وتعليم الكبار
Programs, institutes and special education classes	42	32	10	2580	925	1655	برامج ومعاهد وفصول التربية الخاصة
Credits System	156	88	68	914	435	479	ثانوي مقررات
Grand Total	4576	2917	1659	31697	16666	15031	المجموع الكلي

A 2018 report stated that the total number of students at all levels of GE was 63,967,641, composed of 3,298,911 males, and 3,098,730 females (see Table 2-3; GAS, 2021a). Once in higher education, students can apply to any university in SA. University education is free and students can choose from numerous disciplines.

Table 2-3. Total students by sex and level of education.

Education & Training التعليم والتدريب

Total Students by Sex and Level of Education إجمالي الطلبة والطالبات حسب الجنس ومرحلة التعليم

Table 4-4 جدول 4-4

Stages of Education	2017 [2]			2016 [1]			2015 [1]			مراحل التعليم العام
	جملة Total	إناث Female	ذكور Male	جملة Total	إناث Female	ذكور Male	جملة Total	إناث Female	ذكور Male	
Primary	3166986	1559954	1607032	3357365	1644659	1712706	3844516	1901890	1942626	ابتدائي
Intermediate	1473413	721060	752353	1483865	721638	762227	1797075	886371	910704	متوسط
Secondary	1468913	681445	787468	1654523	767493	887030	1808728	887778	920950	ثانوي
Total	6109312	2962459	3146853	6495753	3133790	3361963	7450319	3676039	3774280	المجموع

Source: General Authority for Statistics المصدر: الهيئة العامة للإحصاء.

1- Including Adult Education 1-يشمل تعليم الكبار

2- Not including Adult Education 2- لا يشمل تعليم الكبار

Note: Student data were calculated based on the Education and Training Survey 2017 and adjusted for 2016 data

ملاحظة : تم حساب بيانات الطلبة بناءاً على مسح التعليم والتدريب 2017 م وعدلت بيانات عام 2016م

School in SA is five days a week, Sunday to Thursday, from 7.45 am to 1.40 pm. It runs for 8 months a year through 2 semesters. This evaluation study took place in the second semester of the 2018/2019 academic year (for more details, see Chapter 4). During school time, there is exercise for 15 minutes in the morning at 7:45, followed by breakfast for 20 minutes, then prayer time for 20 minutes. The classes are 45 minutes each. In primary 1, 2, and 3, there are 30 classes per week, 6 per day, including 3 mathematics classes, and there are 8 coursebooks. In primary 4, 5, and 6, there are 33 classes per week, 7 on Sunday, Monday, and Tuesday, and 6 classes on Wednesday and Thursday, of which 5 are mathematics classes, and there are 11 coursebooks. In intermediate school, there are 35 classes per week, 7 per day, including 5 mathematics classes, and there are 9 subjects. In secondary school, there are 6 levels and each takes 1 semester over 3 academic years. The science and literature programmes comprise 14 coursebooks, and there are similar classes in the first and second levels, with 34 classes a week for boys and 35 classes for girls. In the third to sixth levels in both the science and literature programmes for boys and girls, there are 35 classes and 12 coursebooks. Mathematics classes are only taught as part of the science programme, and there are 5 classes per week. The period of this study was 8 weeks (2 months), encompassing 40 mathematics classes for each class, A and B.

The MoE has a specific department for curriculum development, in which textbooks are developed, composed, printed, and then distributed free of charge to all students from kindergarten to secondary school level. The textbooks are distributed on the first day of the academic year and the students have to bring these books to class every day in order to achieve the grades in the examinations both mid-term and at the end of the semester.

2.5.1 Student Assessment at Primary, Intermediate, and Secondary Levels

The purposes of student assessment are to improve learning and teaching, to measure student achievement, and to determine whether the student is ready for the next stage based on examinations (Al Sadaawi, 2010; Al-Sadan, 2000). The academic year is divided into 2 semesters, each 18 weeks long. The last two weeks in each semester are the final examinations for all students at all stages except primary. Students at the primary level have continuous assessment (CA) throughout the semester (Oyaid, 2009). CA is an evaluation of students' progress during the academic semester and it involves a series of tasks on which students are individually assessed, which differs from an examination. The data collected in CA are used to provide feedback to help teachers make decisions about the next steps for their students (Carlson et al., 2003). CA considers skills development and student need to attain certain levels to move to the next level; otherwise, they have to repeat the basic skill they have not attained to progress.

Student assessment at intermediate and secondary school runs from the first to the last day of the semester, and accounts for 40% of the total score (homework, tests, mid-term exam), with the final examination of the semester making up the other 60%. Students must pass all subjects (minimum of 50% in the continuous assessment and final exam) in each semester to be eligible to advance to the next level (Oyaid, 2009). Students' assessment in mathematics is the same as all for all other subjects at both intermediate and secondary school levels in Saudi Arabia. Al-Saloom (1987) notes the following grading system that is employed as per educational policy for student assessments in SA: Excellent 90–100; Very good 75–89; Good 60–74; Fair 50–59; Fail 0–49.

After students have graduated from secondary school, they have to sit a General Aptitude Test (GAT, part of the Qiyas Tests) and the Achievement Test at the National Centre for Assessment (Qiyas Centre) as a requirement to complete their study at any university, college, or institute after secondary school. The GAT has two sections, Verbal Skills and Mathematical Skills. These aim to measure basic skills such as deductive skills, problem-solving skills, logical relations, reading comprehension, and inductive skills. Students can practise online to prepare for the test (National Centre for Assessment, 2018). The Achievement Test assists stakeholders in universities and other educational institutions in SA to identify the highest achieving students. This test measures students’ proficiency in specific subjects, such as Mathematics, Physics, Chemistry, and Biology (National Centre for Assessment, 2021). The school participating in this study achieved first place in both the GAT and the Achievement Test for Saudi schools (ETEC, 2021).

2.5.2 Education Budget

As previously mentioned, the Saudi government supports education, with the funding increasing each year. In 2010, the total budget for the MoE exceeded SAR 90 billion and with annual increases had climbed to more than SAR 124 billion by 2016 (see Table 2-4) (MoE, 2018e). According to the MoF 2018 Budget Statement, SAR 192 billion was allocated to the MoE (Public and Higher Education) and workforce training in the education sector (MoF, 2018). In addition, the budget for education was SAR 202 billion in 2019 and SAR 205 billion in 2020. This equates to a year-on-year budget increase of 1.4% from 2019 to 2020 (MoF, 2021). According to the MoF Budget Statement for 2021, the most significant project achievements in the 2020 fiscal year for the education sector were resuming education through e-learning platforms and creating educational satellite channels (iEN; for more details about iEN, see section 2.10.2).

Table 2-4. MoE (General) Budget Year 1437–1438, 2016 (H).

MOE (General) Budget Year 1437-1438 (H)						
HIJRI YEAR	GREGORIAN YEAR	TOTAL	MOE FINANCIAL APPROVALS			
			Chapter - I	Chapter - II	Chapter - III	Chapter - IV
			Salaries, Allowances, Wages	Operational Expenditure	Programs and Contracts (Operations, Maintenance, Cleaning)	Projects
1431 - 1432	2010	90,000,620,000	77,520,000,000	4,685,235,000	795,385,000	7,000,000,000
1432 - 1433	2011	94.656,037,000	80,011,242,000	4,766,835,000	925,560,000	8,952,400,000
1433 - 1434	2012	101,466,583,000	85,800,000,000	5,608,623,000	1,105,560,000	8,952,400,000
1434 - 1435	2013	118,425,732,000	102,560,000,000	6,145,521,000	1,620,211,000	8,100,000,000
1435 - 1436	2014	121,253,000,000	104,850,000,000	6,646,000,000	1,684,000,000	8,073,000,000
1436 - 1437	2015	127,442,168,000	107,431,073,000	7,140,000,000	3,094,610,000	9,776,485,000
1437 - 1438	2016	124,319,484,000	111,320,133,000	6,565,316,000	2,934,035,000	3,500,000,000

2.5.3 Ministry of Education (MoE) Objectives and General Aims

The objective of education is to instil students with a comprehensive understanding of Islam and to integrate the Islamic creed and values into their lessons and beliefs so as to support and develop their knowledge and skills (MoE, 2018d).

The first stages of education the Saudi educational system are nursery and kindergarten, which aim to educate children and prepare them for school life (MoE, 2018d). The second stage is the primary level, which forms the basis of students' learning to prepare them for their future life. At this stage, they are taught the truth of Islamic beliefs, experiences, skills, information, and sound attitudes (MoE, 2018d). The intermediate stage is a general level focused on culture and aiming for students to complete the Islamic education approaches and learn about their faith, soul, mind, ethics, and body (MoE, 2018d). Students who hold an intermediate certificate can study in different schools such as General Secondary Schools, Secondary Teacher Preparation Institutes, Agricultural Vocational Institutes, Industrial Institutes, Commercial Institutes, Sports Institutes, and Academic Institutes (MoE, 2018d).

The aim of the secondary stage, the focus of this study, is to move towards a range of subjects relevant to the students' age and their growth. The secondary level guides students in preparing for their lives and the next stage of their education (MoE, 2018d). In addition to the objectives shared at other stages of education, the core aims specific to secondary school are as follows:

- Remain loyal to Allah (God) and seek his satisfaction under his law.
- Solidify Islamic truth and faith.
- Improve students' scientific thinking skills and foster their interest in research.
- Prepare students so they are capable of deciding their future educational route from among the considerable opportunities in SA universities, colleges, and vocational institutions.
- Provide students with opportunities to work in various fields in the Saudi market. (Al-Sadan, 2000)

2.5.4 Policy and Aims of the Educational Services Department (ESD)

Further to the goals of the MoE, the RCJY has established a vision through the following ESD aims:

- Education for knowledge: building an achievable framework for knowledge, values, and attitudes, and establishing experiences.
- Teaching for innovation and creativity: providing learners with thinking skills that render them capable of solving problems in creative ways, processing ideas and information to produce new knowledge.
- Education for work: linking learners to the economic reality and dimensions and preparing the productive individual through the acquisition of basic knowledge that qualifies him/her for training in technical and interpersonal skills.
- Education for the future: providing learners with the necessary skills to interact positively with the requirements of the future.
- Education for life: providing learners with foundations, constants, and social skills.

Furthermore, the ESD has put forward an education development plan that was designed to express a new educational philosophy meeting current needs and maintaining pace with the requirements of the future in the form of specific programmes that include the following:

1) E-learning project: This project aims to improve the educational environment and prepare it to integrate and employ technology to create a setting that stimulates learning and facilitates communication between the parties involved in the educational process.
2) Development of a thinking programme: The program aims to introduce thinking skills into the curriculum and teaching methods. It also provides students with thinking skills that enable them to face problems and solve them in creative ways, and develops teachers' thinking skills to go beyond the ineffective traditional methods of teaching.

2.6 Ministry of Higher Education (MoHE)

Upon completing secondary school, a student can choose whether to go on to higher education. The higher education stage entails helping people improve and develop their skills in a particular area and fitting them for the current and future needs of the Saudi community as part of the national development goals (MoE, 2018d).

The first university in SA was established in 1957 and the number of the universities then grew from one to seven during the 20 years from 1957 to 1975, which was the main impetus for establishing the MoHE (see Table 2-5; Alamri, 2011).

Table 2-5. Summary of the history of universities established sequentially.

	University	Established
1	King Saud University	1957
2	Islamic University	1961
3	King Fahd University for Petroleum and Minerals	1963
4	King Abdul-Aziz University	1967
5	Um Al-Qura University	1967
6	Imam Muhammad Bin Saud Islamic University	1974
7	King Faisal University	1975

The MoHE in SA was established in 1975 and is responsible for the implementation of the government's educational policy. Most of the governmental support entails funding higher education to build new universities, applied colleges, and scientific institutes. Huge funds from the Saudi government support the budgets for higher education. Presently, there are 30 government universities, 10 private universities, and 41 private colleges (MoE, 2018c). All these colleges and universities have different majors (including science, arts, or applied sciences).

The higher education system comprises two years for a diploma, four years for a Bachelor's degree or five years for a Bachelor's degree in a specific programme, such as engineering or medicine, two further years for a Master's degree, and five additional years for a doctorate.

2.7 Teacher Education

In 1925, with the introduction of formal education in SA, any person who could read and write could qualify as a teacher due to the great need for educators (Al Harbi, 2014). Over the history of education in SA, the MoE has established several teacher training institutes, which are described as follows:

- From 1953 to 1967: Primary Teacher Institutes were established to train individuals as primary level teachers in a three-year training programme having completed primary school.
- From 1966 to 1985: Primary Teachers' Preparation Institutions were established to train individuals to be primary level teachers through three-year training programmes having completed secondary school.
- From 1974 to 1988: Science and Mathematics Centres were established for students training to be mathematics and science teachers in primary school.
- From 1975: Junior Colleges were established to improve the quality of high school graduates to be primary level teachers, completing two years of intensive training.

- From 1989 to the present: Teacher Colleges were established to improve the junior colleges, extending the Bachelor's degree from two years to four years and enabling teachers to become educators at all GE levels. (Alshalaan, 2006, cited in Al Harbi, 2014)

Nowadays, teachers in SA must have a Bachelor's degree in a specific subject at minimum to be able to teach it in Saudi schools. A student planning to be a teacher could study at one of the teacher colleges or any university (College of Sciences or College of Art) in SA or attain an equivalent qualification from an institute outside SA. Teacher Colleges have merged with the five universities in SA (King Saud University, Islamic University, King Abdul-Aziz University, Um Al-Qura University, and King Faisal University). Most of the pedagogical and scientific majors are available in Teacher Colleges. They offer a good educational programme that enables each student to develop teaching skills, knowledge, curriculum content, and teaching methods. However, technology-enhanced learning is not prioritised. The College of Sciences and Teachers College offer mathematics majors and both offer a similar programme, as do most of the mathematics majors at other universities in SA. They also have approximately the same credit hours to achieve the programme. For example, King Saud University (KSU) is one of the leading universities in the Arabic Gulf countries; it has the best and oldest mathematics programme in the area. The mathematics programme at KSU requires 136 credit hours to achieve the Bachelor of Science in Mathematics, out of which there are 77 credit hours for mathematics itself, as required by the Department of Mathematics. Also, there are 14 credit hours in the computer programme and mathematics programme and students have the option to choose 9 credit hours from these as elective courses (KSU, 2018). However, given the rapid rate of innovation in technology, these programmes cannot adequately equip students with technology-enhanced learning, given the limited credit hours compared to those for the mathematics programme. This reflects the fact that most universities and colleges in SA are more focused on educating their students in pedagogical and content knowledge in their subjects than fostering them to graduate as teachers. Having graduated with a Bachelor's degree, teachers must sit a Teachers Test at the National Centre for Assessment (Qiyas Centre) as a requirement to be accepted as a teacher in the MoE. The test covers teachers' knowledge, the sciences, and skills (National Centre for Assessment, 2018).

There are a total of 505,284 teachers in SA, 208,038 of whom are male and 220,796 female (see Table 2-6) (GAS, 2021a, cited in MoE, 2021).

Table 2-6. Schools, classrooms, teachers and administrators (GAS, 2021a, cited in MoE, 2021).

الاداريون Administrators		المعلمون Teachers		الفصول الدراسية Classroom		School المدارس			السنوات Years
إناث Female	ذكور Male	إناث Female	ذكور Male	إناث Female	ذكور Male	إناث Female	ذكور Male		
119821		505284		267235		40649		Grand Total	المجموع العام
16553	28196	220796	208038	109510	118574	18844	16553	Government حكومي	1439/1440 (2019)
1974	3160	33110	43340	12510	26641	3278	1974	Private خاص	

2.8 Merger of the Ministries of General Education and Higher Education

In 2015, the MoGE and MoHE were merged into one ministry, known as the MoE. Following this merger, the first Minister of Education was Dr Azzam Al-Dakhil (MoE, 2018c).

2.9 Mathematics and Natural Science Curriculum Development (MNSCD) (2008)

The MoE resolved to draw on successful attempts to improve education systems around the world to develop an effective mathematics curriculum for Saudi schools. As reported by Khormi and Woolner (2019), the McGraw Hill Education and its Saudi representative, Al-Obekan Education, were selected to develop the curriculum for all GE stages in accordance with the standards and practices that had been established by the US National Council of Teachers of Mathematics (NCTM, 2000). This is referred to as “The Mathematics and Science Curricula Project”, and its purpose is to improve students’ skills in a range of areas, such as:

- The creation of new concepts
- Problem-solving
- Product innovation and development
- Communication
- Technology use as per international standards

A core objective of the project is to foster skilled students who can fill the gaps in SA's developing labour market, thereby allowing the nation to become a global competitor.

According to Alshayea and Abdulhameed (2011), the project philosophy is based on 10 principles, several of which relate to this research:

1. Learner-centred learning
2. Knowledge exchange
3. Learning through collaborative learning
4. Active learning
5. Developing thinking skills
6. Linking education to real life

The aims of the project relevant to this research are as follows (Alshayea & Abdulhameed, 2011):

1. Developing mathematics and science curricula in line with the most recent advances in developed nations.
2. Integrating technology and its applications in the curriculum.
3. Implementing professional development for teachers through training and diversity in modern teaching methods.
4. Allowing learners to access knowledge and its construction, enhancing their learning to embrace active learning and self-reliance.
5. Improving the teaching and learning environment in schools.

This study evaluates the impact of an intervention using iPads and associated applications on students' learning. It also assesses the effectiveness of iPad use in terms of teachers' perceptions of the teaching of mathematics concepts.

One element of the Mathematics and Science Curricula Project was the introduction of a new curriculum based on a set of mandatory textbooks for all levels of primary education. The translated Maths Connects series for Saudi primary schools are in line with the aforementioned NCTM (2000) standards and were originally published in the US by Macmillan/McGraw Hill Education. The series is a component of the mathematics curriculum derived from the NCTM (2006) document "*A Quest for Coherence*". This publication encompasses the core aspects of the curriculum, which include the grade-specific significant areas of mathematics. This document offers a framework for arranging curriculum standards within a clearly defined curriculum by presenting a means of developing core mathematical content and links for each grade level up to K-8 (NCTM, 2006).

The aim of the Maths Connect series was to aid teachers in addressing the challenges associated with equipping students with mathematic abilities in line with the NCTM (2000) standards (McGraw-Hill, 2012). Furthermore, McGraw Hill (2012) highlighted that the aim of the Math Connects series was to represent both findings from major mathematics instruction research, best teaching practices, and key aspects of the curriculum. These findings were documented from different research reviews, syntheses, and meta-analyses based on relevant databases related to the McGraw Hill Math Connects series. The Math Connects textbooks offer lessons in problem solving that furnish students with adaptive reasoning skills and a valuable outlook on mathematics. The textbooks allow teachers to solve problems via diverse techniques in each lesson, which are designed to foster discussion about different approaches and perspectives on problem solving. Also, it provides fully integrated technology resources for teachers, students, and parents. For instance, the book has an electronic lesson planner and enables teachers to create assignments and assessments. It also provides students with an ebook, worksheets, and links to Math Online, with online study tools, audio, and a wealth of additional resources, such as self-check, personal tutor, quizzes, and concepts in motion. Thus, the new mathematics curriculum presents a “reform” mindset for teaching and learning, focusing on communication, critical thinking, and problem solving. For example, the textbooks include a rage of “talk tasks”, which afford students an opportunity to verbally describe their understanding of and solution to a problem.

The Math Connects series provides a teachers’ guidebook that contains a time plan, lesson plan, alternative lesson plan, supplementary information, teaching techniques, notes of frequently made errors, and assessment methods for each lesson. According to Khormi and Woolner (2019), this allows teachers the opportunity to simply prepare mentally, as they can follow the lesson plan and structure for the class. It is broadly accepted that professional development plans for in-service mathematics teachers are essential in conjunction with this reform-centric curriculum. Indeed, the NCTM (2006) contends that strong instruction based on the key points of the curriculum is dependent on both extensive preparation for pre-service teachers and continuous professional development for in-service teachers to ensure success. Consequently, the Saudi MoE has introduced a four-phase plan to initiate teaching of the mathematics series to ensure that all teachers can develop efficiently and effectively. The four phases are categorised as follows:

- Phase 1: 1st, 4th, and 7th grades
- Phase 2: 2nd, 8th, and 10th grades
- Phase 3: 6th, 9th, and 11th grades
- Phase 4: 12th grade

As previously mentioned, one aim of this project is to improve skills in technology use to bring them in line with the international standards for mathematics teaching and learning. Therefore, one aim of this research is to examine teachers' perceptions of the use of technology in their classrooms as a support tool for the integration of devices in teaching the new curriculum (focusing particularly on the iPad and its applications). This new curriculum presents a diverse array of teaching approaches that support a learner-centric pedagogy. Thus, it is an opportunity to integrate technological devices such as iPads in the classroom to allow students to be self-reliant in their learning. According to Khormi and Woolner (2019), this curriculum and the incorporation of educational technology enables students to become participants rather than recipients in their education.

2.10 Technology in the Saudi Educational System

In 1985, information and communication technology (ICT) was integrated in the Saudi GE system through specific advanced secondary schools. It was presented in three subjects: (i) introduction to computer science, (ii) BASIC programmes, and (iii) programming and information systems usage. In 1991, the MoE was encouraged to introduce computer studies as part of the curriculum system in boys' schools, then later in girls' schools, making it part of the syllabus at all secondary schools in SA (Oyaid, 2009). Since 1999, computer training programmes for both students and teachers have been provided in every secondary school, covering subjects including information technology (IT), computer applications, computer science, the information age, and information systems (Oyaid, 2009). The Ministry has offered a range of training programmes for teachers in ICT at all training centres under the axis of education management in each region.

The MoE has employed SMART technology, givin 9,000 interactive smartboards to Saudi schools with appropriate software. This was the biggest smartboard sale in the Middle East. Moreover, the MoE plans to purchase more smartboards to cover 50,000 classrooms in the next two years (Sutton, 2013, cited in Alabdulaziz, 2017). Technological initiatives such as computers and smartboards were successfully integrated in the schools, but still require further follow-up and development. Thus, the MoE has established various technology projects to improve learning and teaching through the integration of technology. These projects are discussed below.

2.10.1 King Abdullah bin Abdul-Aziz Education Development Project (Tatweer)

Even taking the abovementioned curriculum development into consideration, the new mathematics curriculum requires additional fundamental input. To address this, the Tatweer project was developed by the SA government to invest even more in improving Saudi education. This project, launched in 2008, focused on improving the quality of the curriculum, addressing learner needs, requalifying teachers, and developing public education to enhance the learning environment while continuing to uphold the principles and values of Saudi society (Hakami, 2010). Dr Ali Al-Hakamihad (the General Manager of Tatweer) stated that the primary goal of Tatweer is to make learners proficient in mathematics and computer science skills. This project would encourage students to study more, gain better communication skills, and become more flexible and innovative in the school environment (Chicago Forum, 2012). This initiative is a national plan for improving the Saudi educational system to address the country's current and future needs and aid its transition toward a more open society (Tatweer, 2018). In English, the term “Tatweer” means “development” and the goal of the project is to establish students as core contributors and participants in their education, rather than just recipients. Moreover, it endeavours to ensure that schools become better pedagogical institutions, which will be reflected in students’ increased levels of academic achievement, especially in mathematics. It has the following aims:

- To improve the Saudi curricula to meet the updated technological requirements.
- To train teachers in how to use technology through specialised training to fulfil the goals of the modern curricula.
- To develop and enhance the learning environment with the integration of technology and the implementation of modern curricula in order to increase engagement and achieve a high level of implementation. (Tatweer, 2018)

As mentioned above, there are different programmes in the Tatweer project aimed at improving the Saudi educational system, such as improving the learning environment. Its aim is to design and develop computer and information technology curricula, focusing on how to integrate ICT in the Saudi educational system and improve teachers’ pedagogical methods through training programmes on how to integrate technology in schools (Tatweer, 2018). One of the aims of this study is to evaluate the impact of an intervention using iPads on teachers' perceptions regarding the teaching of mathematics concepts, including the extent to which teachers' professional development needs in training to use these devices have successfully been met. The Tatweer project axis is:

- Developing learning and teaching in the classroom.
- Developing competence.
- Developing educational outcomes.
- Supporting schools' needs in integrating technological learning in the classroom.
- Incorporating the use of ICT in the educational system.
- Offering training programmes for students to close the digital gap between them. (tatweer.edu.sa, 2018)

The Tatweer project shows that the MoE in SA is pushing for significant change and making considerable investment in the education sector to move away from routine learning and the method of indoctrination in particular. This project is aimed at integrating ICT in the educational system and providing training courses for both learners and teachers in the use of technology in education (Tatweer, 2018). It supports increasing learners' use of technology and improving the school environment to go beyond the traditional school environment (Sait et al., 2007). It prioritises a learner-centric approach that better meets the needs of the students (Hakami, 2010). It also aims to equip schools with ICT equipment, including PCs, smartboards, projectors, and networking, enablking them to participate in e-learning courses and activities. By introducing technology into schools, it is hoped that Saudi students will be able to improve their skills, thereby enhancing their learning and overall education experience (MoE, 2007).

2.10.2 National Education Portal (iEN)

The iEN is a digital portal which is free and safe for both students and teachers to use. It is authorised by the MoE to provide a range of e-educational services to all students, parents, supervisors, and teachers. One of the primary objectives of the National Development of Education was to improve the effectiveness of technology and enhance performance levels in Saudi education. The iEN has in excess of 5 million users and provides more than 2,000 electronic books with over 21,000 digital activities on offer (iEN, 2018). In addition, the iEN offers a variety of sources, such as iEN TV channels and iEN YouTube. The iEN TV channels include 20 satellite TV channels that provide live broadcasts of educational activities and explain all curricular lessons, including those in the mathematics curriculum, for students in the 1st to 12th grades (Madhesh, 2021). Furthermore, the iEN YouTube channel has 291,000 subscribers and provides recorded lessons and live teaching hours. In 2020, the MoE announced that the iEN was ready to provide live YouTube channels and resources for all grade classes during school closures due to the spread of COVID-19 (MoE, 2020).

The development of the iEN was designed to achieve this goal and to contribute to the digital transformation of education within the Saudi Vision 2030 by providing e-learning services (iEN, 2018). The iEN provides:

- Curricula at all educational level as PDF files.
- Teachers' guides and classroom activities.
- Educational enrichment.
- Lesson plans.
- Banks of electronic questions.
- Assess yourself options.
- Virtual learning communities.
- Electronic printing of questions. (iEN, 2018)

2.10.3 Future Gate Platform

The Digital Transformation programme (Future Gate) was one of the digital education programmes launched by the MoE to meet the NTP in 2020. Tatweer Educational Technologies (TETCO), part of the Tatweer Company, is responsible for the provision of the Future Gate project in all schools in SA. There were three phases to be completed in order to integrate the Future Gate project fully in all schools by 2020. In the first phase, selected schools (150 schools in 2017) were to be equipped with high-speed internet and wireless access points. According to the NTP 2020, the remaining schools (Second Phase: 1,500 schools in 2018 and Third Phase: 25,000 schools by 2020) would follow the same patter as the selected schools in the first phase. This project also progressively equipped schools in the first phase with interactive projectors (Al Ohali et al., 2018). However, only 20% of the target installations were achieved and few teachers were furnished with laptops as intended. Nonetheless, the project adopted a new initiative of providing a laptop to every student in SA (Al Ohali et al., 2018).

In addition to providing technical innovations, such as those introduced by the Future Gate project for all schools in SA simultaneously, the primary challenge faced by educational institutions was how to actually implement and optimise the use of the platform in the educational process in line with the development of contemporary technologies (Al-Hubaish, 2018). In this regard, the teachers' experience, technical skills, competence, and ability to employ technology and optimally use the tools offered by the Future Gate platform all play a major role in achieving the desired goal. Moreover, it is essential to identify the obstacles that prevent teachers from using the platform tools effectively and develop the teachers' skillsets accordingly (Al-Hubaish, 2018).

Future Gate targeted everyone related to the educational process, such as students, parents, teachers, school deputies, school leaders, student advisors, and educational supervisors. However, as the students and teachers are the most fundamental components of the education system, the Future Gate platform offers a range of features for learners and teachers to manage their tasks. Creating a new learning environment in which knowledge is delivered to students and the availability of scientific content is increased depends largely on educational technology. Moreover, Future Gate enables teachers to develop their knowledge in scientific and pedagogical areas (TETCO, 2018).

In addition, Future Gate has a learning management system (LMS), comprising a set of programs and applications used to evaluate, implement, and plan for specific learning methods. It is also an e-learning system that provides interactive learning content and facilitates student participation and performance assessment (TETCO, 2018).

Future Gate seeks to provide interactive discussion services among students, as well as video conferences, aimed at increasing the level of student achievement. Furthermore, Future Gate strives to increase the number of users among students through the sharing of the curriculum and courses using different methods. The Future Gate platform offers moral and material motivation patterns for students, such as the announcement of the best 30 students who used this platform at the state level and awarding them valuable prizes. It assists teachers to prepare educational lessons and combats any deficiencies in teachers' pedagogical experience by providing electronic educational packages for both teachers and students. In particular, there are several features of Future Gate that are beneficial to teachers, such as electronic homework, activities, and tests. It also has interactive content for educational purposes, including text, photographs, videos, maps, data, and discussion rooms. Moreover, it supports teachers in managing attendance and absences and creating a smart (virtual) classroom encompassing direct and indirect learning environments that allow students to interact and communicate with other classmates and teachers (TETCO, 2018).

Future Gate also supports interactive education, facilitating interactive activities between classrooms in a school or between separate schools, with supervision from the teachers. In addition, it supports all interactive activities, especially online tests, online assignments, and online worksheets. Furthermore, it supports all learning theories such as the flipped classroom and collaborative activities, for example creating questionnaires and group lessons. It supports the latest global technologies currently used for group lessons and virtual classes, turning the class into an interactive environment (Future Gate, 2018).

A main benefit of Future Gate is that automatic archiving of all interactive educational materials is available, enabling the sharing of documents for all users to be used in future lesson plans, including electronic tests, homework, and electronic lessons. Indeed, the Future Gate platform includes an application which is available on the Apple store and for Android systems for smartphones that works equally effectively across all different types of tablet devices. The Future Gate app was developed and released after publication of the platform in a bid to expand the teaching and learning processes beyond the classroom and school environment. Essentially, this means that both students and teachers can use the app at any time and in any place, whether in class or elsewhere. Furthermore, it is accessible on many devices, including smartphones, tablets, laptops, and PCs. It also aims to take advantage of students' interest in using modern technologies and directing them to the appropriate use of these products (Future Gate, 2018).

2.11 Saudi Arabia's Vision 2030

In 2016, the Saudi government implemented Vision 2030. Essentially, the project is a framework for development and economic growth that aims to position SA as a global leader in all fields. The NTP 2020 was launched in 2016 as part of Vision 2030, incorporating all government departments involved in the development and economic sectors (Saudi Vision 2030, 2016). Its purpose was to attract foreign talent and retain gifted and successful Saudis by providing for all their requirements in a bid to ensure that they make significant contributions to economic development and secure more foreign investment.

Due to the introduction of Vision 2030 and the NTP 2020 in 2016, SA has enjoyed a period of prosperity and progress. The present strategy is to diversify and expand economically by decreasing oil dependency, increasing foreign investment, and reforming the education, health, and tourism sectors.

In terms of educational reform, the MoE will be used by Vision 2030 to enhance and restructure the educational regulations and create contemporary curricula that prioritise high standards of literacy and numeracy and emphasise character building. To accomplish this, the MoE has formed eight strategic objectives in line with Vision 2030, which are as follows:

1) Enhance curricula and methods of teaching.

2) Foster an educational environment that promotes innovation and creativity.

3) Enhance teacher recruitment, training, and development.

4) Ensure students at all levels can access education.

5) Enhance the values and key abilities of students.

6) Improve the educational system so as to meet the demands of the labour market and contribute to national development.

7) Create a more financially efficient education system and implement innovation in terms of financing.

8) Boost the level of private sector involvement in the education industry. (Saudi Vision 2030, 2016, p. 60)

2.12 Summary

This chapter has focused on providing general information about SA, including its location, religion and influence, the education system, and educational history. It is evident that the Saudi government is seeking to develop and improve the current education system. It has paid increasing attention to educational reforms and resolved to draw on successful attempts to improve educational systems around the world. One of the most significant reforms is the development of the mathematics and science curricula in accordance with the most recent advances of developed nations under the MNSCD project.

Furthermore, the Saudi government has prioritised integrating technology in education, with a particular focus on maintaining pace with the newest educational developments around the world, by adopting technology projects. One of the most significant technology projects is Tatweer, which aims to support the MoE in developing public education and improving the learning environment, and learning and teaching approaches, and integrating ICT in schools. A key aspect of Tatweer is implementing the Future Gate project in all Saudi schools. Future Gate is the newest programme to advance the Saudi education system towards electronic learning via the use of new educational learning and teaching tools such as iPads and mobile learning. In addition, the MoE established the iEN, which encompasses iEN TV and YouTube channels offering an array of e-educational services accessible to students, teachers, parents, supervisors, and other educational stakeholders.

Reflecting on the SA context discussed in this chapter, these projects are important to this study and the stated research questions. The first of these, the integration of technology, has wider implications for student achievement, motivation, and understanding of learning and cognition in technology-enhanced learning settings. Thus, examining these projects and answering the research questions will help to understand more fully the new approaches in terms of enhancing learning and teaching.

In light of these reforms and in the context of the ongoing development in relation to GE in SA, this study is especially relevant with its focus on the integration of technology in mathematics education. Furthermore, specifically in terms of mathematics, it could encourage students and teachers to use iPads and other devices to overcome the problems associated with students' learning and teachers' perceptions of the teaching of mathematics concepts. There is a sense of inevitability about adopting technology in GE in SA and it is hoped that the intervention using these devices in education will enhance the quality of learning and teaching, as well as being beneficial in terms of informing future education policies in SA. However, there are potential challenges surrounding the integration of technology in the classroom that should be addressed.

Chapter 3 Literature Review

3.1 Introduction

The aim of this chapter is to summarise and evaluate the existing knowledge associated with the intervention, encompassing tablet devices, software, and pedagogy. The purpose of this study is to evaluate the role of tablet devices in improving instruction in mathematics teaching and learning in secondary schools in SE by determining whether the integration of technology has wider implications for students' levels of achievement, motivation, and teachers' perceptions. In recent times, technology, such as the iPad and other tablet devices, has increasingly been adopted in the education sectors of diverse nations throughout the world as a component of learning and teaching processes. SA is one such country to have done so. These tablet devices potentially play a significant role in Saudi's GE sector. Whilst there are a substantial number of existing studies related to integrating technology at various educational levels, additional research is necessary to evaluate the use of iPads in the classroom and acquire a balanced overview of the evidence presented in the literature. This chapter presents an overview of the most relevant research on the role of tablet devices in education in both SA and other countries around the world. It is organised in five sections to support the research aims. It is also essential to accurately define what is meant by the terms “conventional” and “traditional” in relation to teaching methods to ensure understanding of the literature. In this chapter, unless specifically used with a different meaning in a particular study, the traditional or conventional method of teaching and learning is carried out without using iPads, tablets, or other technological devices. This method typically uses textbooks, worksheets, and pencil and paper to practise content that is conveyed directly from the teacher to the student.

For orientation, section 3.4 and section 3.5 provide the core focus for this research, since the effects of tablet devices and associated apps on students’ mathematics learning can only be understood in the context of the development of mathematics curricula in SA. First though, section 3.2 opens with the history of mathematics education in SA, focusing on the development of mathematics curricula and the significant changes made by the MoE over the years with regard to tackling students’ low achievement and lack of motivation for accomplishing goals in the subject. In addition, this chapter delves into the history of the general integration of technology in the educational system (section 3.3). The scope ranges from the initial introduction of technology to the incorporation of tablets devices and iPads as documented in the literature. It will look at the key moments of technological shift in the educational system, both in the general context and specific to SA.

Section 3.4 evaluates the potential effects of the use of tablet devices and apps on students' learning, concentrating on the potential effects of these devices in terms of students' achievement and motivation levels. In the line with the primary focus of this study, this section also conducts a literature review of students' communication and collaboration levels using these devices, both in and outside school. It also reviews the literature on the effects of using tablet devices on students' creative and critical thinking skills. Furthermore, the literature review examines how using iPads affects students' degree of self-reliance and their level of involvement in mathematics classes. Finally, it discusses the active interaction amongst students through the use of tablets.

In line with the research objectives of the study, section 3.5 reviews the literature on teachers' perceptions of the factors that influence the adoption of iPads and apps in teaching mathematics. It also discusses their professional development and the skills that teachers should improve in order to play an effective role in students' learning and to be capable of instructing them on using iPads and apps.

The fifth section will examine the obstacles to integrating iPads or other tablets in the classroom and their substantial negative impact on the level of willingness to integrate such devices in the classroom setting.

In sixth section will provide a comprehensive understanding of how different learning theories and models respond to the aims of this study and how they apply to the use of the iPad and its apps. Therefore, it is important to select relevant theoretical perspectives and conceptual models that lay a sound foundation for any research study.

3.2 History of Mathematics Curriculum Development in Saudi Arabia (SA)

Many countries around the world, particularly developed nations, endeavour to develop their methods of teaching and learning mathematics because they recognise the importance of this subject in developing society and entering the world of scientific competition. Consequently, since 1923, SA has made significant efforts to reform and develop its education system and has prioritised the continuous development of the mathematics curriculum in order to maintain pace with the developed world. Figure 3-1 summarises key milestones in the development of the SA mathematics curriculum covered in this study. Mathematics as a subject is considered difficult and has become unpopular amongst many students (Yushau, 2006). As noted by Kajander and Lovricj (2005), students typically do not recognise the value and benefits of mathematics for their future. Thus, if students do not have an appreciation of mathematics, they tend not to put in the time and effort necessary to understand the subject and develop mathematical skills.

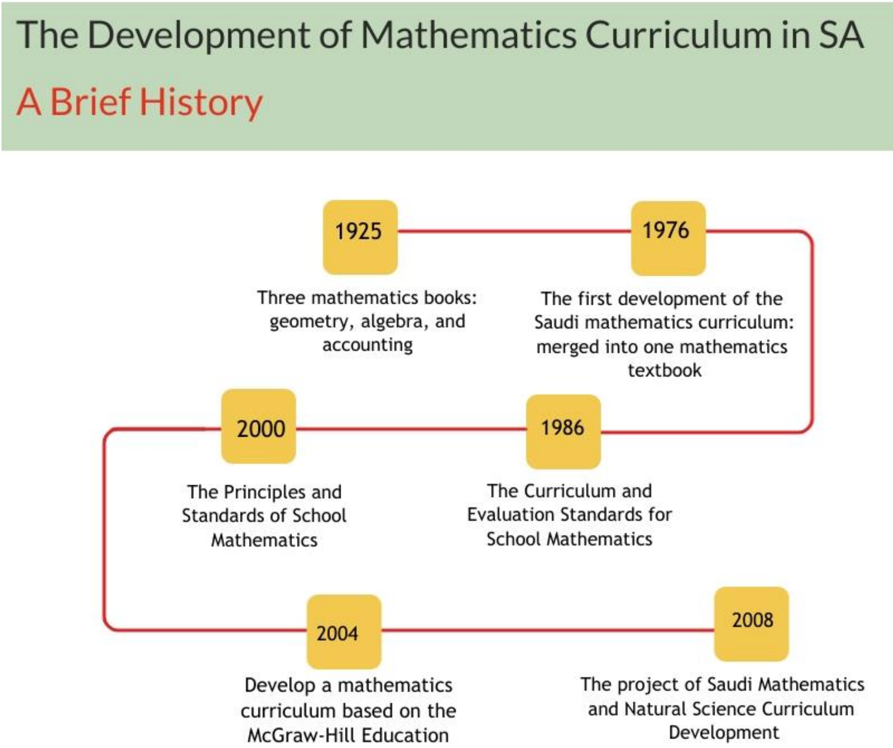


Figure 3-1. Development of the mathematics curriculum in Saudi Arabia (author's own elaboration).

As mentioned above, SA has endeavoured to develop mathematics curricula since education was instituted in the country in 1925, in accordance with the standards and practices established by the NCTM (for additional details of the NCTM, see section 2.9). The NCTM was founded in 1920 as the world's largest mathematics education organisation (NCTM, 2020a). In the late 1980s, the NCTM created a framework for teaching mathematics to students. These curriculum standards focused on the importance of problem solving, connections to reality, and communication (NCTM, 2020b).

In the early stages of the Saudi education system (dating from 1925), the mathematics curriculum consisted of three separate books, covering geometry, algebra, and accounting. Towards the end of the 1970s, the MoE amended the entire national curriculum, making particularly significant changes to the mathematics curriculum (Batterjee, 2011; Khormi & Woolner, 2019). In 1976, the first development of the Saudi mathematics curriculum was undertaken by the Mathematics and Science Educational Centre at the American University in Beirut. This change meant that all three books were merged into one mathematics textbook, the content of which covered the critical mathematics branches, such as algebra, geometry, numeracy, and operations (Khormi & Woolner, 2019).

In 1987, the NCTM released the Curriculum and Evaluation Standards for School Mathematics, which had a major impact on the development of mathematics teaching in public schools in the US. In 2000, the NCTM released a development document of the Curriculum and Evaluation Standards for School Mathematics after reviewing and studying it, called the Principles and Standards of School Mathematics (Ferrini-Mundy, 2000). Martin (2000) reviewed this NCTM document and identified according importance to the use of technology in teaching and learning mathematics as a principle or objective for teaching and learning mathematics. In 1999, the MoE provided educational courses for teachers and students on how to use (cf. section 2.10) to meet this standard.

The standards have played an essential role in developing the educational process in SA, for example describing which learning processes should be followed to improve students' outcomes (Alshehri & Ali, 2016). For many years, the MoE has endeavoured to develop and enhance the mathematics curriculum, and following the NCTM's publication of the standards in 2000, it has been striving to meet these standards and enhance students' achievements in mathematics. However, Saudi students' mathematics attainment remains behind most of the countries in the world, as identified by the results of the Trends in International Mathematics and Science Study (TIMSS). For instance, in the most recent mathematics rankings (TIMSS, 2019), SA was 53rd out of 64 nations and 37th out of 46 nations for the 4th and 8th grades, respectively. Therefore, SA students' achievement in mathematics was at the bottom of the TIMSS listing.

TIMSS is an international evaluation study, providing a database of students' achievements in mathematics and science (Alharbi et al., 2020). In addition, it collects comprehensive information about educators' backgrounds and their practices from different countries throughout the world which can be used to answer critical questions about teachers' role in influencing students' achievement (Burroughs et al., 2019). In 2003, SA scored second to last on the TIMSS reports. This, coupled with the poor mathematics performance, was a clear indicator of the low levels of achievement in mathematics among students in SA (Al-Ewasheq & Rafea, 2010; Khormi & Woolner, 2019). Thus, in 2004, the MoE in SA took the decision to develop a mathematics curriculum based on international experience, which proved effective in improving learning and teaching. Consequently, McGraw Hill Education and Al-Obekan Education, which represents McGraw Hill in SA, worked to develop a mathematics curriculum based on the standards and principles of the NCTM (2000) for all levels of education in SA. The MoE believes that this development is fundamental for improving Saudi's economy and society (MoE, 2006). However, this was already under way in 2007 when the results of TIMSS were released (Khormi & Woolner, 2019).

In response to the low achievement of Saudi students in mathematics compared to developed countries, in 2008 the MoE adopted one of the most significant educational projects in SA. This project, entitled Saudi Mathematics and Natural Science Curriculum Development (MNSCD), was implemented to improve mathematics and science education by adapting distinguished global series of materials, such as those published by McGraw Hill, for all educational phases (Khormi & Woolner, 2019). One of the aims of this project was to increase the ability of students, especially with regard to their problem-solving capabilities, building new concepts, and the ability to use technology in education in accordance with the international standards and principles of the NCTM (Madani, 2009; cf. section 2.9). The MoE established this project to improve the mathematics curriculum in schools and ultimately enhance the level of students' achievement in mathematics (Almaleki, 2010). However, according to Almaleki’s study, which observed 12 teachers and had their 273 students sit an achievement test, in addition to measuring their attitudes towards mathematics, students’ unwillingness to learn mathematics and their low achievement levels were, and continue to be, a substantial problem (Almaleki, 2010). As per TIMSS, it is evident that SA students’ achievement is significantly lower than the international average scores (mean = 500) in all examinations in mathematics for the 4th and 8th grades (2011, 2015, and 2019) at 410, 383, and 398 points respectively for 4th grade students, and 394, 368, and 394 points respectively for 8th grade students (Mullis et al., 2020), presented in Figure 3-2. Moreover, according to the Program for International Student Assessment (PISA), male students in SA had the lowest performance in mathematics among PISA-participating countries in the PISA 2018 (Organisation for Economic Cooperation and Development [OECD], 2020). After the TIMSS 2019 results were released, the Education and Training Evaluation Commission (ETEC, 2020) in SA reported that students lack basic knowledge in mathematics and half of the students could not reach even the lower international standard.

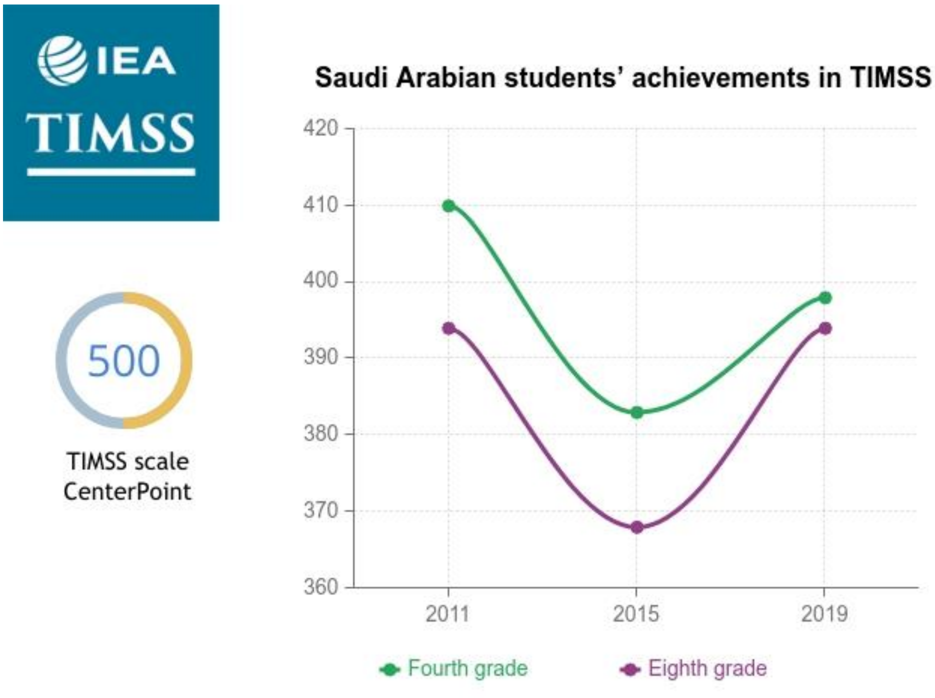


Figure 3-2. Saudi Arabian students' achievements in TIMSS (source: Mullis et al., 2020).

The MoE developed the mathematics curriculum as a solution for the students' low achievement in mathematics. However, Khormi and Woolner (2019), who adopted Billet's framework for reforming the school curriculum, contend that teachers are still using the same conventional teaching style to teach the new mathematics curriculum. This conventional style of teaching (referred to as the traditional method) uses textbooks, worksheets, and pencil and paper to practise content that is conveyed directly from the teacher to the student(s). Khormi and Woolner (2019), who assessed students and obtained feedback from schools regarding the development of the mathematics curriculum, argue that this style is inappropriate for the amended mathematics curriculum and philosophy and consequently students find the mathematics classes boring and unappealing. Thus, low achievement and lack of motivation to learn mathematics remain an issue in the SA education sector.

Therefore, the NCTM suggested that the learning of aspects of mathematics such as problem solving, communication, mathematical reasoning, should be supported with the use of technology (NCTM, 2020b). According to the NCTM (2015b), using technological tools, such as Web-based digital media and communication tools, can support and help students' learning by increasing access to more information, encouraging interaction with others, and facilitating the exploration and identification of mathematical concepts. It is essential, especially with the constant advances in technology, that teachers and students are familiar with the use of technology in education, especially tablet devices, which have become popular among most students. (For more details about tablet devices, see section 3.3.4.)

As discussed, for many years, the MoE has undertaken significant developments and mad amendments to the mathematics curricula in an attempt to resolve the issue of students’ low achievement in mathematics. In this regard, the MoE adopted one of the most significant educational projects in SA history in 2008 by adapting the McGraw Hill global series as the basis for a new mathematics curriculum for all educational phases (Khormi & Woolner, 2019). This had two primary aims: first, to improve SA students’ mathematics abilities in areas including problem solving to enhance their overall mathematics performance; second, to provide support and help for mathematics teachers in their efforts to overcome the challenges associated with equipping their students with the required levels of mathematics proficiency (for more details, see section 2.9).

However, the issue of the low achievement in mathematics still remains in SA and has become a very serious concern among educational stakeholders, particularly following the results of TIMSS and other international assessments. One issue is that Saudi students still depend on their teachers in their learning, but it is difficult for Saudi students to be more independent in a teacher-centred educational context (Albadry, 2018). Even though the MoE has tried to implement student-centred strategies in recent years, the teacher-centred approach is still prevalent and can affect students’ performance in mathematics and make mathematics classes boring and unappealing to them. For example, 65% of Saudi teachers in Gulnaz et al.'s (2015) study agreed that the teacher-centred approach results in discouraging students' learning output. Moreover, students typically feel that mathematics is a hard subject that encompasses many complex areas (Wendling & Mather, 2008).

This evaluation study conducts a literature review to examine the role of technology and its integration in education from its initial introduction through to the incorporation of the iPad and similar tablet devices. It evaluates learning with the iPad and apps, concentrating on the effectiveness of this device in terms of students' achievement and motivation levels, as well as fostering communication and collaboration amongst students, enhancing critical thinking skills, encouraging interaction, and developing self-reliance. The use of technology, such as tablet devices, could provide a new educational environment, which arguably has the potential to enhance students' learning. This study considers evidence of the positive effects of the intervention using iPads and apps and also the neutral or negative impacts on student outcomes. This review helps to understand role of tablet devices in potentially improving mathematics instruction. It also seeks to draw attention to critical discussions from teachers' perspectives concerning integrating the iPad in the education system and understanding their opinion of the extent to which iPad use affects the educational process. This review contributes to comprehending the research issue in terms of teachers’ views concerning the use of tablet devices in the teaching and learning process. It is also essential to ascertain the obstacles that the teachers and students face with the integration of iPads and apps in the classroom to ensure successful implementation with minimal challenges.

The following section considers the history of the integration of technology in education.

3.3 Technology in Schools

The integration of technology and new innovations have created a trend in SA education in accordance with the Saudi Vision 2030 (for more details about Saudi Vision 2030, see section 2.11). One of the aims of the Vision 2030 is to develop the domestic education system by integrating technology in the education process (for more details, see section 2.11). The implementation of technology at all levels of GE in SA has spurred significant developments in the education sector. Specifically, it has been the largest adoption of technology in the education systems of the Middle East (Mirza & Al-Abdulkareem, 2011). As mentioned in the previous chapter (section 2.10), technology has been integrated into Saudi's educational system for many years to support the learning and teaching system. In particular, as mentioned in section 3.2, the mathematics curriculum has been developed and shaped by the emergence of technological innovations. These innovations are no longer considered a luxury in the education system that teachers can choose or decline to employ; rather, they are a major factor in the development and implementation of the curricula and comprise a significant part of the teaching process.

Historically, in parallel with the ever-increasing integration of technology globally, the MoE and stakeholders in Saudi's education sector have demonstrated an awareness of the growing need for the use of technological devices. Thus, they have decided to employ a range of technologies in Saudi’s educational context and make education more accessible, in line with the Saudi Vision 2030. Technology in education is defined by mathematics coordinators and National Math and Science Initiative (NMSI) experts as any tool that can be used by a teacher and student to help enhance the learning process, such as smartboards, computers, tablets (e.g. the iPad), smartphones, video and digital cameras, calculators, and MP3 players, but is not just limited to these devices (Huneycutt, 2013). Moreover, there are different kinds of technologies that can be used and incorporated in education. This section discusses the history of key shifts in the technology used in the education system, both in general and in the education system in SA. It considers the perceived impact of these shifts on mathematics teaching and learning processes. A timeline of the technological innovations in mathematics education reviewed in this chapter is illustrated in Figure 3-3.

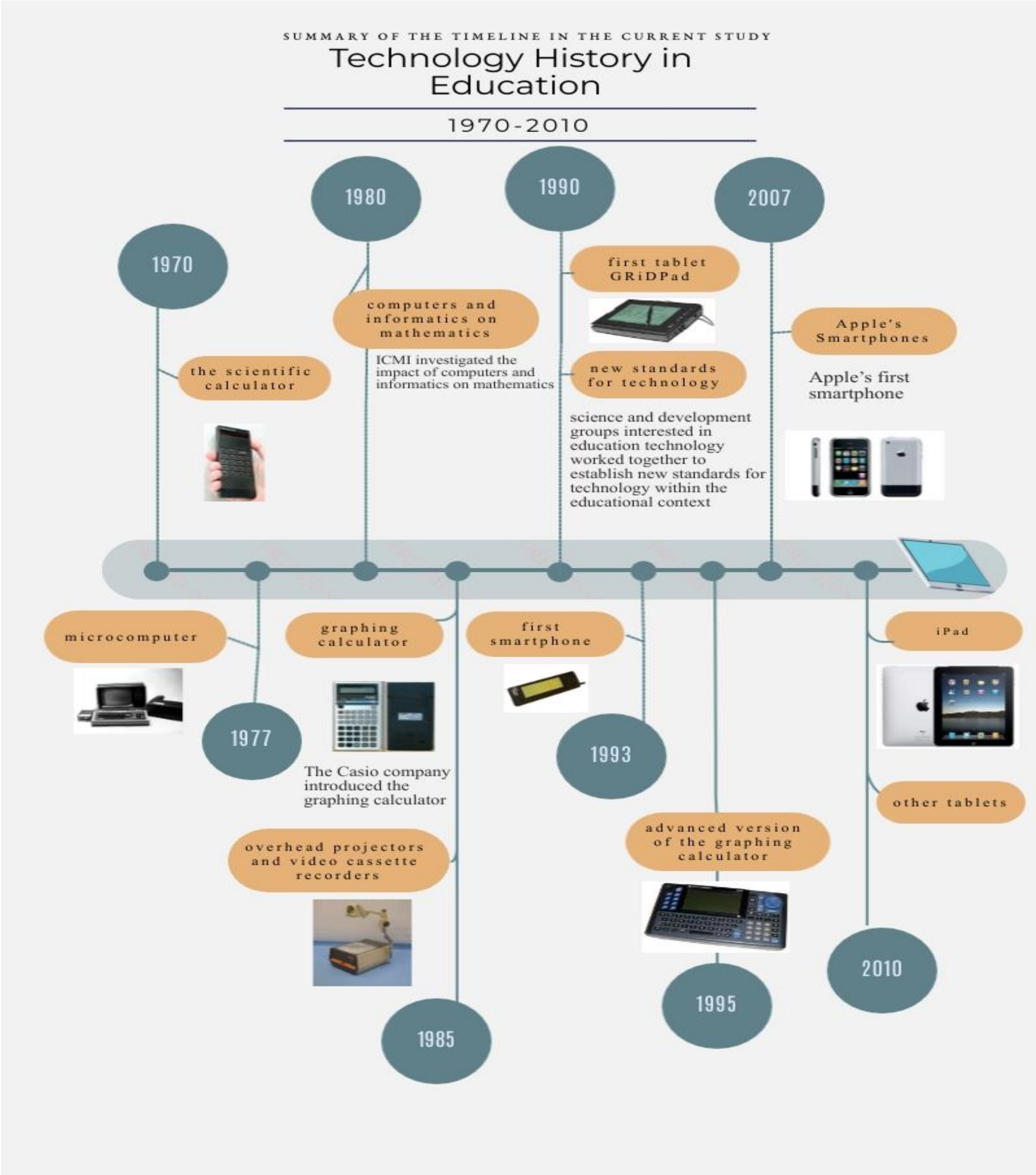


Figure 3-3. Timeline of the integration of technology in education.

3.3.1 Graphing Calculator

In the 1970s, the scientific calculator was introduced in the mathematics classroom as the first handheld technological device (Drijvers & Weigand, 2010). Casio introduced the graphing calculator in 1985 and the advanced version of the graphing calculator was introduced by Texas Instruments (TI) a decade later in 1995. Students were allowed to use it in the mathematics classroom and it brought about a tangible change in mathematics teaching and learning methods due to its advanced graphing, numerical, and problem-solving capabilities (Waits & Demana, 1998). In the existing literature, graphing calculators were shown to support students in solving complex mathematical equations and improved their efficiency (Goos & Bennison, 2008).

Merriweather and Tharp (1999) conducted a study investigating how to teach 8th-grade general mathematics students using the TI graphing calculator. The findings showed that many students were involved in their learning and became excited in the mathematics classroom because they could understand and solve complicated mathematics problems using the TI graphing calculator. Similarly, Bouck (2009) reported that students' mathematics performance improved when graphing calculators were used. In addition, their skills in solving mathematics problems increased and the calculator provided support in surmounting obstacles.

Some studies have reported that most students were able to own graphing calculators because of their affordability and portability. They believed that graphing calculators were more effective than other technological devices (Graham et al., 2008; Waits & Demana, 1998). Tan (2012) notes that graphing calculators are relatively inexpensive devices that can effectively be integrated in the mathematics classroom. Graham et al. (2008) highlight that the graphing calculator's portability and low cost have helped to make it a valuable resource in classrooms. While the graphing calculator is not a tablet device, discussions of its applicability nevertheless concern the accessibility of technology use in education, which is ongoing in the present era, but with modern technology devices.

3.3.2 Personal Computers

The personal computer (PC) was introduced in education with the onset of the technological transformation between the 1970s and the 1990s. In 1977, the first design for a microcomputer was introduced; it served as a PC but could not communicate with other computers. Recognition that this was an important requirement led to the development of computer networks, enabling information sharing, initially within the same room, but later over longer distances and ultimately worldwide (Davis et al., 1989). Since its introduction in education, there has been a substantial body of research into computer integration. The majority of the research supports the idea that integrating technology enhances teaching and learning (Falloon, 2013).

The International Commission on Mathematics Instruction (ICMI) was founded in 1908 as a worldwide organisation to develop mathematics education through improving the quality of learning and teaching worldwide (ICMI, 2021). In the early 1980s, ICMI investigated the impact of computers and informatics on mathematics. The teaching of mathematics and the curriculum itself were viewed as potentially likely to be affected by computer use in the classroom (Churchhouse et al., 1984). The integration of computers in schools was found to support students, especially those who needed additional help, as it provided one way of closing the gap between struggling students and their classmates (Donovan et al., 2010). Moreover, they found that computer use encouraged greater creativity and critical thinking through exposure to alternative learning environments (Donovan et al., 2010). In the mid-1980s, besides the integration of computers, other supportive educational technological tools – electronic and non-digital – such as overhead projectors and video cassette recorders became available. School leaders noted that teachers needed training in these technologies to integrate them successfully (Hofer & Swan, 2011). Technology devices evolve and are upgraded on a daily basis and therefore individuals intending to use them for educational purposes must be educated in their use to obtain maximum benefit. Similarly, tablet devices, a more modern innovation, run various apps that are frequently updated (cf. section 3.3.4). Therefore, stakeholders in the education sector should provide courses for teachers and students on how to use them prior to integrating them into the teaching and learning process.

Computers can be used to access various educational websites or run assorted programs, such as educational programs or games, similar to the features of tablet devices and apps. Kebritichi et al. (2010) reported on a study examining the effects of modern mathematics computer games on mathematics achievement and class motivation. The study participants were 193 students and 10 teachers from an urban secondary school in the southeast of the US. The quantitative study found the achievement of the students in the experimental group was significantly higher relative to that in the control group, but that there was no significant difference in motivation between the two groups. However, in the teacher and student interviews, a positive impact from the computer games on students' achievement and motivation was reported. One of the teachers stated, *"This is definitely the way that we have to go to teach mathematics in the future"* (Kebritchi et al., 2010, p. 434).

PCs have previously been used as a tool of support for students' educational endeavours. Christmann and Badgett (2003) conducted a comparative study of students' academic achievement, examining a group who had received computer-assisted instruction (CAI) and a group who had not. They found that "students receiving traditional instruction supplemented with CAI attained higher academic achievement than did 63.31% of those receiving only traditional instruction" (2003, p. 91). Pilli and Aksu (2013) conducted a study on the impact of using CAI on 4th-grade students' achievement and their attitudes towards mathematics. Their findings showed significantly better student outcomes for those who used CAI than those who did not. In addition, it found that students using CAI had positive attitudes towards mathematics. In another study, Tüzün et al. (2009) reviewed the effects of computer games on primary school students' achievement and motivation by assessing the learning outcomes of 24 students in the 4th and 4th grades in a private school in Ankara, Turkey, using mixed methods. The quantitative data showed significantly positive results in terms of students' learning and the student interviews suggested that their focus on earning grades was complemented by their interest due to being involved in independent study. However, they found that the students reduced their focus on gaining high grades and became more independent when engaging in games activities, which suggested that computer games can be used as an ICT tool to support students' learning.

In 2011, Serin conducted a study investigating the impact of CAI on students' achievement and problem-solving skills in the fields of science and technology. The results revealed that achievement and problem-solving skills in the experimental group increased more than in the control group. Li and Ma (2010) found that computer technology (CT) positively affected students' mathematics learning in K-12 classrooms, which consequently positively influenced their academic achievement. They concluded that the use of a computer can have a positive impact on teaching and learning mathematics, which can ultimately result in higher levels of student achievement (Li & Ma, 2010). Students can use PCs as an educational tool to enhances their level of achievement and support them in engaging in more independent learning by increasing their comfort level with regard to working autonomously. Therefore, it can be stated that classroom environments integrating computers equip students with greater self-reliance that better supports their learning and fosters their critical thinking skills (Donovan et al., 2010; Serin, 2011). The integration of computers allows students to participate to a greater extent and become more independent in their learning, which positively affects their learning outcomes and mathematic achievement (Page, 2002).

3.3.3 The Smartphone

Nowadays, a smartphone is a major part of life. The world's first smartphone was introduced in 1993 by IBM, which was followed by the revolutionary Blackberry; however, these were quickly surpassed by Apple's first smartphone in 2007, which has been especially popular over the last decade (Gowthami & Kumar, 2016).

Mobile technology, such as smartphones, in the 21st century is available to many students. Its usage has become second nature for these students, but it is not ready to be used in the educational system (O'Brien & Scharber, 2010; Shuler, 2009). There are several downsides to using a smartphone for learning, including the screen size, the ease in accessing non-educational resources, and lack of technical knowledge. Thornton and Houser (2005) conducted a study on mobile phone use in English education in Japan. Polling students about the use of mobile phones, they found that 100% of students owned a mobile phone and 99% of them sent emails through their phones, exchanging 200 emails per week, 44% of which were to peers about studying. Moreover, 61% of students used their phone for surfing websites related to their education, but they found that the small size of the screen was an obstacle. Similarly, Iqbal and Bhatti (2020) reported that most students did not consider the smartphone to be effective for educational purposes for several reasons, such as finding it a distraction, causing time wasting, and the keyboard and screen being too small. The authors also reported that the significant barriers to the adoption of smartphones included a lack of technical knowledge, training, and support, with no incentives to use the technology (Iqbal & Bhatti, 2020). This suggests that the iPad may be a better option as it is also a mobile technology device, but has a bigger size screen (for more details, see section 3.3.4), thereby enabling students to avoid using the smaller smartphone screen for educational purposes.

Conversely, on the plus side, the smartphone is an efficient tool for communicating and sharing learning content with others. Iqbal and Bhatti (2020) conducted a study exploring the impact of smartphone use on teachers' perspectives in higher education. They found university faculty members considered that smartphones could be effective for students' learning off-campus and provided excellent utility for communicating with their classmates. The findings also showed that sharing content with other students was straightforward and the smartphone was suitable for explaining complex subjects through multimedia. Furthermore, smartphones are also now widely used for promoting communication among students and teachers via contemporary communication apps. Ifeanyi and Chukwuere (2018) report that smartphones enhance communication among tutors and students, thus enabling them to discuss and explain concepts, facts, and illustrations more effectively.

Since the smartphone appeared, students have adopted smartphone technology to use in their learning environment by themselves. One instance of this is the use of learning apps, allowing students to attend online classes or watch video clips online, which support their learning. Furthermore, smartphone technology not only supports students, but also teachers. Mobile devices support educational systems by helping students and teachers to search for new information and knowledge (Buck et al., 2013). Furthermore, Yu and Conway (2012) highlight that both professors and students consider that smartphones can be used both inside and outside the classroom as a learning tool.

Consequently, mobile technology, especially since the emergence of fourth generation smartphones, has become more widespread in education. Smartphones make learning, teaching and daily lives easier by offering a variety of apps for use inside and outside the school setting. Smartphone apps are essentially the same as those featured on other devices, such as iPads, notebooks, or cameras (Wong et al., 2015). In the classroom, the iPad was the most commonly used mobile learning device in 2011 (Culén & Gasperini, 2011; Murray & Olcese, 2011). Li and Liu (2017) maintain that the iPad offers many features with different functions, such as a camera, a voice recorder, an Mp3 player, a tablet, a drawing pad, and a port to a network or Wi-Fi, and thus it has become a popular tool for educational purposes. The next section discusses tablet devices in education, focusing especially on the iPad.

3.3.4Tablets and iPads

In 1989, the first tablet, the GRiDPad, was created by Jeff Hawkins (Walker, 2011). In April 2010, Apple released its first iPad. The iPad is a tablet with a touch-sensitive screen that allows users to control it by moving their finger. It is similar to other tablet devices from different companies. Towards the end of 2010, several other tablet devices were released onto the market, such as the Galaxy Tab and Dell Streak. All tablet devices have unique properties that are not available on other devices, such as having a flat touch screen, being highly portable, and including many apps that are easy to download directly to the device. Most of these apps can work on different systems across devices.

Since their invention and introduction to the market in 2010, iPads have been used to support learning and teaching. iPads differ from the technology previously used in the classroom, e.g. desktop computers, which are available in most schools and universities. Hart-Davis (2017) argues that there are some important reasons for preferring to use iPads rather than other teaching and learning tools. They aer compact, with a large screen (10.2" retina display and weighing just 1.03 pounds with a thickness of 0.29") and with internet connectivity permitting high-speed surfing and streaming (both Wi-Fi and 4G connectivity), an iPad can support teachers and students to move quickly around the classroom while using it. In addition, the iPad has a stable operating system (iOS), which is easy to use, fast to login and logout of, and easy to control and restore the device (Hart-Davis, 2017). Therefore, in 2015, the school involved in this study decided to give all students an iPad to be used both in school and at home (for more details, see section 4.7.1).

The iPad was partly created to support teaching and learning (Apple, 2018) and the effectiveness of the iPad device in an educational sense is linked directly to apps. Both the iPad and other tablet devices operate through apps. In 2020, there were more than 500,000 educational apps promoting novel skills and knowledge development. Therefore, appropriate and effective app selection is key for the incorporation of the device to be successful. (For further discussion of the role of tablet apps in students' learning, see sections 3.4.1, 3.4.2 and 3.4.4.) While this study evaluates the effectiveness of iPad use in learning and teaching mathematics with no specific app, it does suggest that further research should be conducted to evaluate the impact of a particular app (see section 8.6).

As described by Apple (2018):

> iPad is designed for complete freedom of expression and freedom of movement. With amazing Apps and advanced built-in technologies, iPad can be anything students want it to be, and it has the power to create anything students dream up. Yet it's so intuitive, they can immediately take an idea and run with it. (www.apple.com/education/teaching-tools/)

The iPad and its various apps have contributed to revolutionising the education system, moving from established methods to an educational environment that has implemented the use of efficient technological resources that are appropriate for the modern era (Herro et al., 2013). The continuous access to key educational resources provides students with the opportunity to experience new methods of learning (Falloon, 2013). Thus, the iPad and apps can enhance learning by offering different learning avenues in the classroom (Falloon, 2013). Enriquez (2010) found that the iPad has significantly converted the education system and generated great opportunities for academic development in higher education. Therefore, it is necessary to determine if there is a similar impact in secondary classroom, in this case more specifically in 10th grade mathematics. Haydon et al. (2012) conducted a study to compare use of iPad Apps and worksheets in the context of a high school mathematics class in the US. In this study the students were found to prefer using iPads to solve or analyse mathematics problems over relying on worksheets in class as it was quicker. Thus, teachers and students recognised the value of using iPads in their subsequent classes. The conclusion of Haydon et al.'s (2012) study is that there is a positive effect of using iPads in the mathematics classroom.

Furthermore, the MoE in SA has announced a digital online portal to support learners use of iPads and other electronic resources and the portal website also aims to transfer print books to e-book format (ebook, 2018). The website is available in the Apple store as an app called Future Gate (for more details, see 2.10.3). This app supports videos, lessons, and activities for students engaged in both self-learning and participatory contexts. However, students in this study used an app called the Marefah system, which part of the Blackboard learning system (an online learning platform) employed by the participating school and some other schools in the same district. Students have access to the system to review video records of the lessons and previous tests, upload and download homework and activities, and communicate among themselves and with their teachers.

So far, only a few studies have specifically investigated the use of iPads in the education system in SA. For example, Alzannan (2015) conducted a study that examined the effect of using iPads on students' achievement in the Arabic language at kindergarten in SA during the second semester (four months) of the instructional year 2014. The sample comprised 42 children, both male and female. The class was separated into two groups, one experimental, taught using the iPad, and the other a control, taught using the traditional methods and resources such as textbooks, real objects, and flash cards. The study results showed that the students who used the iPad outperformed those who employed the traditional method and there were also benefits for their motivation. However, although Alzannan (2015) recommended the iPad as a teaching tool, his study was limited and did not mention students' motivation and factors promoting teachers to use iPads. Also, the research focused on the Arabic language as a school subject, not mathematics, and it was at secondary level in SA. The experimental approach can better be applied in two different secondary school classrooms than in one, particularly in mathematics classes, and dividing them into two groups. According to Creswell (2012), splitting one class into two groups can create a threat to internal validity. For example, the control group communicates with the treatment group, thereby enabling them to learn information about the treatment (Creswell, 2012). (For more information on internal validity, see section 4.13.1.1.)

Despite the aforementioned positive aspects of iPad use, some studies have report negative effects when using iPads in the classroom, such as students becoming distracted. For example, Karsenti and Fievez (2013) conducted a study to identify the benefits and challenges facing students and teachers when using iPads for learning and teaching. Data were collected from 6,000 students and teachers at 18 elementary and high schools in Canada. The study found iPads had a negative effect on students' learning and instructors' teaching. iPads can be distracting when used during class time. The teachers themselves mentioned that the students tended to use social networking sites, such as Facebook and iMessage, rather than to listen to their teachers. Thus, distractions were notably greater when the devices were connected to the internet. Similarly, Swicegood (2015) reported that using headphones while working with mathematics apps encouraged students to pay less attention to their teachers.

Since the introduction of the iPad and other tablet devices in 2010, there has been a significant body of research debating their use in education and exploring various related themes. (For further details on themes concerning the potential effects of tablet devices and apps on students' learning, see section 3.4) Although further studies have emerged since the inception of this study in 2017, with various books addressing tablet and iPad use in education, the literature review has been continuously re-examined and updated. Thus, this chapter provides a balanced overview of the various perspectives on the potential impact of employing these tablet devices and their diverse apps on students' learning and achievement. The next section reviews the literature on using tablet devices and apps on students' learning.

3.4 The Potential Effects of Using Tablet Devices and Apps on Students' Learning

This era is witnessing tremendous advances and rapid progression in technology in terms of the development of tablet devices. One of the major developments has been the introduction of these tablet devices in the learning environment. The literature review indicates that there is ongoing debate about whether this has positive or negative impacts on students' learning and offers an overview of the use of these devices in classrooms. Recent research in developed countries has shown that tablet devices provide opportunities to facilitate learning and can solve the issue of low achievement levels. The literature also demonstrates that the use of technology such as tablet devices in the classroom potentially affects students' motivation and engagement. However, while some studies have demonstrated how tablet devices can positively affect students' achievement (Al-Mashaqbeh, 2016; Alzannan, 2015), and their motivation and engagement (Murphy, 2016), as well as having other benefits for students' learning, other studies have not.

In line with the research aims of this study, this section reviews recent studies conducted in different countries around the world, focusing especially on SA, regarding the potential effects of the use of tablets and apps in terms of students' achievement (section 3.4.1), and students' motivation and engagement (section 3.4.2). As tablet devices and their various communication apps facilitate communication among students, the literature review will discuss their potential effect on students' communication and collaboration (section 3.4.3). In addition, existing studies investigating students' critical thinking skills and the impact of technology have produced conflicting outcomes and therefore this will be discussed further (section 3.4.4). Furthermore, it will also provide an overview of studies conducted on students' self-reliance (section 3.4.5), and students' interaction (section 3.4.6) in terms of the impact of using tablet devices and apps.

3.4.1 Potential Effect of Tablet Use on Students' Achievement

The low level of academic achievement in mathematics is one of the biggest challenges that learners face. There are several factors to which this could be attributed, such as failings on the part of the student or teacher, or an ineffective curriculum that causes a lack of confidence in students. As in many other countries globally, the SA government has undertaken many reforms in education in an attempt to identify a solution to this problem, such as developing the mathematics curriculum. Despite these developments, Saudi students have not scored well in the subject for many years. According to the TIMSS results, Saudi students' mathematics achievement is below most other nations (Mullis et al., 2020). This low level of achievement in comparison to other countries is a highly concerning issue for both the Saudi MoE and educational stakeholders. Aside from transforming the curriculum, one of the most significant educational reforms that has been executed in SA is the endeavour by educational institutions to integrate technology in the teaching and learning process in a bid to address this deficit.

Among the technological devices that have recently been integrated in the classroom are tablets, which emerged in 2010 and have since proliferated in mathematics classrooms (Agostinho et al., 2015; Carr, 2012; Ross et al., 2010). Al-Mashaqbeh (2016) conducted a study to examine the different impacts of using conventional teaching methods versus using iPads when teaching mathematics to 80 students in a first-grade class in Jordan. It emerged that using iPads in the mathematics classroom positively affected students' achievement (Mean [M] = 92.62) relative to using the regular teaching method (M = 88.5) at the end of the quasi-experiment. This is in line with several studies which have found that the use of iPads or other tablets has a positive impact on students' achievement levels, some of which are discussed below.

Alzannan (2015) conducted a study examining the effect of iPad use on 42 students' achievement in a kindergarten in SA adopting a quasi-experimental, equivalent control group design. The similar results of this study showed a positive effect on kindergarten students' academic achievement (M = 22.068) in language skills when they used iPads as learning tools compared with students who did not use iPads (dialogue and discussion) as learning tools (M = 20.367). Heinrich (2012) found that 61% of 310 students covering the years 7 to 13 (from 11–18 years old) at Longfield Academy in Kent agreed that their achievement increased through using iPads, while just 11.8% of students disagreed. The majority of teachers (58%) of 71 were neutral on this issue.

However, there are exceptions. Alsalkhi (2013) investigated the impact of using iPads on students' achievements in the 9th grades (secondary school) in Jordan. He found that there was a statistically significant difference in the post-test results between students' performance in the treatment group (listening to a verse, a picture, or watching a video via the iPad) and the control group (teacher holding the primary role in the learning process). Thus, students' achievement was positively affected in the Islamic Jurisprudent Unit with iPad use (Alsalkhi, 2013). This research differs from the current study in that the focus was Islamic education rather than mathematics. In Alsalkhi’s study, the teacher was not experienced or proficient in using iPads and therefore he recommended that for future research the teacher should be trained in how to use such devices and educational apps. The teacher participating in this study had experience of using iPad since 2015, when the school integrated iPads as a teaching and learning tool.

Furthermore, some studies have reviewed literature related to the impact of using technology and tablet devices in the classroom and have found positive impacts, especially for iPad use. For example, Clark and Luckin’s (2013) review identified that parents and teachers agreed that students benefit from the use of iPads, particularly as a means of improving academic performance, as evidenced by improvements in their grades. Also, Fabian et al.’s (2014) review of research on using mobile learning in mathematics found that 77% of 31 studies reported improved levels of student achievement.

While positive impacts in education have been identified, there are also some negative or neutral impacts which cannot be disregarded. Under some circumstances, the use of tablet devices as an educational tool either makes no difference or is deleterious for students’ achievement compared to conventional teaching methods. A relatively recent study by Singer (2015) found an insignificant effect of iPad use on 3rd-grade students’ achievement. This is very similar to Stattel’s (2015) finding that there was no significant difference between a class during treatment using iPads and in the non-treatment period using traditional methods over a total of 10 weeks. The students found it confusing to use the iPad for a short duration and then switch to the non-device treatment for a short period, and so on, for ten weeks. The study would potentially have been more conclusive study if two different groups of students had been taught using the two different methods for at least one month using the tablets, as in the current study. Another study, that appears to cast doubt on the effectiveness of using iPads and game-based learning in mathematics class was Carr’s

(2012) research in the US. He reported that iPad use and game-based learning applications did not affect 104 students’ mathematics achievement levels. This raises the question of why using tablet devices appears to have no effect. Various factors could affect the use of tablets in the classroom as a learning tool, which could subsequently impact students' learning and mathematics performance. Implementing interventions with technology devices must be sensitive to other considerations, such as preparation prior to the integration, providing support, and training teachers. Choosing skilled instructors with the knowledge necessary to incorporate iPads as teaching tools is essential when assessing their value.

App selection is a key element as it has a significant impact on students’ learning and achievement levels. When students use a learning app on a tablet device that has been badly designed or provides incorrect outcomes, it is detrimental to their learning. In contrast, if they use a well-designed app that gives accurate results, their learning should improve. The iPad itself remains a constant in both cases. Moreover, the use of certain apps could be challenging for students who have not been adequately trained, which could affect their learning. Some studies have investigated the effectiveness of using a specific app on an iPad or other tablet in terms of students' achievement levels. Riconscente (2013) conducted a study investigating how the Motion Math App could be used to improve students’ understanding of fractions in the 4th grade in two US schools. The average scores of 122 students on the fraction test rose 15% after practising using this app. Even though the students were only allowed to use the app for 20 minutes on school days, their achievement increased.

A similar study conducted by Kattayat et al. (2017) employed three specific apps (Physics Cheater, Physics Tutor, and Physics One) to investigate whether they positively or negatively affected students’ achievement in applied physics. The findings showed that using the apps helped students to make gains in their learning. The apps provided students with quick information (Physics Cheater), helped them to concentrate on the concepts with no worries about mathematics in physics activities (Physics Tutor), and provided very well resourced and structured assistance (Physics One) (Kattayat et al., 2017). This finding is verified by multiple studies. Arbain and Shukor (2015) established that students’ achievement increased and their learning improved following the use of GeoGebra. Moreover, Alotaibi (2015) found that the mathematics attainment of 12th-grade female students at a secondary school in SA increased after using the Nearpod app and noted that it would be interesting to introduce modern technologies to raise students' achievement in mathematics. It is essential that adequate planning is conducted on the selected app prior to its introduction in the mathematics classroom. Moreover, students should be well trained in the use of the app before it is used in the classroom because, as previously mentioned, this could affect the outcome. The training requirements include how to use the technological device itself and the specific apps prior to incorporation in the learning process.

While studies have reported positive impacts on students’ achievement using a specific app, there are also studies that have discovered contrary results. Rachels and Rockinson-Szapkiw (2018) conducted a study investigating the impact of using a gamification app developed by Duolingo® on 3rd- and 4th-grade students' achievement in learning Spanish at an elementary school. They found no significant difference in achievement between students in the treatment group who used the Duolingo® app to learn Spanish and those in the control group who were taught using traditional instruction. They mentioned that Duolingo® is an adaptive learning technology that requires students to operate at a level that stretches them to the limits of their knowledge of Spanish. This could lead to students facing difficult activities. This finding is interesting and it may be that using a specific app not requiring in-depth knowledge of content beyond the students’ level of proficiency to move to the next stage may produce better outcomes.

Another study carried out by Jaciw et al. (2012) investigated the efficiency of a specific app (tablet-based algebra program) that contained printed textbook content with a series of interactive tools allowing exploration of various algebraic concepts. The results showed no impact on students' performance in the end of course assessment or on the California Standards Test. However, the results of the study must be considered exploratory because the research was not designed to evaluate the difference in impact linked to stronger implementation. In addition, the subsample for the stronger implementation was too small (Jaciw et al., 2012).

As key aspect is that educational tools such as iPads are dependent on internet connectivity (Alsufi, 2014). It clearly seems that the majority of apps require an internet connection to reap their full benefits. However, it is preferable to use an app that can work without the internet to avoid disruption to the students’ learning if there is a weak or no connection in the classroom or at home. In this regard, there are various iPad apps that can work offline, such as game apps (for further details, see section 3.4.2).

Despite the abundance of prior research related to the use of technological devices and apps and their impact on students’ achievement in the classroom, there are limited intervention studies evaluating their impact on mathematics specifically and there is a lack of experimental research on mathematics at the secondary school level. This leads to the question of the extent to which using tablets and different apps can be effective in enhancing students' mathematics achievement. When studies find that they are not effective, is it possible that students have limited access to the device, or they possibly are not technologically proficient in how to use the device and the various apps? Is there a mathematics app that is superior to others in enhancing aspects of mathematical proficiency (e.g. conceptual understanding, comprehension of mathematical operations, adaptive reasoning, procedural fluency, etc.)? This study evaluates the impact of using iPads on students' achievement, helping shed light on the ongoing arguments in the existing literature. The next section explains the potential effects of tablet use on students' motivation and engagement.

3.4.2 Potential Effect of Tablet Use on Students' Motivation and Engagement

Motivating students is a challenge that faces teachers at all education levels and the solution is not clear. However, there are several strategies to support teachers in addressing this problem (Linnenbrink & Pintrich, 2003). Motivation is one of the key aspects in students' academic success, paving the path to achieving goals and promoting students' learning (Sanacore, 2008). When students feel their task in class is valuable, they feel excited about it and they become more motivated (Linnenbrink & Pintrich, 2003). Research has shown that engagement leads to the highest level of students' motivation (Prensky, 2001) and the level of students' engagement is evidence of their motivation being manifested (Reeve, 2013). Learners have diverse levels of motivation; some have high levels, some have low, and others have none (Daskalovska et al., 2012). Exploring the factors that increase levels of students' motivation is an ongoing process among teachers, researchers, and stakeholders in the educational setting. In this regard, technology may play a role, as *"Technology integration in the classroom can become a motivational factor for students, motivating students to pursue their learning with vigor"* (Kyanka-Maggart, 2013, p. 30). Introducing technology such as tablet devices to students may be beneficial for their learning and motivation. Thus, one of the expected outcomes of this research is that the iPad intervention could improve the students' level of motivation and foster their engagement in the classroom. Indeed, technology and the teacher can work together to motivate students, having a positive effect (Prensky, 2001).

Technology can be a factor in increasing the level of students' motivation and engagement in the mathematics classroom when it facilitates the learning process by helping students understand the content and complete the complex activities. Murphy (2016) found that whether outside or inside the classroom, technology positively affects pupils by enabling them to comprehend mathematics lessons deeply and by raising their engagement and motivation levels when learning mathematics. Technology can help students understand how to perform complex mathematics equations. According to Goodwin (2012), the instructors in his study found that students' motivation and engagement increased during the experimental period when using iPads. Students were furnished with iPad devices in Term 2 (2011) and the experimental period was in Terms 3 and 4, lasting a total of 18 weeks (Goodwin, 2012).

However, after reviewing 359 academic research papers, Karsenti and Fievez (2013) found no evidence to confirm or deny that iPad devices or any other technologies could foster students' motivation to learn. Also, Atallah et al. (2015) contended that the iPad is not designed to be a learning tool. They cautioned that it is not equipped to increase students' engagement and teachers should not use this device without a clear pedagogical strategy established by educational experts. This suggests that teachers should have a clear plan to integrate tablet devices in the classroom based on explicit learning goals. Another study conducted by Granito and Chernobilsky (2012) found that not all students in the 7th grade were motivated to use technology to learn social studies and they had low scores after its use. They recommended that technology should be integrated at an early age to support students' learning so that they would become familiar with using it and it would be beneficial for their future education. This leads to further investigation of the value of integrating technology at the secondary school level.

One of the primary factors in increasing students' motivation using technology in the learning process is their internet connection as discontinuity of internet service may become an obstacle for learning that affects motivation negatively (for more details about internet connection, see section 3.6). In the classroom, iPads must be connected to the internet as this allows students to access the web resources they require (Taylor, 2014). If the internet is slow or disconnects, it negatively affects the lesson by delivering the knowledge slowly to students or not at all. Consequently, it negatively affects students' motivation and engagement levels (Ali, 2015). Thus, a weak internet connection can disrupt students' learning by disconnecting their devices (Alsufi, 2014). However, Karsenti and Fievez (2013) argue that when devices are connected to the internet in the classroom environment, the distraction for students is notably greater and their engagement can decrease. This suggests that teachers should limit the internet usage time for students in the classroom if they believe that internet access could be distracting and affect engagement.

In addition, the use of headphones or social media while the teacher is explaining the lesson could also be distracting and cause students to be less engaged with the teacher, which suggests the need to limit students' use of these devices in the classroom. Swicegood (2015) reported that using headphones while working with mathematics apps led students to pay less attention to their teachers. In this regard, iPads can be a distraction for students as they access entertainment and social media apps in the classroom rather than using the devices for educational purposes (Alkaabi et al., 2015). Distractions such as students using headphones or social media platforms can cause a lack of focus that results in their learning being negatively affected. Chou et al. (2012) report that students can experience difficulties arising from unnecessary apps when using iPads. This leads to the question of the role played by applications in motivating and engaging students in the learning process discussed below.

The iPad and other tablet devices offer various kinds of educational apps (as mentioned before), which are useful when students feel motivated and engaged and can promote learning in the classroom. Carvalho and Araújo (2016) found that because students spend most of their time in classrooms, i.e. approximately 15% of their time, using game apps can improve their motivation and encourage them to engage more in classroom activities. Game apps can transform educational tasks into exciting challenges for students and reward them for their dedication (Johnson et al., 2014). A key point is to create educational game apps, as these are appealing to students and are therefore less likely to be rejected (Carvalho & Araújo, 2016). Similarly, Singer's (2015) study found that students exhibit higher concentration and motivation and feel better supported when using iPad applications than using when employing traditional paper and pencil means. In research conducted by Swicegood (2015), the teachers interviewed expressed that app use in the mathematics classroom enhanced students' levels of motivation and engagement. They reported that the students spent more time on their tasks and were therefore more open to diverse forms of learning (Swicegood, 2015). The tablet apps selected must be beneficial and relevant to the content for the teacher to expect increased motivation and engagement among students.

There are many factors that can increase students' level of motivation when using apps for educational purposes. First, these apps can support students in learning mathematics more efficiently as they can receive immediate feedback. Kyanka-Maggart (2013) conducted a study with two different classes of 5th- and 6th-grade students and two teachers in one school. Both teachers observed that their students become more motivated when iPads were introduced because getting feedback immediately prompted them to make an extra effort in the exercises delivered through the apps. Conversely, a delay of several days in providing students with feedback can decrease their motivation and engagement levels.

Second, students must be familiar with using iPads and apps before such technology is introduced in the classroom. If students do not have sufficient knowledge of the technology, it could negatively affect their level of motivation and engagement. According to Kyanka-Maggart (2013), students become more motivated to work hard in mathematics lessons when they have greater knowledge of technology. Indeed, technology knowledge is important for students, especially in terms of how to use particular apps to avoid encountering technical issues that could disrupt their learning. Kyanka-Maggart's (2013) qualitative data revealed the majority of students in both classes preferred to use pencil and paper to complete mathematics' exercises because they needed additional space to do so on the iPad (Kyanka-Maggart, 2013). Nevertheless, students can be trained in the use of iPad device and its apps, specifically using an electronic pen that feels like writing by hand but still provides the benefits of using an iPad. Also, some apps have greater flexibility and allow more space to write and resolve problems in greater detail. However, some students highlighted that they made fewer mistakes when using a pencil and paper than when using an iPad and electronic pen (Kyanka-Maggart, 2013). Karsenti and Fievez's (2013) study also reported that some students preferred not to use the iPad to do mathematics activities and said they could not write extended texts to complete complex equations as more explanatory steps were needed to solve them. However, Swicegood (2015) found that pupils who used puzzle-solving apps to learn, such as Splash Maths, were more likely to succeed than students using the conventional paper and pencil method to solve mathematics problems. It is essential to train students in how to use tablet devices and relevant apps, especially in terms of writing and solving long mathematics equations because otherwise their motivation and engagement in the classroom could be negatively affected.

Motivation is not only important for current academic performance, but it is also essential for students' beliefs in their future success as learners (Autio et al., 2011). Using iPads or other tablet devices may support teachers in encouraging students' motivation, engagement, and responsibility for their education. The studies considered here have provided an overview of students' motivation and engagement in the classroom. Some support the proposition that iPad use encourages students motivation and engagement while other studies do not, indicating the need for further evaluative research on the impact of iPad use on students' motivation. Motivated students are more likely to collaborate and communicate with each other and hence it is also critical to be fully aware of the possible impact that tablet devices and apps could have on students' communication and collaboration, which could in turn affect their motivation to learn. The next section explores this topic.

3.4.3 Potential Effect of Tablet Use on Students' Communication and Collaboration

An important factor when analysing the effectiveness of tablet devices as an education tool is that an attempt is made to understand the impact of these devices on students' levels of communication and collaboration. Collaborative learning among students can be defined as an educational approach to learning and teaching that involves groups of students working together to complete a task, create a product, or solve a problem (Laal & Laal, 2012). The collaboration of students through iPad use allows them to negotiate, debate, search, and present outcomes within task limits (Falloon, 2013). It provides visualisation tools and facilitates ways of communicating and representing their thinking to others (Preciado-Babb, 2012). For example, the collaboration of students on mathematical ideas or finding a solution for a problem and presenting solutions in their groups should lead to understanding of mathematical concepts (Clarke et al., 1993). However, motivation levels may decrease if a group work task lacks a real interactional focus. For example, this could occur when one of the individual members of the group fails to engage with the group task (Pauli et al., 2008).

Indeed, some research has shown that collaborative learning is not always appropriate in everyday classroom practice, even though teachers try to organise different group styles (Baker & Clark, 2010; Blatchford et al., 2003). Some researchers have noticed that students lack collaborative and communicative skills (Li & Campbell, 2008; Pauli et al., 2008). Based on the particular requirements or dynamics, teachers could alter their approaches to improve students' collaborative learning and communication. Emerging technology in education could support collaborative learning (Resta & Laferrière, 2007). Thus, the quality of teaching and learning could be improved by using technology, as well as encouraging interactions between groups of students in collaborative learning (Yau et al., 2003).

Tablet devices could potentially support communication and collaborative learning among students and enhance communication with teachers regarding their studies through various social media apps. These social media apps allow students to communicate, share images and video clips, and express themselves by providing comments and acquiring information from their classmates. According to Zgheib (2014), based on interviews with six faculty who used social media in their courses and analysis of students' posts in social media learning activities (SMLAs), utilising these social media apps can actually equip students with communication and collaboration skills. According to Karsenti and Fievez (2013), iPad use fosters collaboration and communicative learning both among students and between students and teachers. Indeed, in Kyanka-Maggart's (2013) study, one of the students mentioned that communication and knowledge sharing among students is more likely to occur with technology use. As an example, iPad use supports students to share their experiences with one another through collaborative learning via different apps, such as MathBoard, and to develop and utilise their knowledge in more creative ways in connection with other students in the classroom (Kyanka-Maggart, 2013). Another study conducted by Clark and Luckin (2013) also found evidence that iPads facilitate knowledge sharing among pupils. As a researcher, I contend that communication and collaboration among students using social media apps can serve as a distraction and essentially be a barrier that limits students' use of tablet devices for educational purposes. When a student receives a message on a social media app, there is an extremely high probability that he/she will read it and/or respond, which is disruptive to the learning process.

Despite having iPads and various communication apps to support collaborative learning available to them, a study carried out by Chen (2013) reported that students preferred to complete activities individually rather than through collaboration. Working autonomously on an iPad could lead students to feel depressed and lonely, which are markers of social isolation. Indeed, issues of social isolation associated with the use of iPads and smartphones are increasing at an alarming rate (Muhammad et al., 2019). Similarly, Alhumaid (2019) has shown that technology can negatively affect education in several different ways. For instance, social interactions between students and teachers can be distorted by using technology. Also, students may become increasingly isolated and lack any feeling of togetherness or collectivism when using technology as a learning tool (Alhumaid, 2019). My position as a researcher is that students who feel socially isolated when using such technology can communicate with others by voice, video, or text through a range of communication apps. However, Albadry (2018) maintains that some students have difficulties communicating with other students in a group discussion via an app. There could be several reasons for this, such as failing to manage their work simultaneously with others online effectively, or lack of a quiet place to enable them to hear their classmates clearly. Further evaluation is needed to identify appropriate methods for using tablet devices for educational purposes via a range of communication apps.

The above points suggest that learning mathematics may be a struggle for some students, thus causing them to become completely unmotivated to communicate and collaborate with others; however, the methods and tools employed by the teacher can have a great impact on students' levels of understanding. For example, using tablet devices in the mathematics' classroom might also enhance students' attention levels through communication and collaboration. This leads to further questions about the extent to which tablet devices and apps influence students' motivation when they are communicating and collaborating among themselves.

3.4.4 Potential Effect of Tablet Use on Students' Creative and Critical Thinking Skills

Research indicates that a students' level of involvement inside or outside the classroom may have significant impacts on cognitive development in various forms. One of these variables is critical thinking ability (Terenzini et al., 1995). Critical thinking is defined as *"High-level thinking skills exercised in the course of authentic knowledge work; the bar for accomplishments is continually raised through self-initiated problem finding and attunement to promising ideas; participants are engaged in complex problems and systems thinking"* (Binkley et al., 2012, p. 246). Teachers should guide students to develop their critical thinking skills and encourage them to be active problem solvers (Kyanka-Maggart, 2013). The integration of technology in the classroom can give students a broader scope, increasing the interest in and accessibility of learning, which can contribute to helping students focus. Alternatively, there is the possibility that when students employ technology in their learning, the over-abundance of information sources may cause difficulty in focusing on the content. Raja and Nagasubramani (2018) argue that "*Being ever-connected to the online world has resulted in lack of focus and concentration in academics and to some extent, even in sports and extracurricular activities*" (p. S35). As a researcher, I argue that a student's focus is an element of their thinking that can be expanded beyond the classroom walls through the use of technology to connect online to find information and develop knowledge.

Studies related to critical thinking skills and technology present diverse views of tablet-based technology. Cubelic and Larwin (2014) argue that educational technological tools, such as iPads, can support students in exploring and enhancing their creative thinking skills. These tablet devices could positively affect the dimensions of students' critical thinking by helping them explain their thoughts, organise their data, deliver their findings, and examine their arguments (Bagdasarov & Wu, 2017). In addition, they can facilitate learning at the students' own pace and increase creativity; consequently, students' motivation to learn could be strengthened (Rockman & Walker, 1997, as cited in Kyanka-Maggart, 2013). This interesting finding indicates that when students' creative thinking skills are improved, it will be reflected over time in their learning outcomes.

Changing the teaching methods is essential to facilitate students' learning using tablet devices and create an educational environment that promotes creativity and critical thinking. Preciado-Babb’s (2012) study showed that students in the classroom became more creative as a result of exposure to diverse ways of learning and using iPads and apps increased the opportunity for mathematics development in the classroom. More details about the role of tablet apps are provided below.

Mathematics apps could provide opportunities for practising tasks that require creative and critical thinking from students. The various apps can also cater to individual differences between students. Specific apps can be introduced to enhance their capacity to improve their critical thinking skills. Mathematics apps could improve students' mathematical knowledge in areas such as computation strategies, multiplication skills, fractions, and ratios, particularly through undertaking a range of activities, especially those that are complex in nature. Pilgrim et al. (2012) argue that students' skills can further their understanding of mathematics content through the use of complex critical thinking activities in apps, thereby enabling them to attain new levels of mathematics knowledge. For instance, Motion Math is an app that provides tasks at different levels, from easy to complex, to assist students in understanding fractions and ratios (Riconscente, 2013). Research conducted by Goodwin (2012) found that students preferred to enhance their thinking skills by solving difficult equations and participating in activities that required critical thinking. It is important to select an appropriate app for students to improve their critical thinking skills, choosing those that have activities at different levels, ranging from the natural to the more complex. Thus, students can enjoy learning new skills while studying mathematics, engaging in activities starting from the easiest and progressing to the hardest to best support their understanding of the lessons. The next section explains and discusses student self-reliance.

3.4.5 Potential Effect of Tablet Use on Students’ Self-Reliance

Nowadays, students are responsible for their learning and teachers can support them to develop the skills required to be self-reliant in their education. However, it can be challenging to develop students' self-reliance due to some inconsistencies in fundamentals such as the nature of some education methods (Zaitsev, 2019). Self-reliance means “to rely on one’s own capabilities, judgment, or resources; to be independent” (Umoru & Okereke, 2016, p. 45). Although the MoE has adopted different projects to transform educational processes from the teacher-centred approach to the learner-centred approach, such as MNSCD (section 2.9) and Tatweer (section 2.10.1), it remains difficult for students to gain independence in a teacher-centred educational context such as that in SA (Albadry, 2018).

Independent learning is usually linked to a student-centred learning approach. Thus, when independent learning is discussed, it arises in the context of essential issues such as the role of technology in education (Meyer et al., 2008). Meyer et al. (2008) reviewed the literature related to independent learning and its possible effectiveness for students. They determined that independent learning improved students' academic performance and increased their motivation and confidence levels.

Self-reliance is very important for students' acquisition of knowledge and is apparently supported when students use tablet devices. This gives pupils a sense of autonomy and control, thereby fostering independent learning (Clark & Luckin, 2013). Karsenti and Fievez (2013) reported on a program that provided iPads to students in Quebec, Canada, in autumn 2012, which resulted in 87% of 6,057 students from Grades 6 to 10 in different schools having access to iPads at home and school, which they could use for learning. While most students have their own mobile devices, it is essential to support them in building their confidence to realise learning objectives through the use of these devices, because doing so can effectively promote independent learning (Pilgrim et al., 2012).

Using iPads can encourage independent learning and enable students to work on different kinds of mathematics apps, through which they acquire new knowledge (Al Rafi et al., 2013). It is critical that priority is given to improving students' independent learning skills, but this will not happen if students have the tablet device directly as a learning tool without having first been taught how to learn independently. This could be accomplished by assisting students to use the iPad and apps through educational videos, sounds or pictures (Al-Mashaqbeh, 2016). It could be detrimental to students' learning if they are not equipped with the necessary skills or knowledge to use these devices and apps autonomously (Chen, 2013). Students' skills in using tablet devices and apps play a huge role in their learning because they may or may not be motivated to study and acquire knowledge. However, in a classroom environment, it is important for a student not only to depend on him/herself but to interact with others to ensure successful learning. (For more details on the potential effect of tablet use on students' interaction, see section 3.4.6.)

3.4.6 Potential Effect of Tablet Use on Students' Interaction

Interaction among students is important to make the process of learning easier through the medium of individual or group learning. This can be considered a key factor for successful education and students must support and collaborate with one another to have a constructive impact on their learning (Johnson, 1981). However, some contend that the use of tablet devices in education negatively affects interaction among learners, which ultimately results in the failure of education (Erkan, 2019). Lim et al. (2011) argue that technology in the elementary school classroom reduces students' levels of interaction because it creates an individualist environment. Albadry (2018) found that some language learning students at a Saudi university were reluctant to interact with classmates via different interactive apps because they believed that this was less beneficial for them, giving the examples of some students not engaging in tasks and slow internet connection disrupting their online communications. These findings show that students' interactions with these devices and apps can create feelings of isolation among students.

Nonetheless, technology can provide students with different sources of information and knowledge by offering extra space to promote interaction with other students. Ng (2016) argues that communicating via social media apps to share in education online is one of the top resources available for student interaction. These social media apps can provide students with the space to promote interaction, both among themselves and with their teachers. Although most Saudi students are frequent users of social network applications, such as WhatsApp, Twitter, Facebook, and YouTube, they typically do not engage with them as interactive educational apps to any great extent (Alsurehi & Al Youbi, 2014). As such, further efforts are required to identify the appropriate usage of these social media apps.

In addition, interaction among students in the classroom can promote the sharing and acquisition of knowledge among peers. In this regard, tablet devices can facilitate classroom collaboration, as mentioned in section 3.4.3. Jahnke and Kumar (2014) found that students effectively interacted and shared knowledge with their classmates using iPads and they preferred to work as a group. In another example, Tutty and White (2006) found that 74% of students believed that using iPads increased their level of interaction through several factors, including setting up informal workshops in which the students not only took on the role of active participants but also of lecturers. This finding is intriguing because it shows that students become more interactive by sharing what they have learned with others via using a tablet device and apps, which leads to the need for increased evaluation in this area.

In summary, the literature review shows that the use of tablet devices and various apps has produced mixed evidence in terms of their potential effectiveness in the learning process. There is a potential impact of these devices and various apps in enhancing learning in certain areas and in particular ways and there are also some pedagogy-related conditions involved. The benefits of these devices include enhancing students’ achievement and motivation, contributing to greater interaction and fostering communication among students. However, some of the above studies have identified concerns and issues regarding the use of tablet devices and apps. Therefore, the iPad intervention could potentially have a negative impact on students' learning in the classroom, or the students may not be supportive of iPad use.

The literature review indicates that there is an ongoing debate about whether introducing iPads in the classroom has a positive or negative impact on students' learning. This debate continues to raise questions about the impact of tablet devices on students' learning, especially with regard to their levels of achievement and motivation. Thus, this research will add to the literature and contribute to understanding of how iPads can be integrated in learning in secondary schools in SA, focusing specifically on mathematics education. Furthermore, from the perspective of teachers, the following question needs to be address: "What are teachers' perceptions of the effectiveness of using iPads in teaching and learning mathematics concepts?" The following section investigates some of the previous literature on teachers' perceptions.

3.5 Teachers' Perceptions of iPad Use in the Classroom

Ajzen (1991) describes perceptions as the degree to which an individual makes a positive or negative evaluation or assessment of the behaviour in question. Teachers' perceptions of using technology such as tablet devices for teaching in the classroom represent one of the potential barriers or enablers for integrating technology. Indeed, if teachers' perceptions of the integration of technology are negative or superficial, the probability of developing authentic technology use in the classroom will be lower (Reinking, 2011). In contrast, if teachers' hold positive perceptions about using tablet devices and apps, integrating technology in the teaching and learning process will have a good chance of succeeding. Thus, this study puts a particular focus on gathering teachers' opinions, as they play a critical role in providing evidence and in-depth details of their experiences with regard to the effectiveness of iPad use as a teaching and learning tool. This section reviews the literature related to teachers' opinions and expectations of the possible impact that the technology such as tablet devices will have on both themselves and their students.

Initial research suggested that it is important to have an awareness of teachers' perceptions prior to integrating new technology devices in the classroom. In Cavalcanti's (2014) study, some teachers felt challenged and anxious, while others were happy, confident, and felt that using technology would allow them to communicate with others. For instance, tablets can help to overcome communication barriers between teachers and students. They can discuss the materials and related educational issues through various kinds of apps such as the Baaz communication app and social media apps such as WhatsApp (Aldossry & Lally, 2019a).

However, social media apps are not an adequate replacement for face-to-face communication with others, as they cannot properly convey body language and other nonverbal cues such as inflexion (Raut & Patil, 2016). As such, further evaluation is needed to identify an appropriate means of using such devices and social media apps or alternative educational platforms for communication between teachers and learners.

Attard and Curry (2012) incorporated iPads in the mathematics classrooms for students in three different grades for a duration of six months. The teacher reported that that the learners became more engaged during the trial period. An important characteristic of the learning environment is that teachers and students share knowledge between them (Bada & Olusegun, 2015). Students can receive immediate feedback through mathematics apps from their teachers and enjoy being able to see their scores to discover which answers are correct. However, two teachers in Peel's (2019) study asserted that it is better to give students written feedback rather than using the iPad. One found that written feedback via paper and pencil was easier and faster than using the iPad. He also reported that giving written feedback was essential for low-level students because it was more efficient than providing feedback through the internet or any kind of technological device (Peel, 2019). Feedback plays a huge role because students can learn from their mistakes. However, different means of giving and receiving feedback should be revisited by stakeholders in the education sector because tablet devices and apps can support teachers in providing their students with immediate feedback at any time and in any place, allowing the students to learn from their mistakes faster and easier.

Teachers' perceptions concerning the use of technology could also influence students' learning. According to Inan and Lowther (2010), this could affect both learning activities and the teaching methods employed in the classroom. Educational stakeholders should understand these perceptions and address them to support the teaching and learning process as part of teachers' professional development (Pepe, 2016). It seems that the general concern of teachers about the use of iPads and apps in teaching and learning is related to how the intervention should be conducted. Effective training on use of the device and relevant apps would help to alleviate this concern. The next subsection highlights the professional development of teachers and discusses the skills that teachers should improve to play an effective role in students' learning and coaching them in using the iPad and apps.

The difference between teaching training, professional development, and professional learning is not very distinct, but they differ in their goals and objectives, albeit entailing some similar approaches and activities. Teacher training involves the identification of their interests and needs beforehand, considering their target audience, strengthening their skills, and equipping them to deal with different styles of learners (Brand, 1998). Professional development includes teachers' participation in seminars and workshops (in many case for at least 18 credit hours per year), engaging in professional dialogue on educational issues in regular teacher meetings, inclusion in meetings about curriculum development, participation in supervision meetings analysing teacher performance, and peer coaching in which teachers collaboratively learn new strategies for teaching (Kozina et al., 2009). Professional learning includes some formal and informal learning. Intentional formal learning includes taking a course and being certified, which increases teachers' mastery of curriculum objectives, whereas non-intentional formal learning includes the learning of logic and unpredictability, which can be faced in different situations with students. Informal intentional learning involves reflection, participation in reading groups and mentoring, whereas informal non-intentional learning involves learning through activities and in different settings (Knight et al., 2006).

In terms of teachers' professional development, a number of the studies reviewed (e.g. Schembri, 2015; Leary et al, 2013; Cavalcanti, 2014; Guerrero, 2010) highlight five key areas for the successful introduction of technology to aid teaching and learning in the classroom, including: (i) adequate support for teachers; (ii) relevant training courses; (iii) incentives; (iv) familiarising the teachers with using the technology; and (v) teaching experience. One aspect to be considered in using tablet devices and applications in mathematics education is the extent to which teachers perceive using iPads as effective in influencing the teaching and learning of mathematics concepts. It is essential to pay attention to teachers' professional development in terms of how to use the technology, especially tablet devices, prior to integrating them in the teaching and learning of mathematics. Technology is available for teachers in most schools. Therefore, they should be supported through ongoing professional development programmes offering appropriate training on how to use tablet devices and various apps. Enhancing learning using technology will not happen unless teachers have training courses on using these devices prior to integrating them in the classroom (Schembri, 2015). Leary et al. (2013) conducted a study to investigate the relationship between teacher training and students' achievement. They suggested that students' outcomes with an untrained teacher were similar to those with a teacher who used conventional teaching methods. From my perspective, effective training can contribute to high-quality teaching and consequently greater levels of student achievement.

Education is a continuous process; therefore, professional development and education are inextricably linked. Teachers' professional development can be delivered in many different forms, such as face-to-face training programmes, self-directed learning, conferences, workshops, or multiple programmes during a term designed to cover a topic through mentors or educational coaching. Unfortunately, most teachers do not have the time, information, or incentives to continue improving their professional practice (OECD, 2011). Specifically, teachers lack adequate support to attend training sessions or conferences related to the use of technological devices in education (Cavalcanti, 2014). This leads to the question of what kinds of training teachers need.

However, even after teachers have been trained, they still need to spend time teaching their students how to use the technology before integrating it in the classroom in order to ensure the success of the teaching and learning process. However, the teachers in Peel's (2019) study reported that dedicating time to training students on how to use devices at the start of the semester effectively created new layers of distraction. Training students on how to use a specific application at the beginning of each lesson also affects lesson planning (Beauchamp et al., 2015). These findings indicate that stakeholders need to organise development programmes for teachers on how to use tablet devices and educational apps in the classroom because they are already busy preparing for their lessons. Moreover, it would be beneficial to organise educational courses for students to save teachers' time. Thus, professional development should equip teachers with adequate technical knowledge and experience to support students when integrating these technological devices.

As mentioned above, one of the primary sources for teachers' professional development is training courses. Tablet devices can potentially be either effective or ineffective in aiding teaching and learning to achieve the desired educational targets. This largely depends on the quality of the training strategies employed and the extent of the benefits devices provide teachers and students in relation to achieving educational goals (Lee, 2011). However, if the teachers are not well trained, educational progress might be insignificant (Sankar & Abdallah, 2015). Familiarity with the technology and especially teaching students how to use iPads would encourage instructors to make more significant efforts to impart new knowledge to their students (Singer, 2015). Whilst it is important that teachers are familiar with using tablet devices, it is also essential that they are confident in the use of each app prior to introducing it in class to demonstrate mathematics activities. In a study conducted by Alabdulaziz (2017), one of the teachers preferred to use a traditional blackboard to explain mathematics activities rather than using technology. The teacher stated that this was because he liked to construct the solution step by step as he found it particularly beneficial for students who find arithmetic problems challenging. Undoubtedly, teachers require training specifically on the relevant apps and how to instruct students in their use (Singer, 2015). This finding is interesting because it shows that each app differs from other apps in its features and usage; thus teachers must take care to choose appropriate apps and be prepared for its use in the classroom. The findings of this study will clarify who is the appropriate person to choose apps.

Another essential source for teachers' professional development is their experience inside the classroom and their level of comfort with using technology. Teachers need practice inside the classroom to develop their professional skills (Coldron & Smith, 1999). When teacher training encompasses practical work on how to teach content via technology prior to integrating it in the classroom, coupled with their previous practical experience, it is more beneficial for the students. This will be reflected in students' learning and they will find the method of teaching content more interesting. Skills are required on the part of teachers to merge knowledge regarding technology, pedagogy, and content to successfully integrate technology in the classroom (Mishra & Koehler, 2006). Hence, it is essential to consider the depth and breadth of mathematics content and how teachers' knowledge of both it and technology translates into practice in order to enable students to investigate mathematics content through the use of technology (Guerrero, 2010).

One of the primary challenges experienced by teachers when using technology in the classroom is effective time management. Thus, teachers need professional development on time management when it comes to using iPads during classes. According to Alharbi (2013), among the difficulties teachers encounter when introducing technology in the classroom, time management constitutes a significant barrier, with the majority reporting difficulties finding the time to effectively integrate technology use in the classroom while also managing the lesson time. In SA, there are few opportunities for the use of technology devices and apps in education. Alharbi (2013) found that some Saudi instructors disliked using technology in the classroom because they were only allocated 45 minutes for the lecture and this was not enough time to navigate the breadth of information available via technology (Alharbi, 2013). To address this issue, the MoE created the Tatweer project in 2008 to develop and improve the Saudi educational system and support the integration of technology, including preparing in-service teachers by enrolling them in training programmes (Tatweer, 2011). Since then, technology has been integrated in the majority of Saudi schools, but Saudi teachers remain unfamiliar with the use of technology, especially iPads and tablet devices, in the classroom. Thus, teachers should be made familiar with the technology used in order to successfully integrate it in the classroom and positively affect students' outcomes confidence and engagement levels (Guerrero, 2010).

The literature review has demonstrated that teachers' technological knowledge and positive perceptions of technology use in the classroom are essential for teaching with technology. Teachers must be offered professional development opportunities so as to learn how best to integrate technology in the classroom by developing in-depth technological pedagogical content knowledge (Attard & Curry, 2012). However, the literature review illustrates that there has been a lack of teacher professional development with regard to how to use technology, especially iPads and the various educational apps, in the classroom. This could be one of the major barriers to mathematics teachers introducing technology in the classroom. It is essential that professional development is continuously evolving. It must maintain pace with the development of new technological devices and apps, which are constantly being updated. Therefore, this study will assess teachers' perceptions of the use of iPads and other tablets in teaching and learning to make a meaningful contribution to the body of evidence on this topic. However, there are other obstacles which might limit the use of iPads and other tablet devices in the classroom environment. These will be detailed in the next section.

3.6 Obstacles to Integrating the iPad in the Classroom

Researchers have identified several issues that reduce the effectiveness of iPads and other tablets in the classroom and limit their prevalence. These include problems with the internet connection, the lack of Universal Serial Bus (USB) port, the battery dying or losing battery life, broken or damaged screens, using non-instructional apps, have to spend time preparing prior to dealing with technical issues at the beginning of the class, and the device freezing or having problems mirroring to other devices. These issues are discussed in greater detail below.

The first of the major obstacles is disruption of the internet connection or weak internet service. The integration of tablets in the classroom requires full internet service (Al-Huneini et al., 2020). As Dhir et al. (2013) noted, the lack of a wireless internet service in school infrastructure could be a barrier to fully reaping the benefits of using technology, in particular iPads. Internet connection issues are not only problematic for students' motivation (as mentioned in section 3.4.2), but they also reduce the effectiveness of the integration of iPads in classrooms. Lack of connectivity or a weak internet signal negatively affects students' learning when doing activities, downloading, or submitting files (Alsufi, 2014; Williamson-Leadley & Ingram, 2013). Fluctuations in internet signal can cause data loss, primarily when connection issues occur (Parnell, 2018). To stay connected to the internet, the financial costs of maintaining learners' iPad devices and the technical requirements of Wi-Fi access should be supported (Melhuish & Falloon, 2010). Unfortunately, iPads are more dependent on internet service than other tablet devices (Al-Huneini et al., 2020; cf. section 3.4.1). As these new devices require an internet connection, it is essential to provide schools with strong internet services and boost infrastructure by adding a Wi-Fi service that covers all areas of the school.

The second obstacle associated with tablet devices is the lack of a USB connection (Ifenthaler & Schweinbenz, 2013). According to Peel (2019), the iPad device lacks a USB drive port. Thus, some teachers have to transfer large files with their comments or lectures via Cloud storage, but they may not be familiar with using the Cloud and often lack the technical knowledge related to it (Peel, 2019). In the internet era, it is essential to educate teachers and students to use Cloud storage to facilitate the data transfer process as USBs will generally no longer be accessible. Although some tablets, such as the Lenovo Windows tablet, come with pre-installed software that still allow USB sticks to transfer files directly without using the internet (Al-Huneini et al., 2020), there remains the need to educate both teachers and students on how to use Cloud storage.

The third obstacle is the device battery dying or losing battery life (Kyanka-Maggart, 2013). The issue of maintaining a charged device is the students' responsibility, ensuring that their devices are capable of covering the entire duration of the school day so that their learning is not disrupted. Singer (2015) argues that students need to be responsible for recharging their devices if the battery percentage falls below 50%. If students are able to recharge their devices at school, there will be no issue because they can recharge their devices at any time when moving around the school or dropping off their devices to be recharged by the teacher (Henderson & Yeow, 2012). Although previous research has found that iPads and tablets tend to have up to 10 hours of battery life, which is sufficient to cover the school day without needing to recharge devices at school (Sinelnikov, 2012; Stattel, 2015), the batteries often run low as the students fail to charge them at home prior to coming to school, which is detrimental to the learning process. Learning using iPads depends on battery life and Wi-Fi access in order to be able to study anywhere and at any time (Melhuish & Falloon, 2010).

The fourth obstacle to using iPads in school is broken or damaged screens. As noted by Henderson and Yeow (2012), when screens are broken or otherwise damaged, it will hinder the educational process. Moreover, iPads are expensive, as is their maintenance and repair (Heussner, 2010) and thus teachers often limit their use. Tagawa (2018) reported that a teacher did not allow students to use iPads most of the time because he was concerned about the devices being damaged or broken.

The fifth obstacle is using non-instructional apps when teachers are explaining the lesson. Students tend to think of tablets as being for engaging with social media or playing games, which potentially negatively impacts their concentration; therefore, teachers should manage students' expectations (Volk et al., 2017). Giunchiglia et al. (2018) found a negative correlation between students' academic performance and using social media to chat with friends in the classroom, since they were distracted and it was detrimental to their learning. As discussed earlier, while social media can have a positive impact on students' communication, it can also become a major distraction for students. In particular, checking Facebook or Twitter accounts while studying has a negative impact on students' overall performance (Raut & Patil, 2016). This suggests that it is better to use a specific educational platform for communication among students and with teachers instead of using a social media app that can be a source of distraction.

The sixth obstacle is that when teachers use iPads and other tablets in the classroom, they may spend time preparing prior to the commencement of the class, dealing with technical issues and transitioning to technology to carry out activities during the lesson. For this reason, many teachers have expressed a preference for the traditional lecture as it enables them to progress quickly through the material rather than wasting time on setting up technological devices (Swicegood, 2015). According to Stattel (2015), a teacher changed his schedule for his daily mathematics class as a result of bringing iPads into the classroom because students took more time to complete the daily activities using the iPad than they had previously. Thus, students lost time doing their daily activities or projects using iPads (Stattel, 2015). This suggests that the classroom should be equipped with these devices at all times, meaning that they should be ready for the teacher and students and connected to supportive devices, such as projectors or smartboards. Moreover, the students should be well trained and familiar with the use of the device and apps (as mentioned earlier in this chapter), to avoid losing time for activities.

Finally, the last issue that arises when using tablet devices is the device becoming unresponsive or having problems mirroring to other technology devices. Peel's (2019) study found that more than 50% of the 19 teachers reported technical problems such as devices freezing, difficulty in mirroring devices to Apple TV, and slow charging. These obstacles significantly decrease the willingness of teachers to incorporate such devices in their classrooms. Thus, further investigation of the obstacles facing teachers and students in integrating tablet devices and apps in the classroom is needed to enrich the literature.

3.7 Theoretical Framework

The schools in the education system in SA are beginning to integrate the use of technology into their learning and teaching methods. However, the iPad and other tablet devices have, for the most part, not yet been used effectively, whether inside or outside the classrooms. This could possibly be attributable to the failure of students and teachers to fully consider and understand the role these tablet devices play in delivering knowledge and information to students. Consequently, prior to adopting the iPad and its apps to support teaching and learning, it is critical to frame it in the context of the theories of learning and in particular, learning in mathematics, while considering the goals and objectives of the courses or educational systems at hand. However, the need for effective stakeholders in education can be seen in the robust response to an evaluation of the intervention.

In this section, the aim is to provide a comprehensive understanding of how different learning theories and models respond to the aims of this study and how they apply to the use of the iPad and its apps. Therefore, it is important to select relevant theoretical perspectives and conceptual models that lay a sound foundation for any research study. The significance of the choice of theoretical framework is evident prior to the completion of the data collection and analysis phases, particularly as the main contribution the framework is to provide a strong research direction.

To expand the researchers' knowledge of the theories of learning that would aid in understanding the more contemporary ways of thinking and their relevance to the current study, it was decided to examine three major theories and models in the field of research to ascertain which is best suited to achieving the aims of this study. Ultimately, the three theories deemed most pertinent to this study were: (i) constructivist learning theory; (ii) Technology Pedagogical Content Knowledge (TPACK); (iii) a logic model for programme evaluation.

Due to the nature of the research, a logic model for programme evaluation was employed prior to the data collection process, as this was considered the optimum theoretical approach for this work. This section provides details about these theories and the justifications for choosing the logic model while dismissing others for this research.

3.7.1 Constructivist learning theory

The basis of the constructivist learning theory is that learners' personal knowledge foundation is constructed from the creation of innovative concepts and learning approaches. Confidence, intellect, and experience combine to construct new knowledge for learners. Moreover, it entails engagement that is collaborative, and working with groups in creating creativity for learning is a fulfilling way of building knowledge and concepts for learners (Aldoobie, 2015). John Dewey introduced the constructivism theory by conceptualizing knowledge as a problem that needs to be connected with human thinking to identify a resolution. According to Sutinen, Dewey first stated that an emergent problem can be solved by working with others; thus, problem resolution is not to be understood as an individual act, because complexities and obfuscation require the application of more than one mind. The second stage, according to Dewey, is to expend effort to explain the problem using the available individual elements. The third stage is to analyse the problem methodically, leading to the construction of a fact-based hypothesis. The fourth stage is the accurate relation of the problem. In the fifth stage, hypotheses can be used to examine the ideas associated with the problem (Sutinen, 2008).

Bruner (1961) added to the above by proposing that knowledge is constructed by a learners' own prior knowledge, and so learners organize and catalogue information using a coding system. In fact, Lev Vygotsky was the first to theorize that the knowledge of the learner is constructed in conjunction with the wider societal environment. This emphasizes the active role played by teachers inside the classroom in facilitating students' learning processes (Vygotsky, 1980).

Moreover, Piaget's theory of constructivism seeks to establish a framework of children's thinking that encompasses their actions at diverse levels. The implications of this belief are indirect teaching, knowledge acquired from interactions with the outer perimeter, and a theory of learning that disregards resistance to learning (Ackermann, 2001). Technology-propped learning can be related to constructivism learning theories. Evidence shows that there is a correlation between learners' increased levels of interactivity and their use of screens and other non-linear material sources. In addition, learners can independently discern and formulate new knowledge, and learn how to evaluate, analyse, and make their own decisions autonomously. Learners can also draw comparisons between existing and new knowledge, and construct new knowledge (Ng, 2016).

Teachers can straightforwardly impart new knowledge to their students; however, students can also construct knowledge independently, exploring what they need and changing the rules when opportunities are scarce (Bada & Olusegun, 2015).

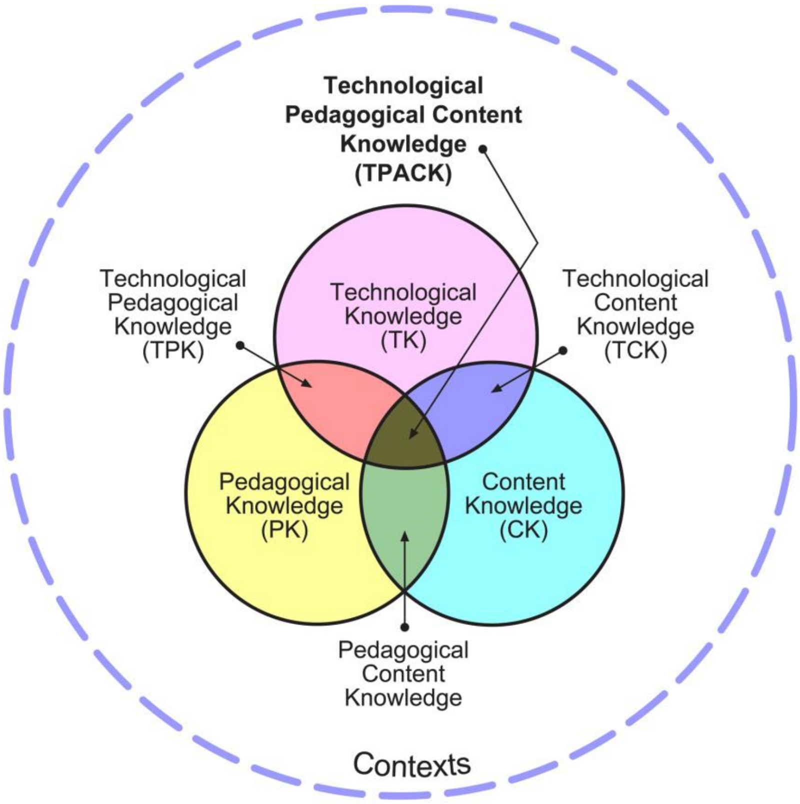
Constructivist learning theory relates the ways in which children become more active and enjoy learning. Through grounded learning students are more motivated and engaged, as it enhances collaboration learning, and promotes communication skills (Bada & Olusegun, 2015). Recent research conducted by Maher and Twining (2017) describes a case study in which students brought their own devices into two Australian primary schools. The study adopted a qualitative research methodology which included interviews, questionnaires, and classroom observations. The findings concluded there was a positive effect on students supporting constructivist pedagogy.

However, Efgivia et al. (2021) argued that due to students formulating their own ideas and knowledge, their formed opinions potentially differ from those of experts. Furthermore, constructing their own knowledge is a lengthy process for students, particularly for those who find it challenging. Therefore, the logic model programme in this study helped the researcher to ascertain the particular changes in the behaviour, knowledge, skills, status, and function levels of the students of the programme from those anticipated from the activities, and are generally expressed individually (Kellogg, 2004).

3.7.2 Technology Pedagogical Content Knowledge (TPACK)

TPACK is a framework designed to support teachers in determining how best to integrate technology into teaching and learning (Mishra & Koehler, 2006). In the 1980s, Shulman introduced the pedagogical content knowledge model (PCK), comprising three components: pedagogical knowledge (PK), content knowledge (CK), and pedagogical content knowledge (PCK) (Jang & Tsai, 2013). Mishra and Koehler further developed PCK to create the TPACK model, supplementing the pedagogical and content knowledge with technological knowledge. TPACK explains the relationship between technology, pedagogy, and content, and provides a model for how to integrate technology into education (see Figure 3-4). The stimulus factor for decisions about teaching materials and pedagogies in the TPACK model is the choice of technology (Koehler & Mishra, 2009).

Figure 3-4. Technological Pedagogical and Content Knowledge (TPACK) (Koehler, 2009)



Content Knowledge (CK):

Content knowledge (CK) is a prerequisite for teaching, as it is essential that teachers are knowledgeable about the subject matter they are delivering to their students. Moreover, content must be stage appropriate, i.e., the content of middle school mathematics is different from the content of mathematics at bachelor's level (Koehler & Mishra, 2009). Teachers in Saudi Arabia are highly knowledgeable about the subject content as they have completed comprehensive studies at the undergraduate level. They noted that technology has made the process of acquiring content knowledge easy as they can conduct research online, and accessibility has also improved due to the ease with which they can now share content (Aldossry & Lally, 2019b).

Pedagogical Knowledge (PK):

According to Koehler et al. (2009), teachers' require in depth pedagogical knowledge about teaching methods and learning to appreciate how their students will learn the subjects they are teaching. Teachers should also be given more information about lesson aims, values, and educational purpose, as well as how best to evaluate students. For instance, teachers use the assessment of students during or after the lessons to monitor them and evaluate the level of their performance (Aldossry & Lally, 2019b). Moreover, in addition to teachers' pedagogical knowledge, they also need teaching training programs and available resources during their in-services; hence, it is very important for school management and/or the education sector to provide these training courses and ensure the availability of resources (Aldossry & Lally, 2019b).

Pedagogical Content Knowledge (PCK):

PCK refers to content and curriculum, which are at the core of teaching, evaluation, and pedagogy. Effective teaching should collate alternative teaching methods, reflecting pupils' prior knowledge, and exhibiting flexibility in terms of finding different ways to engage in teaching and learning (Koehler & Mishra, 2009). In addition, Shulman (1986) said of PCK:

> *"Pedagogical content knowledge also includes an understanding of what makes learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons."* (Shulman, 1986, p.9)

Most teachers in Saudi Arabia have an understanding of content knowledge for their lessons, expect their students' misconceptions within any topic, and can identify connections between different concepts within these topics (Aldossry & Lally, 2019b).

Technology knowledge (TK):

TK encompasses knowledge about how to use technology and resources, including all tools within the domain of technology. Moreover, it entails knowledge about how to harness the power of technology to achieve a goal, and how to avoid barriers to the use of technology, as well as a readiness to adapt to future changes (Koehler & Mishra, 2009). Aldossry and Lally reported that most Saudi secondary school mathematics teachers are not sufficiently technologically savvy to resolve these technological issues. Although their undergraduate studies included learning about the use of technology in the classroom, the fast-paced technological developments since then mean that teachers must update and enhance their technological knowledge through online self-education or advice from their colleagues (Aldossry & Lally, 2019b).

Technological Content Knowledge (TCK):

Technological Content Knowledge is to know which technology is more suitable to use in each subject with a deep understanding of the content knowledge in any subject. The teacher should know how to use technology and be able to select appropriate tools for use in lessons (Koehler & Mishra, 2009). For example, teachers in Saudi Arabia need continuous courses for new technology; meanwhile, they understand that it is challenging to be capable of using all modern technology without help or support. They believe that technology aids them in teaching mathematics more than other methods. Thus, teachers need to increase their knowledge about the use of technologies, especially the iPad and its applications, so as to enhance the understanding of specific concepts (Aldossry & Lally, 2019b).

Technological Pedagogical Knowledge (TPK):

Technological Pedagogical Knowledge refers to understanding how the use of technology can transform teaching and learning methods, and to know how technological tools are related to the design and strategies of pedagogical development (Koehler & Mishra, 2009). Aldossry and Lally (2019) found that Saudi teachers need more knowledge, education, and training in technology use, and in the iPad in particular because there are new applications released every day and they are unaware of the best apps for themselves and their students. Moreover, for their mathematics lessons, teachers must know the most appropriate technology for improving the teaching and learning approaches in their classrooms. Hence, Saudi teachers require that school management or education sector administrators provide training and ensure availability of resources in relation to the iPad (Aldossry & Lally, 2019b).

Technological Pedagogical Content Knowledge (TPACK):

TPACK is the foundation of teaching when using technology, as it requires an understanding of the concept of the subject, knowledge, and pedagogical techniques to teach content using technologies in different ways in order to clarify how to make teaching and learning easy or difficult and to support students. It is also important to understand how technology can be used to reinforce prior knowledge, construct new knowledge, and build on or enhance existing knowledge (Koehler & Mishra, 2009).

The TPACK framework helps teachers to incorporate technology into their teaching to comprehend the intricacies of technology merging (Mishra & Koehler, 2006). Koehler and Mishra (2009) state that teachers need to have an understanding of the best technology to use with a particular subject in order to create a deeper comprehension of topic content. To understand how to integrate technology into the classroom effectively, teachers have to clarify the connection between technology, pedagogy, and target content (Mishra & Koehler, 2006). According to Niess et al. (2009), TPACK can be employed by mathematics teachers who are using technology to compare their understanding and thinking concerning the TPACK concept. For instance, knowledge of teaching methods, planning and management, technical knowledge, and full knowledge of the subject and technology usage such as the iPad are the most effective tools for teaching a mathematics lesson in a secondary school in Saudi Arabia (Aldossry & Lally, 2019b). Essentially, TPACK is the means by which teaching methods can incorporate technology, thereby facilitating teachers to utilise technology to demonstrate the lessons' concepts (TPACK.org, 2012).

However, according to Brantley-Dias and Ertmer (2013), the TPACK framework is too broad in scope, and its constructs contain numerous variants and subcomponents, making them overly complex. Even though the TPACK framework has clarified the significance of the need in teachers' education, more clarification and conversation for the future of education by educating and preparing both students and teachers is necessary. Therefore, the logic model of programme evaluation in this study has developed a new way of understanding the differences in using the iPad and its apps between students and teachers as well as providing a practical and simple guide for checking and confirming that a programme is working to achieve its intended results. It offers a succinct, one-page overview of the programme operations from the start to the conclusion.

3.7.3 A logic model for Programme Evaluation

It is imperative that all parties involved in education continuously develop and implement instructional programmes. To do so successfully and effectively, such programmes must be evaluated, and subsequently, any appropriate improvements and adjustments should be made. In a school environment, programme evaluation enables data to be generated and collected, which can then be analysed and translated into improvements (Sanders & Sullins, 2006). The collection, analysis, and provision of data through evaluations can provide researchers and stakeholders (operators and funders of programmes) with an overview and insight that enables future enhancements. All stakeholders of a programme can benefit from programme evaluation in terms of learning and management, with programme logic model approaches being particularly valuable (Kellogg, 2004).

Essentially, the introduction of iPads and associated apps as an educational tool is not the ultimate driver of educational improvement. Nevertheless, evaluating effectiveness is a critical part of any intervention programme, particularly at the secondary school level (Alter & Murty, 1997). In schools, a key factor for continuous enhancement and success is an awareness of the impact of an intervention. A problem in many organisations is that resources are poured into unproven or ineffective programmes (Kellogg, 2004). An effective evaluation requires the consideration of several key aspects. The programme must be explicitly laid out, with clearly defined goals, and activities therein that support the goals, each of which are adequately resourced and equipped (Patton, 2008). Once the programme is established in this manner, it is implemented and monitored through data outputs. Quantifiable data outputs are extremely beneficial to both programme implementers and managers (Royse et al., 2006). In this study, a logic model for programme evaluation was employed as a framework to determine whether the planned outcomes for the integration of the iPad device were being achieved. Effective programming is facilitated by the use of evaluation and logic models, which provide knowledge, enhanced recording of outcomes, and a better awareness of the most effective approaches and underlying reasons. The logic model enables the robust planning, implementation, and evaluation of a programme, making it a valuable evaluation tool (Kellogg, 2004).

Therefore, this study employs a logic model for programme evaluation as the basis for establishing the effectiveness of introducing iPads and other tablet devices in achieving the intended results for this school. Logic models offer a practical and simple guide for checking and confirming that a programme is working as intended to achieve its desired results. The logic model includes representation of the iPad intervention programme and the available resources, inputs, planned activities, and outputs, thus making it possible to determine and structure pertinent evaluation questions that would accurately reflect the impact of the programme.

3.8 Conclusion

SA, like most countries around the world, particularly developed nations, is endeavouring to develop its mathematics curriculum to improve the methods of teaching and learning. One of the major outcomes of this development has been the incorporation of technology in the classroom. The use of technology has become an important trend in the teaching and learning process since it was first introduced in the 1970s. The last five decades have seen countless developments that have resulted in integrating a range of technological devices in education. The tablet is one such device and iPads are becoming an increasingly important part of the teaching and learning process.

The literature review has provided an overview of the potential effect of the use of technology, especially iPads and other tablets, on students' learning, focusing on their levels of achievement and motivation. It shows that students can benefit greatly from using tablet devices. These benefits include improving their performance, enhancing motivation and communication and collaboration among themselves and with their teachers, increasing critical thinking skills, fostering greater self-reliance, and promoting interaction. It shows that teachers also benefit greatly from these tablet devices. One of the key benefits is that it helps them to overcome communication barriers with their students. It also helps them to maintain positive student engagement in the classroom, which leads to more rewarding engagement.

However, the literature review also shows that teachers need professional development on how to use tablets and the various apps in order to ensure their successful implementation in the educational process. In addition, it shows that teachers' professional development needs to be continuously updated to remain in line with new technological developments, which can be accomplished via effective training. A lack of professional development with regard to how to use the technology, especially iPads and educational apps, in the classroom could be one of the major barriers to mathematics teachers implementing technology in their classes. Other obstacles have also been noted as reducing the prevalence and effectiveness of the introduction of technology in the classroom. These obstacles include: (i) lack of internet connectivity or weak internet service, (ii) batteries dying or loss of battery life, or slow charging capabilities, (iii) the device freezing, and (iv) lack of a USB drive port.

While there is a substantial amount of research available that supports the use of tablets due to the multiple benefits, there are fewer specific evaluations of the use of iPads in mathematics classrooms in the secondary school context, especially in SA. Indeed, this research is the first to evaluate the integration of tablet devices and apps in GE specifically from the viewpoint of both teachers and students and to use mixed methods research to collect the data. Most research has not encompassed teachers’ views of the use of mobile technologies in teaching, instead focusing on information provided by teachers about students’ learning using such technology in the classroom. A broad understanding of teachers' perceptions concerning the integration of tablet devices and apps may contribute to a better understanding of the link between the use of these devices and important educational outcomes, including students' achievement, motivation, engagement, and communication. Finally, the findings of this study will also highlight teachers’ and students’ opinions of important pedagogical issues and seek to provide practical insights for both teachers and students who intend to use tablet devices and apps in the GE system in SA. To successfully introduce and integrate tablet devices in the classroom for the benefit of students’ learning, several aspects need to be considered, including the provision of effective support for both teachers and students, appropriate training in the use of the device and relevant apps, and resolving the obstacles that have been detailed above.

Chapter 4 Research Methodology and Methods

This research evaluates the impact that iPad devices have on student achievement and motivation in 10th grade secondary classrooms. In addition, it aims to determine which factors influence the adoption of iPads among mathematics teachers in a particular secondary school in SA. This chapter describes the research methodology used in the study. To address the research questions, quasi-experimental quantitative data and qualitative data are incorporated in a mixed methods design. There are several kinds of mixed method research designs; the six most common are convergent parallel, explanatory sequential, exploratory sequential, embedded, transformative, and multiphase (Watkins & Gioia, 2015). This study applied an embedded mixed methods design to address the quantitative research question and two qualitative research questions. These questions are separate and not related to each other and thus the data for each are analysed separately. The purpose of using an embedded design in this study was to address the different quantitative and qualitative aspects in a single study (Creswell, 2012). However, the quantitative data were the primary source in this study, with qualitative data as the secondary source (Creswell, 2012).

According to Creswell (2012), the embedded mixed methods design is the most popular for educational research since it can produce a greater amount of detail about the research problem than other approaches. The embedded design aims to collect both quantitative and qualitative data sequentially or simultaneously in a single piece of research, such as an experimental study (Creswell, 2012). In this study, the embedded design made it possible to collect quantitative data and qualitative data simultaneously (Watkins & Gioia, 2015). The quantitative method aimed to evaluate the effects of iPad use on the achievement of the participating students, determining the statistical significance of the results from the pre-test and the post-tests and using the students' test results to identify whether using iPads and the apps made an appreciable difference to their learning.

During the collection of the primary quantitative data, the secondary qualitative data were also collected from students and teachers to support or augment the primary data, i.e. to provide additional sources of information related to research questions not addressed by the primary source of data (Creswell, 2012). Thus, in this study, the qualitative methods aimed to evaluate the effects of iPad use on the motivation of students by gaining an in-depth understanding of their feelings, views, and conceptions about the integration of iPad use. It also sought to evaluate the factors influencing the use of iPads by mathematics teachers in teaching concepts in a secondary school, as well as to obtain in-depth information on their perceptions.

4.1 Research Questions

The purpose of this study is to evaluate the efficacy of iPad use in improving student achievement and motivation. To achieve this, I formed two research questions focused on evaluating the outcomes of an intervention using iPads and the effects on participating students. I also included an additional question to evaluate the outcomes of iPad use related to teachers' perceptions. The research questions are as follows:

1. What are the effects of iPad use on students' mathematics achievement?
2. How does using iPads affect the motivation of students in learning mathematics?
3. What are teachers' perceptions of the effectiveness of iPad use in the teaching of mathematics concepts?

4.2 Research Paradigm

According to Guba and Lincoln (1994), the paradigm represents a worldview, and more specifically, a natural perception of life for the paradigm holder, which helps identify his/her place in the world. It establishes the relationship between the world and the holder's purpose within it. A paradigm consists of four components: ontology, epistemology, methodology, and methods (Scotland, 2012).

4.2.1 Ontology

The starting point for all research is ontology, which informs the researcher's theoretical framework in philosophy (Mack, 2010). Also, as ontology is regarded as "the study of being", it is interested in answering "what is the nature of existence within the structure of reality?" (Crotty, 1998, p. 10). Furthermore, the ontological field of study seeks to identify the very nature of reality. Different ontological stances depend on the researcher's view of reality (Guba, 1990). The different assumptions of reality that exist lead logically to differences in ontological perspectives. Thus, researchers need to determine their position, related to their own perceptions of how things really work (Scotland, 2012).

In educational research, the assumed nature of reality is usually based on the philosophical assumptions that can be most clearly seen in two major ontological views, namely realism and relativism (Pring, 2004). Realism is defined by Pring (2004) as a mindset in which there is believed to be a reality that must be discovered by the researcher as it exists independently of that researcher. The second assumption, relativism, states in contrast that there is no ultimate truth, only relative subjective values; the researcher thus creates their own reality. In this study, the ontological stance adopted is relativism, based on considering differences in participants' explanations and perspectives.

There are multiple perspectives on the factors that influence teachers' perceptions and students' motivations related to the use of iPads in the classroom. These factors exist independently of the researcher, being constructed by the participants according to different variables and needs, which must be explored and interpreted by the researcher.

4.2.2 Epistemology

Crotty defined epistemology as "the theory of knowledge embedded in the theoretical perspective and thereby in the methodology" (1998 p. 3). Epistemology is concerned with the theory of knowledge and is centred on understanding what we know and how we understand what we already know (Crotty, 1998). Epistemology, as described by Wellington (2015), deals with the nature of human knowledge. Constructionist epistemology, in Crotty's view, asserts that no objective truth is waiting to be discovered and therefore the meaning of truth comes into existence based on our realities and how we engage with life (Crotty, 1998).

In view of the nature of knowledge developed by working with different participants who might construct meanings from different perspectives, this study seeks to explore multiple perspectives. Thus, the epistemological stance in this study is constructionist. Each participant may be expected to point out different factors that influence the use of iPads in the classroom. Therefore, I am to construct meaning from all participants' interpretations of the factors that they believe affect teachers' and students' iPad use in the classroom. The study thus takes into account the fact that the participants have different experiences and backgrounds with regard to iPad use and that their perspectives have been constructed over time.

4.2.3 Methodology

Research methodology refers to the philosophy which guides the logic of scientific enquiry and explains how researchers identify and examine multiple and complex realities (Cohen et al., 2007). Also, the research methodology concerning the procedures employed to gather and analyse information, processing data to support hypotheses using evidence rather than assumptions (Myers, 2009). A methodology is defined as "the strategy, plan of action, process or design lying behind the choice and use of particular methods and linking the choice and use of methods to the desired outcomes" (Crotty, 1998, p. 3). Methodology involves designing a framework to collect the data and outlining how to analyse the data. According to Henning et al. (2004), a research methodology is required to organise and support the desired approach to gain information and outcomes that are reflected in the research questions and not just the research objectives. Moreover, defining a research methodology explains why a particular technique is used in preference to others, allowing the findings of the research to be assessed objectively (Kothari, 2004).

4.2.4 Methods

The research methods are specific procedures or instruments used to collect data. According to Crotty (1998), methods are defined as "the techniques or procedures used to gather and analyse data related to some research question or hypothesis" (p. 3).

4.3 Paradigms in Educational Research

There are several theoretical paradigms discussed in the literature, such as positivist and postpositivist, interpretivist, constructivist, transformative, critical, pragmatic, emancipatory, and deconstructivist (Mackenzie & Knipe, 2006). There are two prevalent paradigms in educational research: positivist (realist) and interpretive (naturalistic) (Lincoln & Guba, 1985). The quantitative approach aligns with positivism and the qualitative approach is suited to interpretivism. Recently, another school of thought has argued that mixed method approaches to research fall within an alternative philosophical framework, which is pragmatism (Creswell, 2012; Feilzer, 2010). A mixed methods approach to research is defined as "empirical research which involves the collection and analysis of both qualitative and quantitative data" (Punch & Oancea, 2014, p. 551). Mixed methods research combines quantitative and qualitative approaches in one study or multiple studies to solve a research problem (Creswell & Plano Clark, 2011). The research design of this study is mixed methods, as explained further in the research approach. Thus, the underlying paradigm in this study is pragmatism because it gathers together the positivist and interpretive paradigms. Each is defined in the following paragraphs.

4.3.1 Positivism

Auguste Comte and Herbert Spencer established positivism in the 19th century (Parahoo, 2014). Comte was a French philosopher and the founder of positivism, who believed that there was a general doctrine that real knowledge depends on sense experience and can be advanced by experiment (Cohen et al., 2007; Mack, 2010). Moreover, positivism hold that natural science methods are suitable for research in the social sciences (Bryman, 1988). The positivist position is that reality exists independent from individual experience and the law of causation controls the world and can be tested (Gibbs, 2007). Positivists describe experience through measurement in order to control and predict the forces which surround us (O'Leary, 2004).

The natural sciences and scientific theories can be tested through use of controlled variables and the calculation of statistics based on experiments (Hammersley & Atkinson, 2007). According to Mack (2010), the purpose of positivist research is to test hypotheses and the characteristics of positivist research are that it involves generalisable findings, statistical analysis, and an emphasis on the scientific method. Moreover, positivist research employs a familiar design, such as experimental, and places the features under experiment into pre-test and post-test methods; it usually has a treatment group and a control group (Mack, 2010).

4.3.2 Interpretivism

The interpretivist (constructivist) paradigm arose from the philosophy of Edmund Husserl's phenomenology and other philosophers' study of interpretive understanding called hermeneutics (Mackenzie & Knipe, 2006; Mertens, 2014). Within the interpretivist paradigm, reality entails understanding individuals' behaviours (Parahoo, 2006). The interpretivist stance fits with the notion of personal and social realities and aims to provide in-depth information about subjects' feelings by collecting and interpreting qualitative data (Pring, 2015). According to Mack (2010), the interpretive paradigm entails the ability to construct meaning individually. Also, it is sometimes presented as the anti-positivist position since the interpretive paradigm was developed as a response to positivism (Mack, 2010).

The main ontological assumption of the interpretivist paradigm is that reality is built from the individual and the person's subjective interpretation. The main epistemology of interpretivism is that a person's knowledge is obtained from their experience (Mack, 2010). Thus, the main tenet of interpretivism is that "research can never be objectively observed from the outside, rather it must be observed from inside through the direct experience of the people" (Mack, 2010, p. 4). In a qualitative approach, the researcher interprets the data by examination, which requires analysis of the data to identifying themes, improving on individual descriptions, and writing a conclusion about the subject's personal feelings (Creswell, 2003) because the ontological assumption of interpretivism is subjective, not objective (Mack, 2010). Although positivists argue that only a singular objective reality exists and objective inquiry is the only possible method (Creswell & Plano Clark, 2007), interpretivism was used in this research to explore further the students' and teachers' feelings about the introduction of the iPad in their learning and teaching environment.

4.3.3 Pragmatism

Mixed methods research arose as a result of a period of debate referred to as the "paradigm wars", praised for its ability to produce a sustained exchange of opinions over a long period of time, outlining the advantages and disadvantages of qualitative and quantitative research methods (Feilzer, 2010, p. 6). The most common research methods associated with positivism are quantitative. In contrast, interpretive research is associated with qualitative methods (Mackenzie & Knipe, 2006). However, mixed methods utilises both qualitative and quantitative methods and thus there should be a balance of focus on both positivism and interpretivism in such research.

The positivist and interpretivist paradigms are set apart from the ontological perspective because they offer different perspectives of reality. Positivists argue that there is just one reality, while interpretivists state that multiple realities exist. The epistemological difference between the positivist and interpretivist schools of thought focuses on the interaction between the researcher and the subject. While positivism emphasises that the subject under investigation and the researcher should be separated, interpretivists argue that researchers should invest more heavily in their interaction with the subject under investigation (Mackenzie & Knipe, 2006; Teddlie & Tashakkori, 2009). To solve the problem of incompatibility between the two paradigms, quantitative and qualitative methods (mixed methods) must be combined in a new paradigm, pragmatism (Mackenzie & Knipe, 2006). Adopting pragmatism as an alternative paradigm rejects consideration of the conflicting issues of reality and truth, focusing instead on a philosophical interpretation. Pragmatism argues that single or multiple realities can be employed to solve different practical problems (Creswell & Plano Clark, 2007; Dewey, 1925).

Pragmatism is a paradigm suited to mixed methods research, enabling researchers to combine their quantitative and qualitative assumptions to complete research as it "supports the use of a mix of different research methods" (Feilzer, 2010, p. 6). Indeed, it is possible to use "any and all paradigms to employ mixed methods rather than being restricted to any one method, which may potentially diminish and unnecessarily limit the depth and richness of a research project" (Mackenzie & Knipe, 2006, p. 8). Also, pragmatism is not committed either to a reality or to a philosophical system; rather, it enables researchers to use whatever technique or procedure they consider to be the most supportive of their chosen method

(Creswell, 2014). Pragmatic researchers concentrate on "the what and how to research based on the intended consequences" (Creswell, 2014, p. 40). A mixture of methods can thus employ pragmatism as the theoretical framework (Feilzer, 2010; Mackenzie & Knipe, 2006). Compared with positivism and interpretivism, pragmatism employs different assumptions and multiple methods; it has a different worldview and of course a different way of collecting and analysing the data (Creswell, 2014). The data collection tools in pragmatism may include those typical of both the positivist and interpretivist paradigms, such as experiments and interviews (Mackenzie & Knipe, 2006).

4.4 Research Approach

To answer the research questions, a researcher should search for an appropriate research design that allows the use of appropriate methods for collecting and analysing relevant data (Muijs, 2010). This might require the researcher to use more than one research method (Cohen et al., 2005; Yin, 1994). This evaluation features one quantitative research question and two qualitative research questions and thus required a mixed methods research design. According to Johnson and Onwuegbuzie (2004), “Mixed methods research is formally defined here as the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study” (p. 17). The strength of mixed methods is that the use of more than one method enables a large amount of evidence to be collected, which leads to good corroboration of results and the drawing of strong conclusions. Also, the findings can be generalised to a greater extent and plentiful data support comprehension and highlight any missing points in either the qualitative or quantitative research (Johnson & Onwuegbuzie, 2004).

Quantitative research was used to evaluate the effects of iPad use on the achievement of students in mathematics performance assessments. According to Creswell (2012), performance measures can replace an achievement test, which would otherwise be performed to measure individual ability. To assess the achievement of students, the researcher must evaluate whether the treatment affects the dependent variable or the outcomes. Thus, an experimental design is required that allows evaluation of these factors, including a pre-test and post-test to assess students based on defining a treatment group and comparing the results for this group with those of a control group (Creswell, 2012).

Qualitative research was used to evaluate the effects of iPad use on the motivation of students in learning mathematics. It was also employed to evaluate the effect of iPad use on the perceptions of teachers regarding the teaching of mathematics concepts. Qualitative research is best suited to address a research problem if a researcher does not know the variables and needs more exploration, but also when a researcher wants to understand the participants' points of view and allow them to explain perspectives in their own words (Creswell, 2012). Thus, semi-structured interviews and focus groups were set up to collect qualitative data. Teachers' perceptions were analysed through data gathered from semi-structured interviews (see Appendix 1A, 1B), while information regarding student motivation was gathered from focus groups (see Appendix 2A, 2B). One of the advantages of one-to-one interviews rather than a multiple member format is that the participants feel more comfortable answering the interviewer's questions honestly. The semi-structured interviews used in this study to gather in-depth information about the impact of iPad usage on the teachers' perceptions related to the teaching of mathematics concepts were conducted on a one-to-one basis.

Focus group interviews are used to collect data from a group of four to six people. Focus group interviews were used with the students in this study to explore the impact of iPad use on their for learning mathematics, each group containing six students. The advantage of using focus group interviews is that the participants yield useful information that is amplified and extended as members encourage each other to take part. Focus group interviews could be the best choice when participants have similar knowledge and can cooperate (Creswell, 2012). Thus, each group of students was encouraged to share their experiences and knowledge about iPad use in mathematics lessons with each other and during the interview.

4.5 Definition of the Logic Model

First introduced more than two decades ago, the logic model functions as a planning and evaluation tool that establishes the purposes, and positive and negative aspects of a programme (McCawley, 2012). There is an existing body of literature that details the development of a robust logic model, its practical applications, and its multi-contextual value to organisations. The primary function of a logic model is to describe the causal links between the stakeholders, theoretical assumptions, inputs and outputs, resources, activities, and outcomes (McCawley, 2012; Kellogg, 2004).

Essentially, a logic model is a diagram of the link between the requirements of the programme and the associated actions to put it into effect. It offers a succinct, one page overview of the programme operations from the start to the conclusion. The diagram comprises a set of boxes that depict the components, inputs or resources, activities, outputs, and outcomes of the programme individually (Randolph, 2010). The diagram provides a visual overview of the relationship between the goal of the programme, the activities or interventions, and the results or effects (McCawley, 2012; Westmoreland et al., 2009). The diagram presents the interconnections between the components in the bid to accomplish the goals of the programme. Figure 4-1 depicts a basic logic model. Other forms of logic models are flowcharts with arrows linking the core elements and tables containing graphic organisers (Westmoreland et al., 2009). Ultimately though, whatever form it takes, a logic model is a visual guide to the functions of a programme.

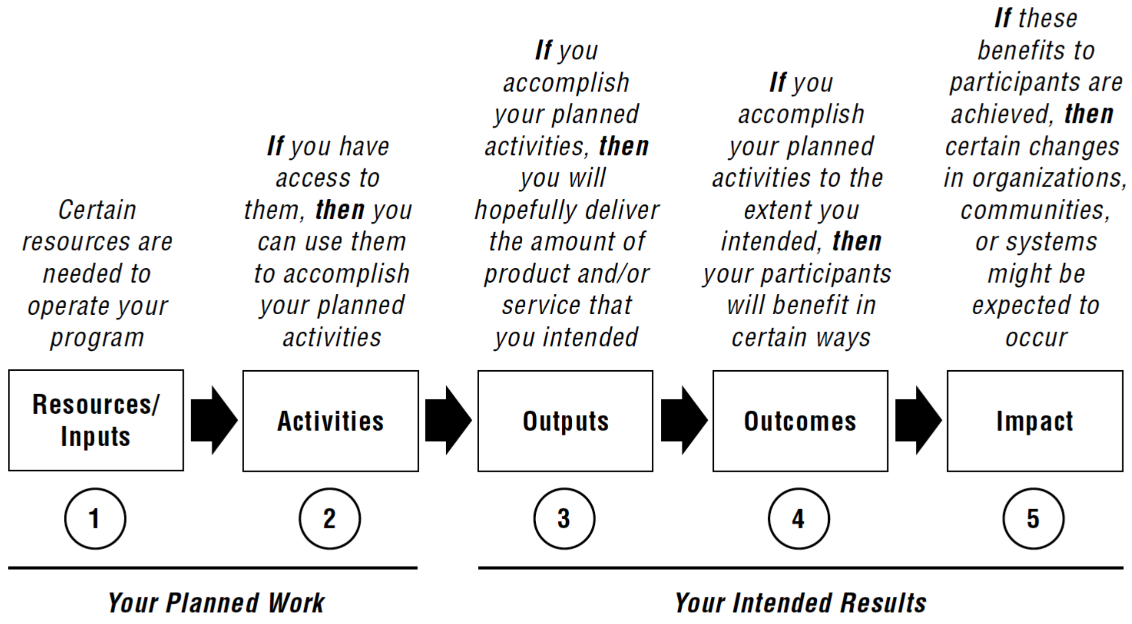


Figure 4-1. Basic logic model (adapted from W.K. Kellogg Foundation,2004, Logic Model Development Guide).

Logic models are derived from the topic of programme evaluation. The concept emerged from a growing awareness of the need to structure and organise the evaluation process among evaluators of programmes (McLaughlin & Jordan, 2004). As they have evolved, logic models have gained popularity among programme managers for both planning and evaluation purposes. In addition, as accountability and quantifying outcomes have increasingly been prioritised, logic models have been used to provide a clear look at the change process, its underlying assumptions, and the avenues to achieving goals. Logic models have become more common among researchers carrying out intervention research planning (Brown et al., 2007). Another benefit of logic models is that they can facilitate agreement between stakeholders debating an issue (Hernandez, 2000).

4.6 Elements of a Logic Model

A similar concept map, which describes the different elements of the programme, is used in all logic models. Further to defining the problem or issue being addressed by the programme, there are five core elements that show the links between the available resources, the planned activities, and the goals: (1) inputs or resources, (2) activities, (3) outputs, (4) outcomes, and (5) effects (Kellogg, 2004).

4.6.1.1 Inputs or Resources

Inputs or resources can include the available human, financial, organisational, and community assets that can be employed to accomplish the programme goals (Kellogg, 2004; Westmoreland et al., 2009). More specifically, human assets include time invested, financial assets include costs and expenditures, organisational assets include facilities, and community assets are supporting assets, such as equipment, the knowledge base (teaching resources and curricula), and stakeholder involvement in planning and implementation (McCawley, 2012). The purpose of resources is to support and enable the programme activities. For the researcher, input descriptions facilitate enhanced communication about the standard and effectiveness of an intervention. Furthermore, well-described inputs enable more precise problem evaluation (McCawley, 2012).

4.6.1.2 Activities

Activities depict the approach of the programme. They present the way in which a programme plans to utilise the previously detailed inputs to accomplish the tasks. Activities are also known as the action steps that are required to generate outputs for the programme (McLaughlin & Jordan, 2004; Newcomer et al., 2015). They encompass all elements of programme delivery, including the processes, tools, events, technology, and actions. The activities form the basis of implementing client changes or generating outcomes (Kellogg, 2004). With regard to an intervention programme within a school, the activities include curricula and testing, and teaching events, such as classwork, field trips, and participant tours. By describing the activities, a link is formed between the problem and the intended outcomes of the programme (McCawley, 2012). Activities result in the programme outputs.

4.6.1.3 Outputs

Outputs are directly generated by the activities of the programme. They can include the service types, levels, and targets that the programme intends to deliver (Kellogg, 2004). Outputs are a gauge of the level of activity that has transpired and the stakeholders involved in the programme. Participants are the core of the logic model and therefore any information about them is a critical component of the output description (McCawley, 2012). In the context of a school intervention, outputs can include data such as the number of class periods taught, the number of students in those classes, attendance rates, class demographics, and details of each activity’s duration (Kellogg, 2004).

4.6.1.4 Outcomes

Outcomes are the particular changes in the behaviour, knowledge, skills, status, and function level of the participants of the programme that are anticipated from the activities and are generally expressed individually (Kellogg, 2004). Some programmes have numerous outcomes, represented by short-term, intermediate, and long-term outcomes (McLaughlin & Jordan, 2004). Short-term outcomes encompass changes in awareness, knowledge, abilities, motivation, and attitude, representing positive change. Intermediate outcomes include changes in practices, behaviours, and end-user technology use. Finally, long-term outcomes include higher achievement scores, enhanced grades for the semester, better attendance rates, and more engaged participation (McCawley, 2012). Programme stakeholders must be able to access and comprehend the outcome results. An unfavourable scenario is when the programme outcomes in the evaluation reports are of interest to the evaluators but are largely irrelevant to the stakeholders, meaning that they are not pertinent to those directly affected by the intervention (Hernandez, 2000).

4.6.1.5 Impact

Long-term outcomes are also known as programme goals or programme impacts. The impacts are the changes at the organisational, community, and/or system levels that are anticipated from the activities of the programme. They can encompass enhanced conditions, greater capacity, and/or policy changes (Kellogg, 2004). Due to the principle of causation, which is the basis of a logic model, the activities within a programme cycle generate outcomes that subsequently have an effect on both participants and the organisation. Consequently, the role of programme evaluation is to establish the degree of this impact. Whilst making causal links between outcomes and impacts is challenging, researchers can illuminate the relationships between them, providing greater insight into the meaning of the programme (Westmoreland et al., 2009).

4.7 Research Design

The research design governs the way in which the researcher collects, analyses, and interprets the data (Creswell, 2012). At this stage, it is necessary to determine the parameters of the mixed-methods strategy (Creswell, 2011). Creswell (2009) identifies six mixed-method designs: the convergent parallel design, the explanatory sequential design, the exploratory sequential design, the embedded design, the transformative design, and the multiphase design. The research design chosen for this study was embedded mixed methods (see Figure 4-2). According to Creswell, use of this method means that the researcher collects quantitative and qualitative data during an experiment study, then analyses the results separately; thus, the two types of data answer different research questions (Creswell, 2012). The purpose of this research was to evaluate the effectiveness of iPad use in mathematics teaching and learning for a secondary school in SA. Thus, the quasi-experimental design was conducted as the primary quantitative approach and the secondary qualitative approach was carried out during the quasi-experiments. This research employed an embedded design that combined quasi-experimental quantitative data (pre-test and post-tests) and qualitative data (semi-structured interviews and a focus-group interview).

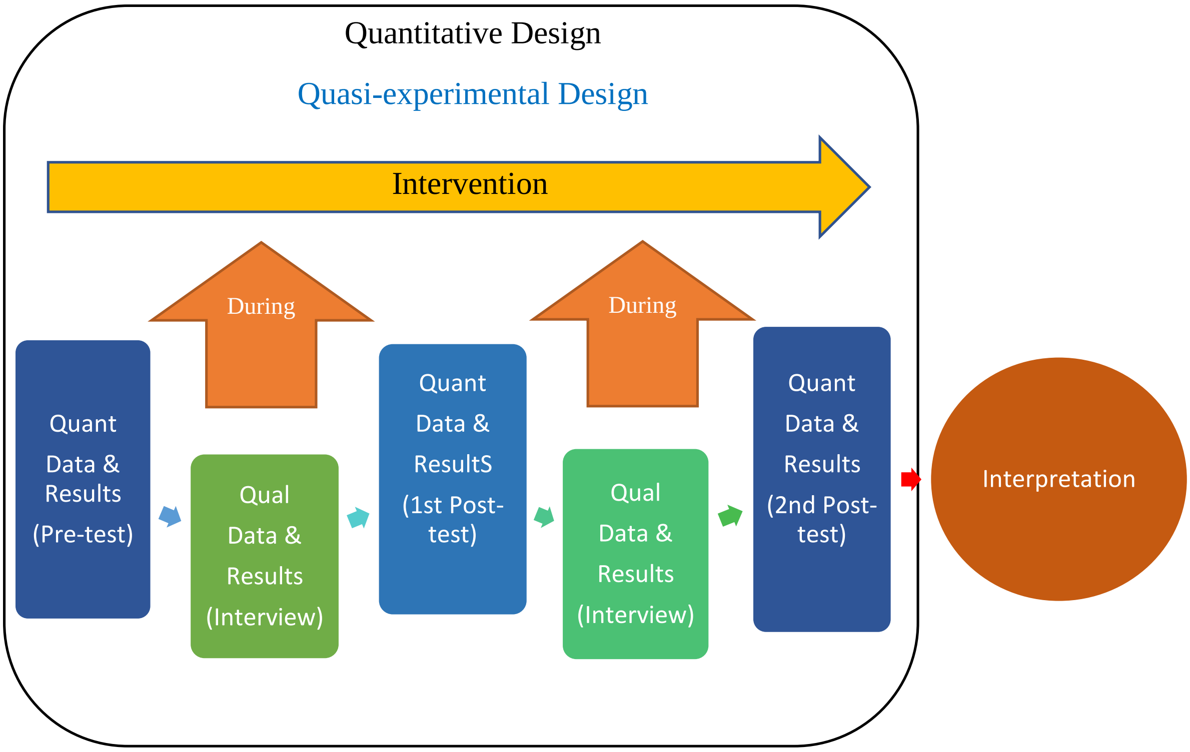


Figure 4-2. Embedded mixed methods design.

4.7.1 Intervention of iPad use in the school

In 2015, the Educational Services Department in Al Jubail City in SA, represented by Alrowad Secondary School (cf. section 2.2.1), furnished all its new students with iPads. This initiative fell within the interest of the Royal Commission in Jubail in developing the educational services provided to students in this city to improve the academic and educational process and to contribute to building future generations' creative capabilities. This secondary school is one of the few schools in SA that has integrated the iPad and other devices and distributed them to all students from the 10th to 12th grades. There were two classes involved in this study, from 6 of the 10th grade classes, and the evaluation programme started in the second semester of the 2018/2019 academic year. Hence, the participating students had had experience of using iPads for at least one academic semester (four months). They had the same curriculum textbooks provided by the MoE as mentioned in Chapter 2. The duration of the evaluation programme was two months, during which time the students in the two classes studied two chapters of their mathematics textbooks (for more details, see the next section). Furthermore, both classes used the same apps from the school management's suggested apps list (see Appendix 3), such as the Marefah system, or suggested by the teacher, such as GeoGebra.

A teacher wishing to work at this school needs to be a highly qualified educator and the headteacher must have at least a Master's degree. Also, all teachers needs to be enrolled in a training programme on using the iPad as a part of their professional development. Furthermore, the 10th grade classes have two mathematics teachers, each teaching three classes. Only one of these teachers participated in this study to avoid or reduce any threat to the validity of the research (see section 4.13). Also, this teacher had experience of using iPads and apps since 2015, as mentioned above.

4.7.1.1 The Context of the Research Site (The School) Before the Intervention

Alrowad Secondary School is considered one of the leading schools in Saudi Arabia. In particular, its employment of technology is renowned. The school has developed a strong technology infrastructure and has equipped each student with an individual iPad and has consequently been classified a smart school. As a result, Alrowad Secondary School will only enrol students who are outstanding. Due to its smart school status, it has established a website, the Marefah System, and there is an application for this system on smart devices such as iPads. The app enhances the learning system and encourages students to use the tablet devices for their learning process which includes explanations of lessons, homework, worksheets, and tests. Like other subjects, teachers in mathematics classes have been teaching by using both technology and books, paper, and pencils. Therefore, if a student forgets their device or simply prefers to, they can follow the lesson and solve the exercises by using either the tablet device or the print book. In this school, mathematics teachers give pre-tests for students through the Marefah System App at the beginning of the lesson to evaluate the students' understanding of a new lesson or a previous lesson for a 5-minute period. Then at the end of the lesson, teachers give students post-tests to assess the extent to which students understand and comprehend the lesson that has been explained. Additionally, at the end of the lesson, teachers give students homework through the Marefah System App to encourage students to use the iPad at home for learning purposes. A mathematics teacher can also use any other appropriate app such as GeoGebra, which is used by most mathematics teachers in the school for teaching and learning mathematics. Furthermore, there are monthly tests in the Saudi education system, as mentioned in chapter 2, and these tests are presented in this school via iPads through Marefah System App. Accordingly, the school has created a test bank for all subjects in the app. Finally, for all subjects, the teacher determines the most suitable app for each lesson.

4.7.2 Evaluation of the iPad intervention

The purpose of this study was to evaluate the effectiveness of using iPads to enhance instruction in mathematics teaching and learning at this secondary school. An evaluation of whether the intended outcomes for the integration of iPads were achieved was conducted using a programme evaluation design based on a logic model framework. Programme evaluation using a logic model employs programme outputs measured against the anticipated programme outcomes to create a methodical and effective programme development process (Spaulding & Falco, 2012). Within a logic model, outcomes are the final result of the implementation of the planned activities. The long-term impacts of many school interventions, such as the integration of iPad use, are on areas such as curricular reform, classroom practices, teacher education, and learning within environments boosted by technology. The effects take place over a lengthy period. Therefore, evaluation of the impact was outside the scope of this study. However, it was possible to evaluate the outcomes (Spaulding & Falco, 2012). As shown in Figure 4-3, I determined a number of outcomes that could be quantified based on the programme outputs.

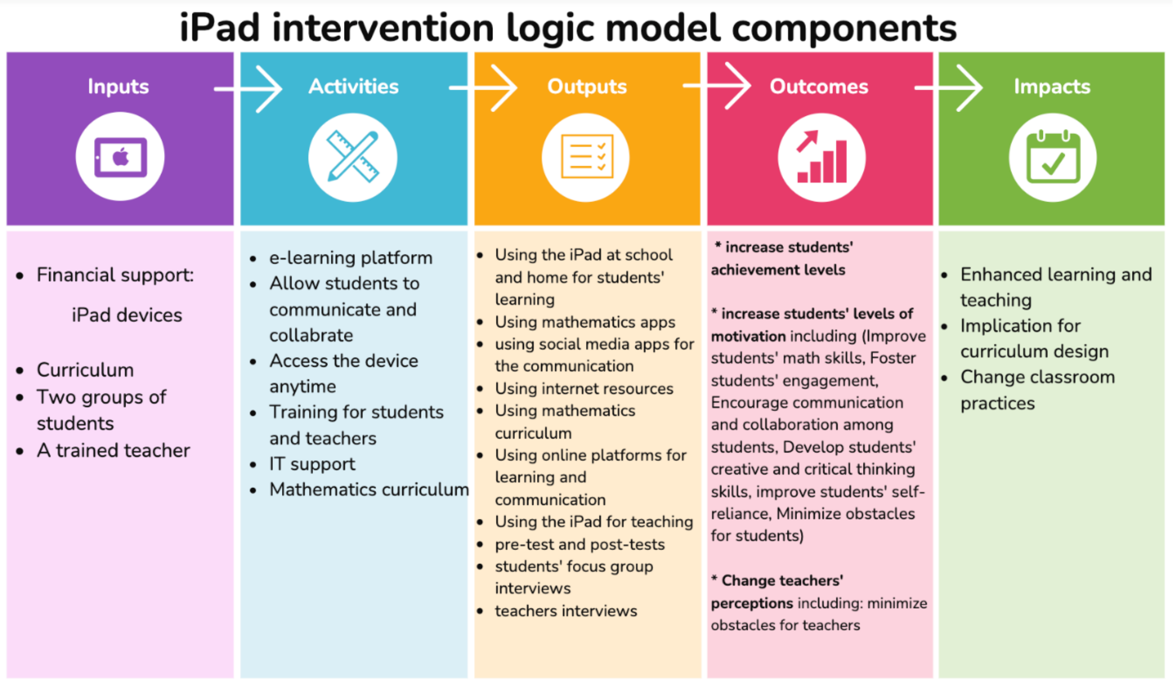


Figure 4-3. iPad intervention logic model components.

Drawing on these outcomes, the three primary elements selected to be measured in this study were students' achievement levels, students' motivation levels, and teachers' perceptions regarding the integration of iPads or other tablets in the classroom. There is a lack of research focusing on these issues in a mathematics context, particularly in terms of teachers' perceptions and their opinions of iPad use within the classroom. Studies have provided data from teachers related to students' perceptions rather than their own perceptions. The findings of this study will highlight the perspectives of both students and teachers.

Undeniably, there is a need for a rigorous evaluation of iPad use before fully integrating it in the secondary school classroom in order to determine whether it has wider implications for students' achievement, motivation, understanding, and cognition in technology-enhanced learning settings. Moreover, it is necessary to ascertain whether using iPads has wider implications for teachers' perceptions about the teaching of mathematics concepts. Thus, this evaluation used an embedded design that combined quasi-experimental quantitative data (pre-test and post-tests) and qualitative data (semi-structured interviews and focus group interviews). More details about the data design are provided in the following sections.

4.7.3 Quantitative Data Design

Quantitative research comprises scientific study including both experiments and other systematic methods. It emphasises quantified measures and control of performance (Proctor & Capaldi, 2006). In quantitative research or logical positivism, the researcher uses experimental methods and quantitative measures to test hypothetical generalisations, and focus on the measurement and analysis of the relationships between variables (Denzin & Lincoln, 1998; Hoepfl, 1997). Quantitative data are generally expressed by numbers that can be measured and can be used to record information about society and science (Walliman, 2011). The advantage of using quantitative methods is that it is comparatively quick to collect data, analysis can be performed in a short period of time, and the findings can be generalised to different populations (Johnson & Onwuegbuzie, 2004). Also, for quantitative data, the variables can be measured using instruments, i.e. tools that gather and measure the quantitative data. Quantitative tools are designed to collect samples that answer the research questions formulated before the start of the study (Creswell, 2012). According to Hoy (2010), the key to quantitative research is measurement and statistics, because there is a relationship between mathematical interpretations and experimental observation. There are two approaches to the collection of quantitative data: experimental and non-experimental (Creswell, 2014). According to Creswell, in an experimental design the researcher tests an approach to determine whether there is an impact or not on the outcome or on a dependent variable. The experimental design has two main types: between-group design (true experiments, quasi-experiments, and factorial designs), and within-group design (time-series experiments, repeated measure experiments, and single-subject experiments) (Creswell, 2012). In this study, a quasi-experimental design was used as it was a more practical and feasible way of conducting the study than other experimental designs and could lead to generalisable findings (Campbell & Stanley, 2015). The quasi-experimental approach encompasses a broad range of non-randomized intervention research, which tests the existence of a causal relationship typically through pre-post designs, interrupted time-series designs, and comparison group designs (Newcomer et al., 2015). Indeed, the quasi-experimental study design is sometimes called the pre-post intervention design and is often used to evaluate specific interventions. Thus, the aim of using a quasi-experimental study is to evaluate an intervention that based on non-randomization (Eliopoulos et al., 2004). The quasi-experimental design ensures that all students receive an equivalent experience and none is disadvantaged. This is to determine the statistical significance of the results after each experimental period. In this study, to examine the statistical significance of the results of the pre-test and the post-tests, paired t-tests were used. The following subsection contains further explanation.

The most common experimental design is the between-group approach, which is quasi-experimental. Quasi-experiments involve the non-random assignment of participants to groups because the experimenter chooses participants to take part in some of the experimental groups (Creswell, 2012). In the research performed for this project, the quasi-experiment was appropriate to evaluate the impact of using iPads on student achievement in mathematics and to minimise bias in assessing the difference between traditional learning and learning using the iPad. The assignment of participants was non-random because it was inappropriate to create groups that comprised a random assignment of participants for the experiments (Creswell, 2012). Moreover, researchers often do not wish to randomise the intervention for reasons such as ethical considerations and the potential for non-equivalent groups, which present a threat to internal validity and can be a weakness of quasi-experimental design (Harris et al., 2006). Also, the random assignment of participants would have disrupted the educational process (Creswell, 2012). For these reasons, this evaluation did not use randomization (Eliopoulos et al., 2004). In this study, to evaluate the effectiveness of using iPads required the participation of two existing classes of 10th graders, one of which was designated the experimental group and the other the control group. The two classes were considered equivalent based on the judgment of the teacher and as confirmed by the results of the pre-test for both groups (see section 5.5.1).

The quasi-experimental design could be vulnerable to the effects of a variety of extrinsic variables that might have affected the relationship between iPad use and the students' achievement. Measures were taken to reduce the impact of extraneous variables on the experiments. According to Muijs (2010), groups used for such studies should be in the same school to ensure that they are equivalent and the groups should have similar structures in terms of variables such as gender, socio-economic status and ability. At Al-Rowad Secondary School, classes have equal numbers of students and non-random distribution to address individual differences, such as differences in their achievement, knowledge, and characteristics (physical and mental abilities). The Al-Rowad Secondary School has 6 classes at 10th grade and the school management takes care of the distribution of students in each class. The management distributes students depending on their skills and knowledge to ensure all classes have an equal education level. In this study, two existing classes (A and B) of 10th grade schoolchildren were enrolled as participants (see section 4.8 for more details about the sample). Two mathematics teachers teach mathematics to all six classes, three classes each. To ensure that the teaching quality was the same for both classes (A and B) and therefore could not be a factor affecting the outcomes, both were taught by the same mathematics teacher.

The duration of the quasi-experiment was two months. In the first month, the teacher designated class A the experimental group and class B the control group. In the second month, the treatment was switched: class A became the control group and class B the treatment group. This is called a crossover design or switchover design and is a specific approach to repeating experimental measures and providing the same treatment in two successive periods (Salkind, 2010). As shown in Figure 4-4, to test the equivalence of the groups, both classes A and B were given a pre-test on the first day of the quasi-experimental period (Creswell, 2012). (For more details about the quantitative data collection, see section 4.8.)

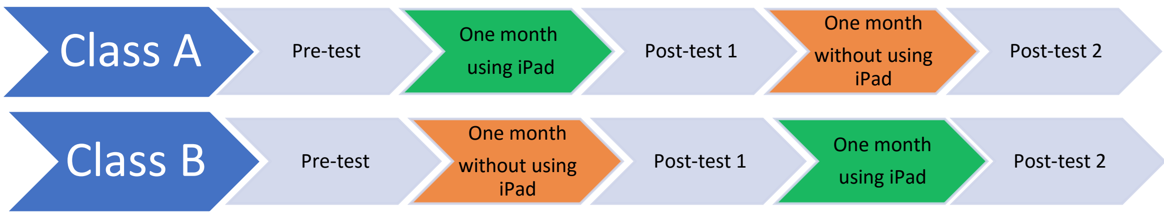


Figure 4-4. Quasi-experimental design to consider students' use of iPads for mathematics learning.

In the first month of the quasi-experimental period, the school gave iPads to class A as a tool for mathematics learning, while class B used traditional learning methods (paper and pencil, as mentioned in section 4.7.1, and 1.3.1.2). Moreover, students of class A were allowed to take their devices home every day and use them for their learning and for communication with other pupils and their teacher regarding their studies. Appropriate iPad learning activities were conducted for one month with the experimental group. For example, class A was allowed to use apps that supported their mathematics learning inside the school and covered the lessons in the fifth unit of the student's mathematics book. The teacher controlled the choice of apps and trained the students in their use to ensure all the students knew how to use them. Students could also suggest apps and the teacher would decide whether or not to use them in class. However, the teacher mentioned that certain applications were mostly used in class by students in both classes A and B: the Marefah System, GeoGebra, and different communication apps, such as social media apps, and Airdrop. GeoGebra covers all the lessons in the fifth unit (first month) and sixth unit (second month) of the student's mathematics book and the Marefah system is a Blackboard-type learning management system provided by the school. At the end of the first month, the first post-test was performed with both classes to assess any differences between them (see Figure 4-4).

In the second month, the treatment was switched between the two classes. Class A became the control group and class B the experimental group. Thus, class A used traditional methods in their learning and class B used the iPad as a learning tool. Class B in the second month had the same affordances and parameters as applied to Class A in the first month. Thus, the members of class B were allowed to use all the apps for learning mathematics as class A had done and they could take the iPads home at the end of the school day. Switching the treatment between the classes offered the opportunity for all students in both classes to use the iPads in their learning. This quasi-experimental design ensured that all students received an equivalent experience and none was disadvantaged. At the end of the experiment, all participants took the second post-test (see Figure 4-4).

The quasi-experimental approach presented potential threats to internal validity because the participants in the two classes were not randomly chosen. Also, when a design involves pre-testing and post-testing to collect data, there are additional concerns, such as testing equivalence between classes and potential regression (Creswell, 2012). To mitigate these issues, the teacher involved in the research was a trainer proficient in the use of technology, especially the use of iPads to teach mathematics in the 10th grade at the Al-Rowad Secondary School. He taught 6 classes of 10th grade students, including class A and class B, and he was experienced in teaching mathematics using iPads and apps (see section 4.7.1). Moreover, both classes had the same materials, the same instructor, and were at the same educational level (10th grade) in the same school. They were offered the same opportunities to use iPads in their learning. In addition, students in both classes were assessed by the same teacher during the same period.

During the collection of the quantitative data, qualitative data were also collected to provide further results. The method used to collect the qualitative data is explained further in the next section.

4.7.4 Qualitative Data Collection

Qualitative research does not involve statistical procedures or measurable techniques to collect the data (Strauss & Corbin, 1990). In qualitative research, the essential concept, the process of the study, or the idea forms the central tenet of the work. Qualitative research provides descriptions or interpretations of people's feelings and experiences of phenomena and how these phenomena have happened (Johnson & Onwuegbuzie, 2004). Qualitative research is performed through various research designs, such as narrative research, case studies, grounded theory, and phenomenology (Creswell, 2014; Lewis, 2015). This research adopted a case study design that falls under the embedded research design.

Case study has been defined as "the study of the particularity and complexity of a single case, coming to understand its activity within important circumstances" (Stake, 1995, p. xi). Case studies are used in many fields. Data for case study research can be collected from one or multiple sources with use of one or multiple tools over a period of time, enabling thorough dissection of the large amount of data gathered to produce detailed analysis and evaluation (Creswell, 2014; Schell, 1992; Yin, 2009). A single case study can be the basis of research for different studies, such as typical, oblique, or critical cases. Multiple cases can be used to compare different instances (Schell, 1992). In this study, a single case study was used to collect qualitative data because the sampling was from one secondary school in SA (see section 4.8).

The nature of qualitative data collection can be categorised into four types: observations; interviews and questionnaires; documents; audio-visual materials (Creswell, 2012). This study employed interviews. The interview allows the researcher to investigate phenomena which cannot be explored through observation or other methods, such as interviewees' perceptions. Moreover, the researcher can seek additional information when initial answers are incomplete, unclear, or not objective. Also, some research participants prefer to speak rather than write and the interview format offers the potential to provide more information and extend the answers to questions in a conversational format (Mackey & Gass, 2015). There are different types of interview: one to one; focus group; telephone; e-mail (Creswell, 2012). This research adopted one-to-one interviews for teachers and focus group interviews for students. According to van Teijlingen (2014), one-to-one interviews can be further categorised into structured, semi-structured, and unstructured. In this research study, semi-structured and focus groups interviews were used to understand and address the qualitative research questions. Furthermore, they were used to allow further probing questions to be asked related to the teachers' and students' initial answers (van Teijlingen, 2014). Thus, the semi-structured interview was used to find out more details about the teachers' perceptions concerning the integration of iPad in teaching and learning mathematics. Furthermore, the focus group interviews were used to evaluate the effectiveness of using iPads in enhancing students' motivation (further details are provided below).

4.7.4.1 Semi-structured interview

During the period of quantitative data collection, qualitative data collection was also conducted through semi-structured interviews with teachers and focus groups with the students (for more details about qualitative data collection, see section 4.11).

In a qualitative interview, the researcher poses questions to the participants that address the research topic and aim. These questions should be open-ended to encourage the participant to give full answers, including opinions and examples of their experiences. The interview is recorded (Creswell, 2012). According to Brinkmann (2014), the interview has become the most popular technique practised to generate knowledge regarding topics in human and social sciences, especially in psychology. Also, they are the optimal way to obtain knowledge from the interviewees about topics related to human feelings or experiences (Brinkmann, 2014). The interview method offers advantages for data collection. First, interviews can provide useful information from participants whom it would otherwise be difficult to observe; they also enable participants to offer more detail than other methods do (Creswell, 2012). Moreover, motivation, perceptions, values, and personal beliefs can be investigated best through the medium of an interview (Richardson et al., 1965).

As mentioned before, the interview type employed in this research was semi-structured. Semi-structured interviews employ a set of questions drawn up before starting the interview; however, these questions can be developed depending on the discussion as it progresses during the interview. It is a flexible method that enables the researcher to change, add, or delete questions if the original ones prove unsuitable during the interview, or to explain the questions to the interviewee (van Teijlingen, 2014). According to Stringer (2004), interviewers can explain and improvise, straying from the original planned questions during the interview process. Semi-structured interviews aid in exploration of the interviewee's beliefs, motivations, and values. Also, this format supports the researcher in the search for answers to all the questions regarding the research problem. Moreover, during the interviews, non-verbal indicators on the interviewee's face or in body language can assist in evaluating their credibility and the validity of their answers and it can increase their response ratio (van Teijlingen, 2014). Semi-structured interviews were used in this study to discover information and to understand feelings and experiences regarding the intervention integrating the iPad in the classroom. Thus, the teacher interviews were used to generate knowledge and perceptions about using the iPad as a teaching tool.

I obtained permission to interview all mathematics teachers in the Al-Rowad Secondary School in Saudi Arabia from the schools' management. There were only four in the school and all consented to participate in this study. The sample of teachers' interview is a small sample because purposive sampling leads to gather a depth of information from a smaller number of the interviewees that should be carefully selected (Teddlie et al., 2007). Thus, semi-structured interviews were conducted with four teachers. All were teaching at the same secondary school, the Al-Rowad Secondary School in SA. One of them was the instructor of the two classes in the experiment (A and B). Two teachers were interviewed during the first month of the experimental period and the other two during the second month. The sequence is shown in Figure 4-4. The teacher of classes A and B was interviewed during the second month of the quasi-experimental period. I chose this specific time because I wanted to ensure that he had obtained as much experience and thoughts as possible regarding the intervention. The interview questions were devised and tested in a pilot study with four teachers in a secondary school in SA through Skype. The pilot study showed that the interview questions did not cover some of the aspects related to the research questions, after which they were improved and became more suitable. (For more details about the teachers' pilot interview questions, see Appendix 4A, 4B).

4.7.4.2 Students' focus group interviews

Focus groups take the form of group interviews in which the focus is on a specific theme (Walliman, 2011). Focus groups can be used to gain information from participants who feel more comfortable in group situations or who have issues with one-to-one interviews; besides, the group dynamic can encourage participation from those who would otherwise tend to provide short answers and can bring differences of knowledge and opinion between participants to the fore (Rabiee, 2004). A focus group interview enables collection of data from a group of people, typically numbering four to six, at one time (Creswell, 2012). The main feature of using focus group interview is the use of purposeful interaction to generate data (Merton et al., 1990; Morgan, 1996). Thus, the advantages of the focus-group interview are the increased interaction between participants and the potential provision of important information while offering efficient time management. Individual interviews, in contrast, sometimes lead to wasted time because interviewees may be reluctant or unable to answer a specific question (Creswell, 2012). In this study, focus group interviews were used for student participants to understand the effect of integrating the iPad in the classroom on their motivation. In the focus groups, the students were able to interact with each other to discuss the integration of the iPad as a learning tool and they could explain themselves to each other to generate the information when answering the interview question. The outcome of interaction in focus groups leads directly to investigation of complex motivations and behaviours, making them better than other methods, such as individual interviews (Morgan & Krueger, 1993). Focus group interviews were implemented in both classes to discover the groups' feelings regarding iPad use and to compare the results between the groups. According to Rabiee (2004), focus group interviews offer more information regarding opinions and they uncover more differences in viewpoints between groups than individual interviews can. Furthermore, focus group interviews were used in this study to save time, making it possible to interview most of the students involved in the experiment, which would not have been possible with individual interviews. Eight groups of six students were formed from classes A and B, four groups from each. During the first month, a focus group interview was held with two groups from class A and two groups from class B. The other four group interviews were conducted in the second month of the experimental period. This sequence is shown in Figure 4-4. The aim of this design was to gain information from those students who were using the iPads and those who were not and then to gain their reactions to the removal of the iPads from the initial groups to give them to other groups after the switch of classes from experimental to control and vice versa. (For more details about the students' focus group interview questions, see Appendix 2A, 2B).

4.8 Population and Sampling

A target population in research is "a group of individuals who have the same characteristics" (Creswell, 2012, p. 142). This study examined the target population of students and teachers at Alrowad Secondary School in SA. A small or subset group of the target population is a sample. This sample supports researchers in their aim of generalising the results across the target population (Creswell, 2012). The researcher must declare the choice of sample early and take this decision into account before starting data collection data to avoid obstacles such as wasted time and expense (Cohen et al., 2007).

This research took place in two classes of students in the 10th grade at Alrowad Secondary School in Al Jubail City in SA. Alrowad Secondary School has 6 classes of 10th grade pupils. The sample drawn for this research comprised 50 students from two classes, 25 in each class. The two classes were taught by one instructor and contained equal numbers and characteristics of students to try to eliminate any bias. In addition, four teachers were invited to take part in interviews, including the teacher of both class A and class B.

The school was chosen because it is one of a few technological schools in SA to have introduced the iPad to all students to be used in their learning since 2015 (see section 4.7.1). Whether selecting either an entire school or an individual small group in a school, the researcher needs to consider the sample. In some qualitative research, the researcher must select individuals based on who is willing to volunteer to take part or who is available during the period of study (Creswell, 2012).

4.8.1 Sample Size

The sample comprises participants who agree to take part or volunteer to be studied in the experimental section of the project (Larson-Hall, 2015). The larger the size of the sample, the better the findings, as a larger amount of information offers more validity, particularly with regard to extrapolation to a whole population (Cohen et al., 2007). However, the number of variables, the overall size of the population, and funding affect the sample size (Creswell, 2012). For example, a sample size of 30 may be the minimum required for statistical analysis of the data and thus the sample size in this case is very small (Cohen et al., 2007). The sample size is usually smaller in qualitative research than in quantitative research (Mason, 2010). In general, quantitative research can employ bigger sample sizes than qualitative research because qualitative research requires more concentrated effort, for example conducting interviews (Fraenkel & Wallen, 2006).

Mixed-method sampling involves a combination of techniques that depend on the research design and requires additional considerations to determine the appropriate sample size (Sandelowski, 1995; Teddlie et al., 2007). In this study, mixed-method sampling was used to collect the data. The sample size in the quantitative research was 50 student participants and for the qualitative research, the sample comprised four teachers and eight groups of students (each group containing six students), as shown in Table 4-1.

Table 4-1. Research samples used for quantitative and qualitative data collection.

Mixed-Method Sampling		
Sample	Quantitative	Qualitative

Students	Class A	25	**4 groups (6 students** in each group; total 24 students)
	Class B	25	**4 groups (6 students** in each group; total 24 students)
Teachers		-	4 teachers
Total sample		50	12

4.8.2 Research Participants

Purposive sampling was used in this research, in which subjects are included in the sample based on possessing particular characteristics being sought (Cohen et al., 2007). Purposive sampling is a non-probability sampling technique that works for both qualitative and quantitative research. A purposive sampling technique involves selecting certain cases, whether groups of individuals or individuals themselves, based on a particular purpose, which may include them being especially experienced or knowledgeable (Cresswell & Plano Clark, 2011; Tashakkori & Teddlie, 2010; Tongco, 2007). In any non-probability sampling method, the researcher selects the sample individually, as long as the member of the sample is available (Creswell, 2012). Purposive sampling is mostly used in qualitative research in order to identify and select information to make the most effective use of limited resources. However, it can also be used to collect quantitative data, as long as the limitations regarding generalisability are acknowledged (Palinkas et al., 2015).

Al-Rowad Secondary School is one of a few schools in SA to have provided iPads to all students. One teacher taught the two tenth-grade classes and they had similar educational levels; they could thus be compared as they had similar characteristics. Furthermore, I had no connection with the students, the teacher, or the choice of apps used in the quasi-experimental study, reducing the potential for researcher bias when examining the impact of iPad use on students' achievement. Such risks are examined in more detail in the external validity section (see section 4.13.2.1.

4.9 Quantitative Data Collection

4.9.1 Instrument

An instrument is a tool used to document or measure quantitative data and must be defined before data collection. It could take the form of a test or questionnaire to measure achievement or to evaluate individuals' abilities (Creswell, 2012). In this study, quantitative data were collected to measure students' achievement.

The quantitative measures performed in this research took the form of a pre-test and two post-tests for each group. The pre-test took place for both groups on the first day of the quasi-experimental period. The learning outcomes of class A were compared with the outcomes of class B. In the first month, class A used the iPad in their learning and class B used the traditional learning methods (book, paper and pencil). At the end of the first month, both classes took the first post-test. After that, in the second month of the quasi-experimental period, iPad use was switched (see section 4.7.3); class A used the traditional learning methods, while class B used the iPads in their learning. At the end of the second month of the quasi-experimental period, all students in the two classes (A and B) took the second post-test. Then, the learning outcomes of class A were compared with those of class B. The timing of data collection is illustrated in Figure 4-5.

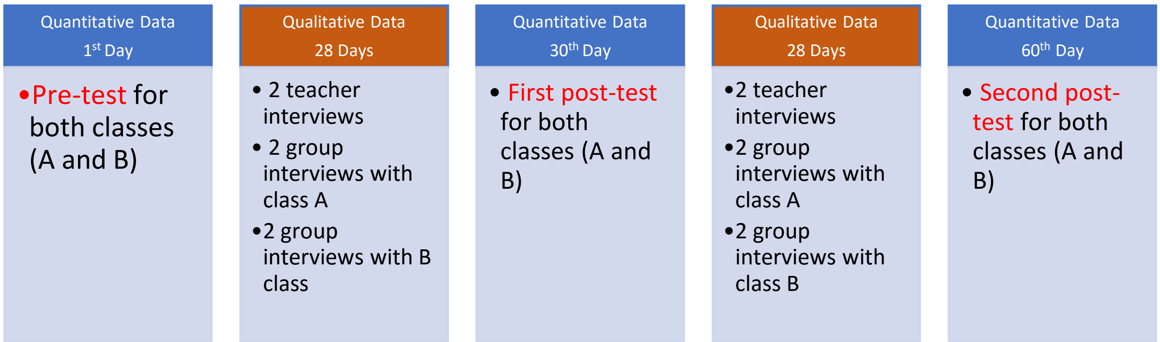


Figure 4-5. Timing of data collection.

The tests were based on a pencil-and-paper instrument, taken from the Assessment Guide – Teacher Edition provided by the MoE. The MoE equips each student with a free mathematics book each semester in SA (see section 2.5). The mathematics book contains several units and each unit has several topics. Thus, both classes A and B had the same mathematical content during the experiment. Moreover, each lesson and unit in the students' books have a test for each lesson and unit taken from the assessment guide. The students in classes A and B studied two units during the experimental period, one on quadrangles (Unit Five) in the first month and the other on similarity (Unit Six) in the second month. The teacher and I chose the tests from the Assessment Guide – Teacher Edition to be used for the pre-test and two post-tests. The pre-test and first post-test were from Model One in Unit Five and the second post-test was from Model One in Unit Six, each comprising 20 multiple choice questions (see Appendices 5 and 6).

4.9.2 Validity and Reliability of Instruments

Validity is a term applied to developmental evidence to illustrate that the interpretation is appropriate for the proposed use (Creswell, 2012). The validity of quantitative data is developed by choosing the sample carefully and by using suitable instrumentation and statistical treatments (Cohen et al., 2007). Validity is the degree to which the evidence correlates with the interpretation of test scores and how well the measurements correlate with what they were intended to measure. It is a broad, comprehensive term used to help the researcher assess the success of the test tool (Creswell, 2012). According to Mackey and Gass (2015), validity can be categorised as different forms: content validity, face validity, construct validity, predictive validity, and criterion-related validity. This study employed face validity to assess the extent to which the measures tested what they were intended to measure. Face validity is defined as the degree to which respondents or experts contributing to an assessment instrument suit it to the targeted assessment objectives and construct objectives (Hardesty & Bearden, 2004). According to Campbell et al. (1963), Bracht et al. (1968), and Lewis-Beck (1993), cited in Cohen et al. (2007), the validity of quasi-experiments is more significant than true experimental validity, especially in educational research because the researcher controls the measurement and treatment in the non-random assignment and they can be more appropriate than a random assignment.

Although the two mathematics tests that were taken from the Assessment Guide – Teacher Edition published by the MoE have high levels of validity, the validity of the two tests were checked to confirm their applicability in this research. Therefore, the two tests were presented to the arbitrators (the mathematics teachers who were involved in this intervention) to validate the two tests, check, and give their opinion about these tests in terms of: the clarity of the test items, the distribution of the marks for the test items, the suitability of the content of the items, and any adjustments they considered appropriate. Accordingly, all recommendations and comments from them were considered prior to the intervention. For instance, in the Assessment Guide – Teacher Edition, each Unit has different levels of Models of tests, and the teacher who taught the two classes in this study recommended Model One from each Unit (Unit Five and Unit Six). Also, the marks changed to 1 point for each question.

Reliability is defined as a measure of consistency, replicability, and dependability (Cohen et al., 2007). There are three measures of reliability: stability, equivalence, and internal consistency (Cohen et al., 2007; Mackey & Gass, 2015). In this study, stability (test–retest) was used to assess the reliability of the test instruments employed. This concept is explained in the next section.

Stability, as measured by the test–retest method, means that the reliability instrument produces a stable score for each of two tests administered to one sample over time (Creswell, 2012). Moreover, if there are two groups of students that have similar characteristics such as age, gender, and ability, the groups will produce similar test results in two tests performed separately. The characteristics of the groups will have a bearing on their answers, but these characteristics will affect the results of both groups similarly (Cohen et al., 2007). In this study, stability (test–retest) reliability was used to assess the reliability of the tests employed. According to Cohen et al. (2007), a researcher who uses this approach can measure reliability by demonstrating that the test results produced by the two classes show high correlation, and similar means and standard deviations.

Two mathematics tests were taken from the Assessment Guide – Teacher Edition (see Appendices 8 and 9). The form of the first test covered the pre-test and first post-test and related to the subjects taught in the first month's lessons. The second test taken from the guide was used for the second post-test and covered the work taught during the second month of the quasi-experimental period. To measure the reliability of the two mathematics tests, each was administered to a pilot group. Therefore, two pilot classes were formed of students from two different secondary schools in SA. The first pilot class undertook the first test and the second pilot class undertook the second test. Each pilot group comprised 25 students. Both pilot classes performed the tests on the same day and then they took retests after two weeks. The pilot classes were used to evaluate the tests before the start of the quasi-experimental period.

Cronbach's alpha coefficient was used to measure the reliability of the tests. The value of Cronbach's alpha coefficient for the first test was 0.784, which is regarded as very high (close to 1.00). This signified that the reliability and credibility of the first test were very high and that it could be depended on in the field implementation of the study. The value of Cronbach's alpha coefficient for the second test was 0.792, which can similarly be regarded as very high (close to 1.00). This similarly signified that the reliability and credibility of the second test were very high and it was appropriate for use in the field implementation of the study. Table 4-2 shows these results.

In this study, reliability was assured to as great an extent as possible by giving the pre-test and post-tests under the same conditions to all students in both classes A and B. The same conditions were ensured by giving the tests at the same time and on the same day. The teacher, who taught both classes, assessed the results of the tests and offered corrections to the students so that they would feel comfortable and to ensure consistency of marking.

Table 4-2. Cronbach's alpha coefficients calculated through use of a pilot study to ensure the reliability of the two tests.

Test	Cronbach's alpha coefficient

First test	0.784
Second test	0.792

4.10 Quantitative Data Analysis

The analyses of data in the embedded design, incorporating both quantitative and qualitative data, were kept separate because of the data addressed different research questions (Creswell, 2012). The study design aimed to compare the means of the dependent variable of students' achievement in mathematics for both classes A and B. As mentioned before, during the first month of the quasi-experimental period, class A was the treatment group and class B was the control group. In the second month, the treatment was switched; class A became the control group and class B became the treatment group. The treatment group used iPads in their mathematics learning, while the control group used traditional methods (book, paper and pencil) to learn mathematics.

4.10.1 Statistical Analysis Methods

To address the quantitative research question, quasi-experimental study design was used. The quantitative research question was: What are the effects of iPad use on students' mathematics achievement? To answer this question, three tests were performed by all groups: pre-test, first post-test, and second post-test. On the first day of the quasi-experiment, both classes performed a pre-test to establish the academic level of the students in the two classes. After one month, all classes performed the first post-test. After two months, all classes took the second post-test.

I employed multiple statistical methods through use of a statistical analysis program entitled SPSS to address the first research question. The reason for choosing this program is explained in Chapter 5. Several statistical tests were performed through SPSS. These were:

- The Kolmogorov–Smirnov test and the Shapiro–Wilk statistic to test the normal distribution of the sample.
- Levene's test, to assess the homogeneity between the samples. The samples must show a normal distribution of homogeneity to use the t-test.
- Independent samples t-test. This test procedure compares the means for two groups of cases. Ideally, for this test, the subjects should be randomly assigned to two groups, so that any difference in response is due to the treatment and not to other factors.

- Paired samples t-test. This procedure compares the means of two variables for a single group computing the differences between the values of the two variables for each case.
- Calculation of eta squared to determine the effect size for the independent samples t-test.
- Cohen's d coefficient, to calculate the effect size for the paired samples t-test.

4.11 Qualitative Data Collection

For the qualitative part of the study, data was collected to gain an understanding of the effects of iPad use on the motivation of students in learning mathematics and to evaluate teachers' perceptions of the effectiveness of iPad use in the teaching of mathematics concepts. The collection of data in qualitative research depends on the use of several question forms and analysis across responses to the research questions to ensure they cover all aspects of the topic under study, eventually synthesising the findings. The data are taken from the study participants, such as people or sites (Creswell, 2012).

There are three categories of research question types in qualitative research. The first is "what" questions, which are used for exploratory research. The second is "how" questions, which tend to be used for explanatory research and potentially to lead to the use of experiments and case studies. The third is "why" questions, which are used for descriptive research (Schell, 1992). This research used "how" questions, as appropriate for a case study (Schell, 1992).

4.11.1 Instrument

The precepts of case study research are that multiple sources of evidence are employed to deepen understanding and support the results derived from one source to another, as well as to examine a particular phenomenon within a certain environment (Yin, 2009). Moreover, the best way to understand the human aspects of research is for the qualitative researcher to select groups and individuals to collect the research data (Creswell, 2012). As mentioned previously, teacher interviews and student focus groups were selected as instruments for the qualitative study, discussed below (see Table 4-3).

Table 4-3. Qualitative data collection.

Qualitative Data Collection	Semi-structured interviews (teachers)	To address the research question: What are teachers' perceptions of the effectiveness of iPad use in the teaching of mathematics concepts?

	Focus group interviews (students)	To address the research question: How does iPad use affect the motivation of students in learning mathematics?

4.11.1.1 Teacher interviews

Semi-structured interviews were conducted with four mathematics teachers who had experienced using iPads to teach mathematics during the implementation of the study. The aim of choosing trained teachers was to ensure that they had been through the same experience of using technology in the mathematics classroom. The teacher interviews were used to evaluate the effect of iPad use on perceptions regarding the teaching of mathematics concepts (see Table 4-3). During the interviews, the questions and responses were recorded using audio so that I could refer back to the conversations to gain accurate information from each interview (Creswell, 2012). The duration of each interview with the teachers was about 40 minutes. The interviews were conducted in Arabic and transcribed in Arabic before being translated into English (see Appendix 1A, 1B).

4.11.1.2 Student focus group interviews

Focus group interviews were conducted with 48 students (for more details about the sample size, see section 4.8.1) who agreed to take part and had signed the consent form (see Appendix 7A, 7B). The students came from both classes, A and B. The focus group interviews were used to evaluate the effects of iPad use on the motivation of the students (see Table 4-3). The duration of each interview was about 30 minutes. Eight focus group interviews were conducted: four focus groups comprising students from class A and four focus groups comprising students from class B. As mentioned before, four groups of students were interviewed in the first month of the quasi-experimental period, two from class A and two from class B. Then, in the second month of the quasi-experimental section, the other groups were interviewed (see Figure 4-5). All students in class A used iPads for their learning during the first month and class B students used traditional methods. For the second month, this was switched.

Each focus group comprised six students; thus in total 48 students were involved in the focus group interviews (see section 4.8.1). The focus group interviews were conducted in Arabic and transcribed in Arabic before being translated English (see Appendix 2A, 2B).

4.11.2 Validity and Reliability of the Instruments

Validity in qualitative research refers to the levels of depth, honesty, scope, and richness achieved in the data collected (Cohen et al., 2007). It also concerns the measure of objectivity that the research has achieved and the quality of the information supplied by the participants in the research (Cohen et al., 2007). Validity can be increased by choosing the sample carefully and ensuring the chosen instruments are appropriate. In this study, four teachers were chosen to be interviewed regarding their experience of using iPads in their teaching and of the impact of this on students' learning. These teachers enhanced the validity of this study because they had abundant experience of iPad use as the main pedagogical tool.

Reliability in quantitative research refers to the consistency of the instrument when no change is made to the entity being measured (Leedy et al., 2005; Mackey & Gass, 2015). The quality of evaluation in qualitative and quantitative studies is different and therefore the reliability concept has been argued to be irrelevant in qualitative research (Golafshani, 2003). However, according to Lincoln and Guba (1985, cited in Cohen et al., 2007), *"reliability"* in qualitative research can be viewed in terms of *"credibility"*, *"confirmability"*, *"consistency"*, *"neutrality"*, *"transferability"* and especially *"dependability"* (p. 148). Therefore, the idea of reliability can be transferred to all types of research. (For further details, see Validity and Reliability in Mixed Method Research, section 4.13.)

According to Cohen et al. (2007), the most efficient way to improve the validity and reliability of interviews is to minimise the forms of bias that can skew the results. The characteristics of the interviewer and the respondents and the fixed content of the interview questions are the potential sources of bias in interviews. Also, there are some particular biases, such as the interviewer's expectations, attitudes, and opinions, or the phrasing of questions that can result to misunderstanding on the part of the respondents. For this study, I chose to interview teachers with knowledge of teaching mathematics, had undergone training courses and had experienced use of iPads as a teaching tool, and had trained students on how to use iPads as a learning tool.

4.12 Qualitative Data Analysis

Qualitative analysis requires deep understanding of the transcripts, the concepts discussed, and the participants' answers to the questions posed in order for the researcher to meet the aims of the study. The researcher must be able to organise and code the data by gathering it into themes and then interpret the results and conduct strategies to validate the results. The object of the coding is to understand the data and split the text into different parts that address different issues, then label the parts. After that, the researcher must examine the issues and break them down into themes that can be coded (Creswell, 2012). According to Tesch (1990) and Creswell (2007), there are several steps that the researcher should follow to code the data:

1) Carefully read the entire transcripts.

2) Choose the shortest and most interesting interview transcript.

3) Start to code the documents, identifying text segments and marking them with circles around the relevant parts.

4) List all code words and put similar codes together in groups.

5) Read the list, group lists of codes carefully and look back to the data; identify whether there are any new codes on rechecking; encircle quotes that support the codes.

6) Finally, reduce the number of codes to obtain between five and seven themes that encompass the main points made by the participants. A theme is made up of similar codes that are arranged together in a group to create a significant idea, i.e. the ideas most discussed by the participants. (Creswell, 2007)

In this study, the semi-structured teachers' interviews ranged in duration from 30 to 45 minutes and they were recorded. The student focus group interviews ranged in duration from 20 to 30 minutes for each group and were also recorded. The semi-structured interviews and focus group interviews were conducted in Arabic. I transcribed them in Arabic and then translated them into English before analysing them through thematic analysis.

4.12.1 Thematic Analysis

Thematic analysis is generally used in qualitative research (Braun & Clarke, 2006). Thematic analysis is considered to be a foundation for qualitative analysis methods because the complex approaches to qualitative analysis require rigorous treatment (Holloway & Todres, 2003). Thematic analysis supplies useful core skills for a qualitative researcher to conduct further qualitative analysis (Braun & Clarke, 2006). The importance of thematic analysis lies in describing and organising an overall set of data (Boyatzis, 1998). The significant focus of this study was on discovering the impact of iPad use on the teaching and learning of mathematics in a Saudi secondary school. To discover whether the research supported the use of the technology, I sought to identify perceptions of differences or similarities in student achievement when they used or did not use iPads in their learning and what differences or similarities were observed by teachers when they taught mathematics using iPads. Thematic analysis was a suitable method for this project because it made it possible to determine similarities and differences in the set of data (Boyatzis, 1998; Creswell, 2009).

As suggested by Braun and Clarke (2006), the qualitative data collected in this study (obtained from semi-structured interviews and focus group interviews) were analysed in six phases. The first phase was to become familiar with the data. I collected the data myself in Arabic and then translated the information into English. I highlighted some relevant words during the first reading of all the transcripts. The second phase was the creation of the first codes. After reading the transcripts and becoming familiar with the data, I was able to code the qualitative data manually by taking notes on the transcript files. I re-analysed the data, highlighting and circling words to indicate potential themes, and ensured that all essential words were included in the notes.

The third phase was to search for themes. At this stage, I re-analysed the words rather than coding them. Different codes were assigned to potential themes and these were correlated within the subjects identified. The fourth phase was to review and refine the themes. In the reviewing stage, I needed to read all the codes for each theme to establish whether they fitted together and analyse again for more potential themes and codes. Then, at the refining stage, I considered the *"validity"* of the themes and drew a thematic map (Braun & Clarke, 2006, p. 91), which reflected the whole dataset to support the production of the themes. The fifth phase was to define and name the themes. I refined, defined, and analysed the themes and determined which part of the data was present in each theme. The sixth phase involved producing the data report and writing up the description of the data as an analytic narrative. The report required illustration with sufficient evidence and arguments related to the research question (Braun & Clarke, 2006).

4.13 Validity and Reliability in Mixed Methods Research

Mixed methods research incorporates both a quantitative approach and a qualitative approach. While the terms of validity and reliability are related mainly to the quantitative approach and engage with positivism, they can be used as criteria for a qualitative approach to interpretive research. Combining approaches has been criticised due to various differences in the purpose and philosophical assumptions of quantitative and qualitative work (Burns & Grove, 2003). Validity and rigour, for example, are experimental analytic terms that do not apply to interpretive research, which based on creativity and values perception (Polit & Beck, 2008). Other appraisal criteria must thus be adopted for a mixed methods study (Lincoln & Guba, 1985), as shown in Table 4-4.

Table 4-4. Appraisal criteria for mixed methods research

Appraising Criteria (Mixed Methods Studies)	Quantitative Methods	Qualitative Methods
Truth Value	Internal Validity	Credibility
Applicability	External Validity	Transferability
Consistency	Reliability	Dependability
Neutrality	Objectivity	Confirmability

4.13.1 Truth Value

The truth value is tested by examining the internal validity for quantitative research and credibility for qualitative research.

4.13.1.1 Internal validity

Internal validity concerns the data variables, the set of data, or a particular gathering of inferences made by the researcher. Also, the results must reflect the phenomena under study (Cohen et al., 2007). In other words, all possible variables that could be causes for the findings must be shown to be controlled by the researcher (Mackey & Gass, 2015). Moreover, internal validity depends on the validity of the references regarding the effect of the relationship between the dependent and independent variables (Creswell, 2012).

This study adopted a quasi-experimental design to collect quantitative data through testing before and after the intervention. In an educational experimental study, the researcher cannot tightly control the environment and observe all events. However, in this study I formed two classes, a treatment group and a control group, and these groups undertook the same activities during the experimental period (Creswell, 2012). To reduce any internal validity bias, the prior knowledge of the students required consideration. To avoid any potential threat to internal validity due to differences in knowledge, a pre-test was performed by both groups at the beginning of the experimental period (Harris et al., 2006). In terms of the strategies deployed to avoid or reduce any threat to internal validity, two different classes were involved and taught by the same instructor over the same period of time at the same level in the same school.

4.13.1.2 Credibility

Credibility refers to the internal validity of qualitative research and reflects the confidence that can be placed in the research results (Guba & Lincoln, 1985; Korstjens & Moser, 2018). Credibility establishes whether the findings of the research represent a reasonable view of information related to the participants' data based on correct interpretation of their original views (Korstjens & Moser, 2018). Achieving credibility can be done by several methods, such as member checking (Birt et al., 2016; Korstjens & Moser, 2018; Lincoln & Guba, 1985). The transcripts of the interviews and focus groups were thus given to the teacher involved in the experimental procedure who taught both classes to ask him to confirm the perspectives presented. This allowed the findings from the interviews and focus groups to attain greater credibility.

4.13.2 Applicability

Applicability can be tested by examining the external validity for quantitative research and transferability for qualitative research.

4.13.2.1 External validity (generalisability)

External validity is the degree to which the results can be generalised to the wider population or situation (Cohen et al., 2007). External validity of experiments is conferred when the results can be generalised to other subjects, different tests, or settings (Bracht & Glass, 1968). Threats to external validity or generalisability affect the researcher's ability to extrapolate the sample data to other populations, measures, or treatments (Creswell, 2012).

Three threats may affect generalisability. The first is the potential interaction of participant selection and treatment, which leads to the formation of special cases that nullify generalisability beyond the experimental group. The second is the particularity of the setting, which may again nullify generalisability beyond the experimental group. The third concern is the interaction of history and treatment, which arises in attempts to generalise the results to past and future cases (Cook & Campbell, 1979, cited in Creswell, 2012). To avoid these threats in this study, the work was made generic rather than particular, and therefore could be extrapolated from all individual participants to the population (Cook & Campbell, 1979, cited in Creswell, 2012). Cook and Campbell argue that to solve this problem, the researcher should analyse the effect of the results of each different kind of treatment. This quasi-experimental study involved the members of two classes from 10th grade in one school and each class contained the same number of students. Moreover, every student involved in the study had an opportunity to use an iPad in their learning. Thus, I had the opportunity to analyse the impact of iPad use on all students in both classes A and B during the quasi-experimental period of the study.

4.13.2.2 Transferability

Transferability in qualitative research is considered a form of external validity. It is defined as the ability to transfer the results of the study from one site or setting to another (Lincoln & Guba, 1985; Polit & Beck, 2004). Although the results derived from the qualitative data cannot be generalised due to the use of purposive sampling, they do have some transferability (Collingridge & Gantt, 2018). A researcher can achieve transferability by giving full details and descriptions of the participants and of the research setting (Creswell, 2012).

4.13.3 Consistency

Consistency is tested by examining the reliability of quantitative research and the dependability of qualitative research.

4.13.3.1 Reliability

In this study, the reliability of the quantitative research methods was assured through the use of the test–retest method, as discussed previously (see section 4.9.2).

4.13.3.2 Dependability

Dependability is equivalent to reliability in quantitative research methods and indicates that performance of the same study in the same environment would produce the same findings on the same subject (Lincoln & Guba, 1985; Polit & Beck, 2008). The researcher can achieve a measure of dependability by asking the respondents to check the results (Bloor, 1978; Cohen et al., 2007). The qualitative findings of this current research were from semi-instructed interviews with teachers and focus group interviews with students. The results of these were checked by the teacher to observe whether the results were dependable and reliable.

4.13.4 Neutrality

Neutrality can be tested by examining objectivity for the quantitative approach and confirmability for the qualitative approach.

4.13.4.1 Objectivity

Objectivity indicates that the quantitative findings are not biased (Denzin & Lincoln, 1998). In this research, the results of the quantitative data analysis (tests) were objective, as discussed previously in Quantitative Data Collection section 4.9.

4.13.4.2 Confirmability

In qualitative research, confirmation corresponds with objectivity in quantitative research; this occurs when the data and interpretation of the findings are not affected by the researcher, being concluded only from the data (Guba & Lincoln, 1989; Korstjens & Moser, 2018). An external audit can be used to achieve both confirmation and dependability (Guba & Lincoln, 1989). In this study, the teacher was used as an external source to check the interview responses.

4.14 Ethical Considerations

To address ethical concerns, researchers are required to understand that during the collection of data, they enter the participants' area of existence and reality (Silverman, 2013). The researcher should take full responsibility regarding consideration of the participants' rights (Creswell, 2003). There are three main areas of ethical concern: informed consent, privacy, and any potentially harmful consequences from the interviews (Cohen et al., 2007).

Based on this, I applied to the Research Ethics Committee of the College of Social Sciences at the University of Glasgow for approval of this study. The ethics form was reviewed and approved by the committee (see Appendix 8). Also, I obtained an Approval Letter for the implementation of study at Alrowad Secondary School from the Education Services Department at the RCJ in SA (see Appendix 9). Teachers and students signed the consent letter (see Appendix 10A, 10B and Appendix 7A, 7B, respectively) before taking part in this study and after reading the plain language statements, which contained full explanations of the study objectives and the procedures for data collection (see Appendix 11A, 11B and Appendix 12A, 12B). I gave each participant a copy of the consent letter and plain language statements.

Before conducting this study, I confirmed to all participants that their identity and personal information would be kept confidential and no names would be mentioned in the published findings. The results that contained names would be destroyed. Furthermore, I explained to all participants that they were volunteers in this study and they could withdraw at any time during the study, or they could choose not to answer any question without penalty and without giving a reason; the study would not affect teachers' performance reviews or students' grades or students' relationships with teachers. The quasi-experimental research design was a significant aspect for both classes of students (A and B) because the exchange of the treatment between them ensured that both classes were treated equally. This was done by exchanging the treatments among two classes A and B: using the iPad and without using the iPad for the learning process, respectively. This method could impact students' learning process; however, the research design of this study was to evaluate the effectiveness of using the iPad before, taking away, and after the treatment. This design will ensure that all students receive an equivalent experience and that none is disadvantaged

The purpose of withdrawing the treatment (iPad) from Group A students mid-way through the study is to ascertain whether the impact it had had on their learning would continue without it. Giving the treatment (iPad) to Group B was to determine whether their achievements differed with iPad usage. Thus, switching the treatment was done to establish the effect of using the iPad and its apps before and after the treatment for both groups, and to provide additional evidence of the effectiveness of using iPads in supporting mathematics learning among students. Moreover, it was to gain information from those students who were using the iPads and those who were not and then to observe their reactions to the removal of the iPads from the initial groups to give them to other groups after the switch of classes from experimental to control and vice versa.

My role as the researcher was not to teach students the mathematics concepts; rather, it was to collect quantitative and qualitative data from all participants in this study. I monitored the progress of the study, see section 1.6 for more details about the researcher's role.

4.15 Conclusion

This chapter has provided details of the methodology and methods employed in the study, giving a clear description of the use and implementation of the instruments and how the data were collected with respect to the research sample. Mixed methods were used to collect the data from a secondary school in SA and to enhance the validity and reliability of the findings. Moreover, this chapter has described the research problem, approach, and design in greater detail. It contains information regarding the participants, instruments, and procedures. The statistical tests and thematic analysis used to analyse the data and provide answers to the research questions have been detailed. Table 4-5 shows the tools and methods used to obtain answers to the research questions and to analyse the data. The next two chapters set out the findings derived from the analysis of the quantitative and qualitative data obtained from the secondary school in SA.

Table 4-5. Summary of the research methods employed in the study.

Research Questions	Method	Analysis
What are the effects of iPad use on students' mathematics achievement?	Pre-test and post-tests	SPSS

How does iPad use affect the motivation of students in learning mathematics?	Focus group interviews	Thematic analysis
What are teachers’ perceptions of the effectiveness of iPad use in the teaching of mathematics concepts?	Semi-structured interviews	Thematic analysis

Chapter 5 Quantitative Findings

The purpose of this research was to evaluate the outcomes of an intervention introducing iPads for mathematics learning in two classes in tenth grade at Alrowad Secondary School in SA. The students participated in this evaluation programme for eight weeks in the second semester of the 2018/2019 academic year (see section 4.7.1). The outcomes evaluated in this study included improving students' achievement levels, increasing students' mathematical skills, enhancing students' levels of motivation, fostering students' engagement, encouraging communication and collaboration, developing students' creative and critical thinking skills, developing students' self-reliance, minimising obstacles for students in the use of technology, changing teachers' perceptions, and minimising obstacles for teachers in using technology (see section 4.7.2).

This evaluation study employed an embedded mixed methods approach that incorporated quasi-experimental quantitative data together with qualitative data from a single case study. The case study centred around the 10th grade students attending Al-Rowad Secondary School in SA. After integrating iPads in the classroom, the motivation and achievement levels of the students were analysed, as well as the ways in which mathematics teachers adapted their teaching methodologies to the introduction of the technology. To determine the impact of iPad use on students' achievement, the results of a pre-test administered at the beginning of the evaluation program were compared to a first post-test administered in the middle of the programme and a second post-test administered at the end of the programme. The remaining outcomes were evaluated using focus group interviews with the students (see section 6.1) and semi-structured interviews with the teachers (see section 6.2) administered during the programme.

5.1 Determining the Effects of iPad Use on Student Achievement

The purpose of this study was to determine the effects of iPad use on the achievement of students with regard to mathematics performance in two 10th grade classes at a secondary school in SA. The two classes were designated class A and class B. Both classes were taught by the same teacher. The quasi-experiment in this study was conducted over two months. In the first month, class A received mathematics education using iPad as an experimental group, while class B, the control group, received mathematics education using traditional methods. Then, in the second month of the quasi-experiment, the treatment was switched so that class

A became the control group and class B became the experimental group. Both classes received a pre-test on the first day of the quasi-experimental phase and then both classes sat the first post-test at the end of the first month. At the end of the quasi-experiment, they sat the second post-test. Assessing both classes before the evaluation programme began, in the middle of the programme as the treatment was switched, and at the end of the experimental period, enabled comparison of mean achievement between the two classes at different stages. Each class comprised 25 students, as explained in section 4.8.

This study aimed to use the quantitative data to answer the following question: What are the effects of iPad use on students' mathematics achievement? To address this research question, the means of class A and class B were compared across nine treatments, including within class and with a class. The t-test was used to determine if there were statistically significant differences between the means of the two classes and within the classes. The nine comparisons of the means are divided into three categories.

Within class A

- Class A pre-test and class A first post-test
- Class A pre-test and class A second post-test
- Class A first post-test and class A second post-test

Within class B

- Class B pre-test and class B first post-test
- Class B pre-test and class B second post-test
- Class B first post-test and class B second post-test

Between classes

- Class A pre-test and class B pre-test
- Class A first post-test and class B first post-test
- Class A second post-test and Class B second post-test

To compare the means, t-tests were calculated within the SPSS statistical program to identify differences between class A and class B. Before using the t-test, distribution of the sample had to be tested for normality, followed by a comparison of the means within class A, within class B, and the mean of class A and class B (see Table 5-1).

Table 5-1. Nine comparisons of mean test values.

Within Class A	Within Class B	Class A and Class B
A pre-test and A first post-test	B pre-test and B first post-test	A pre-test and B pre-test
A pre-test and A second post-test	B pre-test and B second post-test	A first post-test and B first post-test
A first post-test and A second post-test	B first post-test and B second post-test	A second post-test and B second post-test

5.2 Test of Normal Distribution

In this research, a t-test was used to compare the means of the dependent variable between the two classes. A t-test is used to determine if the differences between two classes for a continuous variable are statistically significant (Muij, 2010). The aim, in other words, is to find out whether observed differences between the two samples are large enough to be attributed to underlying performance differences, or if they simply reflect noise created by sampling variation. To use a t-test to compare small samples, the assumption of normality must be met. There are several ways of testing the normal distribution of a sample, such as kurtosis values, skewness, histograms, and tests such as the Kolmogorov–Smirnov test and the Shapiro–Wilk statistic. The preferred choice to check if the sample data are normally distributed or not is the Shapiro–Wilk test (Shapiro & Wilk, 1965) as this is widely seen as the most powerful normality test (Ghasemi & Zahediasl, 2012; Razali & Wah, 2011). The Kolmogorov–Smirnov test is also one of the most powerful choices for checking the normality of a sample (Razali & Wah, 2011). By running the pre-test data from classes A and B through both the Kolmogorov–Smirnov and the Shapiro–Wilk tests at a significant level ($\alpha = 0.05$), the following results were obtained (see also Table 5-2.):

- The Kolmogorov–Smirnov test for samples A and B gave p-values of 0.125 for class A and 0.200 for class B, both of which are greater than ($\alpha = 0.05$), meaning that both samples were normally distributed.

- The Shapiro–Wilk test, for the same samples, gave a p-values of 0.108 for class A and 0.596 for class B, both of which are greater than ($\alpha = 0.05$). This also means that both samples are normally distributed.

Table 5-2. Tests of normality.

Sample	Kolmogorov–Smirnov			Shapiro–Wilk		
	Statistic	df	Sig. p-value	Statistic	df	Sig. p-value
A	.155	25	.125	.934	25	.108
B	.137	25	.200	.968	25	.596

According to Park (2009), the t-test can be used with a single sample, independent samples, or paired samples; for the purposes of this study, it was decided to use the independent samples t-test and the paired samples t-test within the SPSS software. According to Kim (2015), the paired t-test can be used when the comparison of the two groups is dependent on each other and the independent t-test can be used when the comparison of the two groups is independent of each other.

5.3 Comparing Means within Class A

To understand whether or not there was a statistical difference in the means of class A when using traditional teaching methods as against the iPad, three types of mean comparison were analysed, namely:

- Class A pre-test and class A first post-test
- Class A pre-test and class A second post-test
- Class A first post-test and class A second post-test

5.3.1 Class A Pre-Test and Class A First Post-Test

A paired samples t-test is used to compare the means of two variables for a single group. In other words, the paired t-test is used to compare two sample means where there is a pairing between the samples; it is a suitable means of measuring an interval scale variable with normal distribution (McCrum-Gardner, 2008). It was employed to investigate whether the within-class means of A for the mathematical performance of students were statistically different before and after iPad usage at a level of significance of $\alpha = 0.05$.

Table 5-3. Paired samples t-test results for class A pre-test and class A first post-test.

Paired Sample	N	Mean	Std. Dev.	t-value	df	Sig. p- value	Mean Difference	Std. Error Difference
Class A pre-test	25	13.12	2.991	8.168	24	0.000	- 5.440	0.666
Class A first post-test	25	18.56	1.502					

As can be seen in Table 5-3, the t-value is 8.168, which is greater than the tabulated t-value of 2.064 at df = 24, and the p-value of 0.000 for the t-test is less than $\alpha = 0.05$. This means there is a statistically significant difference between class A pre-test and class A first post-test, i.e. the use of iPads made a difference in the level of mathematical performance between the pre-test and the first post-test for class A.

Moreover, in Table 5-3 it is notable that the mean of class A on the first post-test (M = 18.56) is higher than the mean for the pre-test (M = 13.12), suggesting that the students in this group experienced an increase in their mathematical understanding between the pre-test (taken before they had touched an iPad) and the first post-test (by which time they had been using the iPads for a month).

To indicate the level of statistical significance, it is useful to consider the effect size. Having found a statistically significant difference between the two tests, effect size measurements can reveal more information about the relative size of the experimental treatment and the size of the effect (Thalheimer & Cook, 2002). Researchers report that the effect size is useful for three reasons. First, the effect size makes it possible to show the reported effects of the measurement as a standardised metric, as well as the measurement of the dependent variable, which in turn reveals how the result can be generalised beyond just announcing the statistical significance. Second, researchers can bring in the findings from previous studies by comparing standardized effect sizes. Third, researchers can use the effect size from previous studies when they are planning a new study (Lakens, 2013). According to Fritz et al. (2012), researchers tend to prefer to calculate Cohen’s d manually to estimate the effect size, rather than using a statistical software package like SPSS. Rice and Harris (2005) report that the values of Cohen’s d are commonly interpretated as follows: small effect size (d = 0.2), medium effect size (d = 0.5), and large effect size (d = 0.8).

The effect size for the impact of using iPads on the level of mathematical performance using Cohen's d is calculated as follows:

From equation $d = \frac{t}{\sqrt{N}}$

$d = \frac{8.168}{\sqrt{25}}$ = 1.63

Thus, d = 1.63 > 0.8, indicating a large effect size, i.e. the effect of using iPads for the students in class A, as per the first post-test, is significant in improving the level of performance on mathematics tests.

5.3.2 Class A Pre-Test and Class A Second Post-Test

A paired samples t-test was employed to investigate whether the within-class means for class A on the mathematics performance of students were statistically different when they went from never having used an iPad in mathematics class to using an iPad for the first month, and then reverting back to traditional teaching methods in the second month, at a level of significance of $\alpha = 0.05$.

Table 5-4. Paired samples t-test results for class A pre-test and class A second post-test.

Paired Sample	N	Mean	Std. Dev.	t-value	df	Sig. p-value	Mean Difference	Std. Error Difference
Class A pre-test	25	13.12	2.991	2.219	24	0.036	- 2.200	0.992
Class A second post-test	25	15.32	3.625					

As Table 5-4 illustrates, the t-value is 2.219, which is greater than the tabulated t-value of 2.064 at df = 24, and the p-value of 0.036 is less than $\alpha = 0.05$. This means there is a statistically significant difference in mathematical performance between class A on their second post-test and class A on their pre-test.

As shown in Table 5-4, the mean for class A on the second post-test (M = 15.32) is greater than the mean for class A on the pre-test (M = 13.12). This indicates that the level of performance for the class A students in their second post-test increased and improved due to their use of the iPads in the first month. Although they did not use the iPads in the second month, it is reasonable to assume that their level improved overall from the time of their pre-test due to their use of the iPads in the first month and learning mathematics over the two-month period.

The effect size for the influence of the use of iPads on the level of mathematics performance using Cohen's d was calculated as follows:

From equation $d = \frac{t}{\sqrt{N}}$

$$d = \frac{2.219}{\sqrt{25}} = 0.44$$

Thus, d = 0.44 > 0.2 and < 0.5, indicating a medium effect size, i.e. there was a medium-sized effect of the use of iPads on increasing and improving the level of mathematics performance.

5.3.3 Class A First Post-Test and Class A Second Post-Test

A paired samples t-test was employed to investigate whether the within-class means for class A on mathematical performance were statistically different after not using iPads in the second month at a level of significance of $\alpha = 0.05$.

Table 5-5. Paired samples t-test results for Class A first post-test and Class A second post-test.

Paired Sample	N	Mean	Std. Dev.	t-value	df	Sig. p-value	Mean Difference	Std. Error Difference
Class A first post-test	25	18.56	1.502	4.079	24	0.000	3.240	0.794
Class A second post-test	25	15.32	3.625					

As shown in Table 5-5, the t-value is 4.079, which is greater than the tabulated t-value of 2.064 at df = 24, and the p-value of 0.000 is less than $\alpha = 0.05$. This means there is a statistically significant difference between the class A first post-test results and the class A second post-test results. In other words, the iPads made a difference in performance between the first post-test and the second post-test, even though the students stopped using the iPads in the second month and reverted to the traditional teaching environment.

Moreover, Table 5-5 shows that the mean for the class A students in their first post-test (M = 18.56) is greater than their mean in the second post-test (M = 15.32). This suggests that the use of iPads in the first month improved test performance, but after they were taken away in the second month, the students' performance dropped somewhat.

The effect size for the influence of the use of iPads on the level of mathematics performance using Cohen's d was calculated as follows:

From equation $d = \frac{t}{\sqrt{N}}$

$$d = \frac{4.079}{\sqrt{25}} = 0.816$$

Thus, d = 0.816 > 0.8, indicating a large effect on performance from using iPads at the first post-test stage in terms of improvement.

5.4 Comparing Means within Class B

In this section, paired samples t-tests are employed to investigate whether the within-class means for the mathematics performance of students in class B were statistically different before using iPads and not using iPads in the first month, and then how their mathematics performance changed after they had iPads in the second month at a level of significance of $\alpha = 0.05$.

5.4.1 Class B Pre-Test and Class B First Post-Test

A paired samples t-test was used to investigate whether the within-class means for the mathematics performance of students in class B were statistically different before and after one month of traditional learning methods at a level of significance of $\alpha = 0.05$.

Table 5-6. Paired samples t-test results for Class B pre-test and Class B first post-test.

Paired Sample	N	Mean	Std. Dev.	t-value	df	Sig. p-value	Mean Difference	Std. Error Difference
Class B pre-test	25	13.88	3.193	1.254	24	0.222	- 1.480	1.181
Class B first post-test	25	15.36	4.508					

As shown in Table 5-6, the t-value is 1.254, which is less than the tabulated t-value of 2.064 at df = 24, and the p-value of 0.222 is greater than $\alpha = 0.05$. This means that there was no statistically significant difference between class B students in the pre-test and the first post-test a month later.

Table 5-6 also shows a mean for class B on the pre-test (M = 13.88) very close to that for class B on the first post-test (M = 15.36). The difference between them is only 1.480, suggesting that there was virtually no difference in performance across the first month of the quasi-experiment, which is not surprising given that class B continued to be taught using traditional methods in the first month, with no access to iPads.

5.4.2 Class B Pre-Test and Class B Second Post-Test

A paired samples t-test was employed to investigate whether the within-class means for the mathematics performance of students in class B were statistically different without using iPads in the first month of the quasi-experiment and with using iPads in the second month at a level of significance of $\alpha = 0.05$.

Table 5-7. Paired samples t-test results for Class B pre-test and Class B second post-test.

Paired Sample	N	Mean	Std. Dev.	t-value	df	Sig. p-value	Mean Difference	Std. Error Difference
Class B pre-test	25	13.88	3.193	6.553	24	0.000	- 4.760	0.726
Class B second post-test	25	18.64	1.868					

As shown in Table 5-7, the t-value is 6.553, greater than the tabulated t-value of 2.064 at df = 24, and the p-value of 0.000 is less than $\alpha = 0.05$. This shows a statistically significant difference between the class B second post-test and the class B pre-test results, which indicates that the iPad use made a difference to the level of mathematics performance in the period between the two tests.

The mean for class B in second post-test (M = 18.64) is greater than that for class B in the pre-test (M = 13.88), confirming that the students' mathematical performance improved over the entire two-month period due to the availability of iPads in the second month.

The effect size for the influence of the use of iPads on the level of mathematics performance using Cohen's d was calculated as follows:

From equation $d = \frac{t}{\sqrt{N}}$

$d = \frac{6.553}{\sqrt{25}} = 1.31$

Thus, d = 1.31 > 0.8, indicating a large effect of iPad use on improving the level of mathematics performance within the group.

5.4.3 Class B First Post-Test and Class B Second Post-Test

A paired samples t-test was employed to investigate whether the within-class means for the mathematics performance of students in class B were statistically different between the two tests, i.e. before using iPads and after using iPads in the second month, at a level of significance of α = 0.05.

Table 5-8. Paired samples t-test results for Class B first post-test and Class B second post-test.

Paired sample	N	Mean	Std. Dev.	t-value	df	Sig. p-value	Mean Difference	Std. Error Difference
Class B first post-test	25	15.36	4.508	3.065	24	0.005	- 3.280	1.070
Class B second post-test	25	18.64	1.868					

As can be seen in Table 5-8, the t-value was 3.065, which is greater than the tabulated t-value of 2.064 at df = 24, and the p-value is 0.005, which is less than α = 0.05. This means that there is a statistically significant difference between the results for class B on the second post-test and those on the first post-test, suggesting that iPad use in the second month improved their performance.

Table 5-8 also shows that the mean for the students in class B on the second post-test (M = 18.64) is greater than that for the first post-test (M = 15.36), suggesting that the level of mathematical performance of the students on their second post-test had improved over their first post-test results because of their iPad use in the second month of the experiment.

The effect size for the influence of the use of iPads on the level of mathematical performance using Cohen's d was calculated as follows:

From equation $d = \frac{t}{\sqrt{N}}$

$d = \frac{3.065}{\sqrt{25}} = 0.61$

Thus, d = 0.61 > 0.5, indicating a medium effect. In other words, there was a medium-level effect of iPad use in the second month on the students' level of mathematics performance.

5.5 Comparing the Means of Class A and Class B

In this section, independent samples t-tests are employed to investigate whether the means of class A compared with those of class B on mathematical performance are statistically different before using iPads, for class A using the iPads in the first month against class B not using iPads, and for class B using iPads against class A not doing so in the second month. All comparisons were run at a level of significance of $\alpha = 0.05$.

5.5.1 Class A Pre-Test and Class B Pre-Test

The comparison of sample means from two independent groups is measured by the independent samples t-test when there is normal distribution (McCrum-Gardner, 2008). An independent samples t-test was employed to investigate whether the means of the pre-tests for both classes on the mathematics performance of students were statistically different before iPad use at a level of significance of $\alpha = 0.05$.

The most popular and commonly used statistical test for one or two categorically independent variables assumed to have the same dispersion of scores is Levene's test of homogeneity of variance (Gastwirth et al., 2009). Levene's test has a significance level of 0.05 or higher. If the groups have equal variance, the null hypothesis is rejected (Garson, 2012).

Table 5-9. Descriptive results of the pre-test.

Sample	N	Mean	Std. Dev.
Class A pre-test	25	13.12	2.991
Class B pre-test	25	13.88	3.193

Table 5-10. Independent samples t-test results for the pre-test.

Sample	Levene's test for equality of variance		t-test results				
	F	Sig. (p-value)	t-value	df	Sig. (p-value)	Mean Difference	Std. Error Difference
Pre-test	.065	.800	0.869	48	.389	- 0.76	.875

As can be seen in Table 5-10, the p-value for Levene's test is 0.800, greater than α = 0.05, meaning that there is homogeneity between the samples. Moreover, the t-test gives a value of 0.869, less than the tabulated t-value of 2.011 at df = 48, and the p-value of 0.389 is greater than α= 0.05, indicating no statistically significant difference between the mathematical performance of class A and the class B in the pre-test. Furthermore, as shown in Table 5-9, the means of the pre-tests for the two classes were very similar (class A: M = 13.12 vs class B: M = 13.88); this is consistent with expectations as the two classes presented the same levels of performance in the pre-test stage.

5.5.2 Class A First Post-Test and Class B First Post-Test

An independent samples t-test was employed to investigate whether the means of the class A first post-test and the class B first post-test for mathematical performance were statistically different from the means before iPad use for both classes at significance level of α = 0.05.

Table 5-11. Descriptive results of the first post-test.

Sample	N	Mean	Std. Dev.
Class A first post-test	25	18.56	1.502
Class B first post-test	25	15.36	4.508

Table 5-12. Independent samples t-test results for the first post-test.

Sample	Levene's test for equality of variance		t-test results				
	F	Sig. (p-value)	t-value	df	Sig. (p-value)	Mean Difference	Std. Error Difference
First post-test	.749	.391	3.367	48	.002	3.200	.950

As can be seen in Table 5-12, the p-value of 0.391 is greater than α = 0.05, meaning that there is homogeneity between the samples. Moreover, the t-value was 3.367, which is greater than the tabulated t-value of 2.011 at df = 48, and the p-value was 0.002, less than α = 0.05, indicating a statistically significant difference between class A and class B in the first post-test. Thus, iPad use made a difference to the performance between class A and class B in the first month of the intervention. Table 5-11 shows the mean values (class A: M = 18.56 vs class B: M = 15.36), which demonstrate a greater improvement in performance for class A, who were the students who had the iPads in the first month.

Eta-squared is a test used to measure the ratio of the total variance in a dependent variable which relates to the membership of different groups on an independent variable (Richardson, 2011). According to Ronan and Johnston (2003), an eta-squared value between 0.01 and 0.06 indicates a small effect, between 0.06 and 0.14 indicates a medium effect, and anything over 0.14 points to a large effect.

The effect size for the influence of the use of iPads on the level of mathematical performance using eta-squared was calculated as follows:

From equation $n^2 = \frac{t^2}{t^2+df}$

$$n^2 = \frac{(3.367)^2}{(3.367)^2+48} = 0.191$$

Thus, n^2 = 0.19 > 0.14, making it a large effect, indicating that iPad use by the students of class A greatly improved their performance.

5.5.3 Class A Second Post-Test and Class B Second Post-Test

An independent samples t-test was employed to investigate whether the means of the second post-tests for both classes were statistically different from the means before iPad use at a significance level of α = 0.05.

Table 5-13. Descriptive results for the second post-test.

Sample	N	Mean	Std. Deviation
Class A Second post-test	25	15.32	3.625
Class B Second post-test	25	18.64	1.868

Table 5-14. Independent samples t-test results for the second post-test.

Sample	Levene's test for equality of variance		t-test results				
	F	Sig. (p-value)	t-value	df	Sig. (p-value)	Mean Difference	Std. Error Difference
Second post-test	1.361	.249	4.070	48	.000	- 3.32	.816

As can be seen in Table 5-14, the p-value is 0.249, which is greater than α = 0.05, meaning that there is homogeneity between the samples. Furthermore, Table 5-14 shows that t-value of 4.070 is greater than the tabulated t-value of 2.011 at df = 48, and the p-value of 0.000 is less than $\alpha = 0.05$, indicating a statistically significant difference between the second post-tests for the two groups, namely that iPad use did make a difference to mathematical performance. Moreover, the means shown in Table 5-13 (class A: M = 15.32 vs class B: M = 18.64) demonstrate higher performance by the class B students, who had access to the iPads in the second month of the quasi-experiment.

The effect size for the influence of iPad use on the level of mathematical performance using eta-squared was calculated as follows:

From equation $n^2 = \frac{t^2}{t^2+df}$

$$n^2 = \frac{(4.070)^2}{(4.070)^2+48} = 0.257$$

Thus, $n^2 = 0.257 > 0.14$, meaning that the improvement in performance for class B students in the second post-test was large.

5.6 Conclusion

The findings reported in this chapter draw on quantitative data collected from two classes of 10th grade students in a secondary school in SA in three different tests: the pre-test, the first post-test, and the second post-test. The pre- and post-tests were applied to determine the effects of iPad use on the performance of students in mathematical assessments. The sample consisted of 25 students in each class, giving a total sample of 50 students. The same teacher, with experience of the teaching materials and iPad use in the classroom, taught both groups, and the same 10th grade mathematics textbook was used for both groups.

Class A was instructed using iPads while class B was instructed using traditional methods in the first month of the quasi-experiment. On the first day of the quasi-experiment, both classes took a pre-test, and after completing the first month, both classes took the first post-test. In the second month, the classes swapped, with class A reverting to traditional methods and class B using the iPads. At the end of the second month, both classes took the second post-test.

To answer the research question concerning students' achievement, the within-class means for class A, the within-class means for class B, and between-class means for classes A and B were compared using t-tests undertaking in SPSS. A paired-samples t-test was used to investigate whether the within-group means for mathematical performance of students in either class A or class B were statistically different after using the iPads at a significance of $\alpha = 0.05$. An independent samples t-test was used to compare the means of class A with those of class B for the mathematical performance of students and identify any statistical differences before or after using the iPads for both classes at a significance level of $\alpha = 0.05$. The results are summarised in Table 5-15.

Table 5-15. Summary of differences in means and significance levels.

	Difference in means	**p-value (sig. p < 0.05)**	**Difference in means**	Sig. **p < 0.05**	**Difference in means**	Sig. **p < 0.05**
Class A	Pre-test 1 – Post-test 1		Pre-test 1 – Post-test 2		Post-test 1 – Post-test 2	
	Learning during the treatment group phase		Test of intervention + rest period		Test of intervention	
	-5.440	0.000 significant difference	-2.200	0.036 significant difference	3.240	0.000 significant difference
Class B	Pre-test - Post-test 1		Pre-test 1 - Post-test 2		Post-test 1 - Post-test 2	
	Learning during the control group phase		Test of intervention + rest period		Test of intervention	
	-1.480	0.222 No significant difference	-4.760	0.000 significant difference	-3.280	0.005 significant difference
Classes A & B	Pre-test A - Pre-test B		Post-test1 A - Post-test1 B		Post-test2 A - Post-test2 B	
	Learning during treatment group and control group phase		Test of intervention + rest period + switch of treatment		Test of intervention	
	-0.760	0.389 No significant difference	3.200	0.002 significant difference	-3.320	0.000 significant difference

This chapter aimed to determine if there were effects of iPad use on students' achievement in terms of mathematics performance in two tenth-grade classes (A and B) in a secondary school in SA. To address the research question, the means of the two classes were compared in nine different configurations, divided into three categories: within-class A, within-class B, and between class A and class B.

The within-class A results indicate a statistically significant difference between the pre-test and the first post-test. It is clear that the test results improved after using the iPads for a month. Moreover, the statistically significant difference between the pre-test and the second post-test two months later shows that this improvement in performance was sustained by the students, even though they had no access to the iPads in the second month. However, there is also a statistically significant difference between the first post-test and second post-test for class A students, which points to a decrease in performance after the iPads were removed from them during the second month of the quasi-experiment (see Table 5-15). To sum up, the achievement of students in class A increased due to using iPads as a learning tool during the first month. However, their performance decreased in the second month of the quasi-experiment when they reverted to traditional teaching and learning.

The within-class B results show no statistically significant difference between the pre-test and the first post-test, which is consistent with expectations as the students did not have access to iPads prior to the pre-test, nor did they use them in the first month of the quasi-experiment. After two months, the class B results illustrate a statistically significant difference between the pre-test and second post-test, suggesting that their iPad use in the second month made a difference to their mathematical performance levels. Similarly, the results illustrate a statistically significant difference between the first and second post-tests in class B (see Table 5-15). Thus, the class B students' achievement was not affected during the first month of the quasi-experimental as they did not use the iPad as a learning tool. However, their performance increased and was positively affected during the second month when they were using the iPad.

The results illustrate no statistically significant difference between class A and class B in the pre-test, with both groups presenting the same level in mathematics. However, after one month, the results show a statistically significant difference between class A (iPad use) and class B (traditional methods) in the first post-test. Thus, iPad use made a difference in the level of mathematical performance between class A and class B. Moreover, the results illustrate a statistically significant difference between class A (traditional methods) and class B (iPad use) in the second post-test. Thus, iPad use made a difference in the level of mathematics performance between the students of class B and class A in the second month (see Table 5-15).

In sum, the achievement of students in class A increased with iPad use in the first month of the quasi-experiment in contrast to the students in class B. In turn, the performance of class B increased with iPad use in the second month, while the performance of class A decreased after the iPads were taken away from them.

The results of the pre-tests, first post-tests, and second post-tests for class A and class B showed statistically significant differences in students' achievement, with increases in mathematics performance for students using the iPads in learning mathematics against using traditional methods. These findings are important for secondary school mathematics teachers and students in SA because learning mathematics using iPads clearly improves performance levels on assessments compared to using traditional learning methods.

However, this quantitative element of the study did not look at the more qualitative areas, such as student motivation and teacher perceptions. Some students and/or teachers may be reluctant to embrace the integration of iPad use in learning and teaching mathematics because of fears around students' performance or motivation, or the possibility of the technology affecting the perceptions and understanding of mathematical concepts. The next chapter (Chapter 6 – Qualitative Findings) explores and covers these areas, presenting the qualitative findings.

Chapter 6 Qualitative Findings

This chapter presents the results of the qualitative research conducted within the secondary school in SA, using interview data from mathematics teachers and students in the 10th grade to understand and assess the effectiveness of iPad use in enhancing instruction in mathematics teaching and learning. The purpose of the qualitative findings is to evaluate the outcomes for the intervention introducing iPad use in two classes in the 10th grade at Alrowad Secondary School in SA. The outcomes evaluated in this study included increases in students' mathematics skills, changes in students' levels of motivation, heightened student engagement, greater communication and collaboration, developments in students' creative and critical thinking skills, greater self-reliance on the part of students, minimising the obstacles for students related to iPad use, changes in teachers' perceptions, and minimising obstacles for teachers in iPad use (cf. section 4.7.2).

To determine the effects of iPad use on students' motivation and teachers' perceptions of its effectiveness in the teaching of mathematics concepts, data were collected through teachers' interviews and students' focus group interviews administered during the evaluation programme. More specifically, semi-structured interviews were conducted with four teachers and focus group interviews were conducted with eight student groups, each consisting of six students. Through the information collected from the student focus groups, this study attempted to answer the second research question: How does iPad use affect the motivation of students in learning mathematics? Through the information collected from the semi-structed interviews with teachers, this study attempted to answer the third research question: What are teachers' perceptions of the effectiveness of iPad use in the teaching of mathematics concepts?

To address the research questions, both the student focus group interviews and the teacher interviews were thematically analysed (see section 4.12). This was done to gain a comprehensive understanding of the data by identifying essential themes relating to iPad use. This chapter is divided into two sections. The first section concerns the findings from analysis of the student focus group data (section 6.1). The second section provides analysis and reports the findings of the teacher interviews (section 6.2). In third section (section 6.3) will be combining the results from the three approaches (intervention, students focus group and teacher interview. The key themes discussed in the two parts are summarised in Table 6-1.

Table 6-1. Chapter sections and themes and sub-themes covered.

First Section (Student Focus Groups)	
Themes	**Sub-themes**
Promoting students' performance in mathematics	The iPad and its apps assist in improving students' mathematical skills iPad apps help students study and prepare for tests iPad use provides immediate feedback for students iPad assist in searching for information and understanding the content
Lack of knowledge regarding using iPads and apps	
iPads and apps encouraging students to study and organise their time	
Promoting students' communication and collaboration	
Lack of desire to use iPads	
Obstacles facing use of iPads in learning	Interrupted or slow internet connection Low batter level and difficulty recharging Apps freezing during use Fragile iPad screens breaking easily
Second Section (Teacher Interviews)	
Themes	**Sub-themes**
Facilitating teaching and learning mathematics through iPad use	
Assisting in achieving lesson objectives	
Lack of technological skills in how to use iPads and apps	
Selecting appropriate apps	
Assisting in improving students' performance in mathematics	Assisting teachers to know the academic level of the students immediately Giving students flexibility in learning Assisting in preparing students for tests Potentially affecting the basic mathematical operations skills of students
Assisting teachers to motivate students to learn mathematics	Improving student engagement Increasing interaction among students Facilitating collaboration and communication among students Developing creativity and critical thinking in students Improving students' self-reliance Assisting the teacher by providing immediate feedback to students
Lack of willingness to use iPads in teaching mathematics	
Barriers to the use of iPads and apps in learning	Lack of internet connectivity Issues with battery charging or forgetting the charger Forgetting the iPad Using non-instructional apps in the classroom

6.1 Students' Focus Group Interviews

The students in classes A and B were invited to attend a focus group interview during the quasi-experiment concerning iPad use. It was hoped that they would express their feelings, opinions, and perceptions regarding the reality of using the iPad and apps in learning mathematics. There were eight groups in total (cf. section 4.7.4), four from class A (A1, A2, A3, and A4), and four from class B (B1, B2, B3, and B4).

The reason for interviewing students in both classes was to collect data contrasting the use of iPads to learn mathematics versus the traditional approach. This was useful to comprehend the perspectives of students and to develop insights into iPad use in the secondary school. Also, it facilitated understanding of the differences and similarities between using iPads or not in the classroom.

At the beginning of the students' focus group interviews (see Appendix 2A, 2B), before moving on to considering iPad use specifically, a couple of general questions were asked about students' attitudes towards mathematics and their feelings, opinions, and perceptions about mathematics: *"Do you like mathematics? Is maths challenging for you?"* Most of the students stated that they preferred mathematics to other subjects and they believed that it depended on the teacher in terms of how the material was taught. However, they did sometimes find some mathematics problems, equations, and tests challenging. Students in group B2 recounted *"there are several maths problems that defy us, such as mathematical equations".* Mathematics is difficult for most students and is considered a challenging class. Still, it would perhaps not be as difficult for students if they learned mathematics using a supportive educational tool such as the iPad. Students in class B who reported facing difficulties in mathematics class in the first month of the quasi-experiment found that using the iPad as a learning tool in the second month supported them in doing multiplication and division in a straightforward way, with group B3 stating *"we were suffering from multiplication and division"*, indicating that these operations were no longer a problem after iPad use and its apps. Group A4 said "*mathematics was complicated, but now it has become easier because we can download any app which can help us. Apps help us a lot."*

In evaluating the students' feelings, opinions, and perceptions, six final themes emerged, namely: promoting students' performance in mathematics, lack of the knowledge regarding using the iPad and apps, encouraging students to study and organise their time, promoting communication and collaboration, lack of desire to use the iPad, and obstacles to using the iPad in learning (see Figure 6-1). These themes are presented in greater detail in this section.

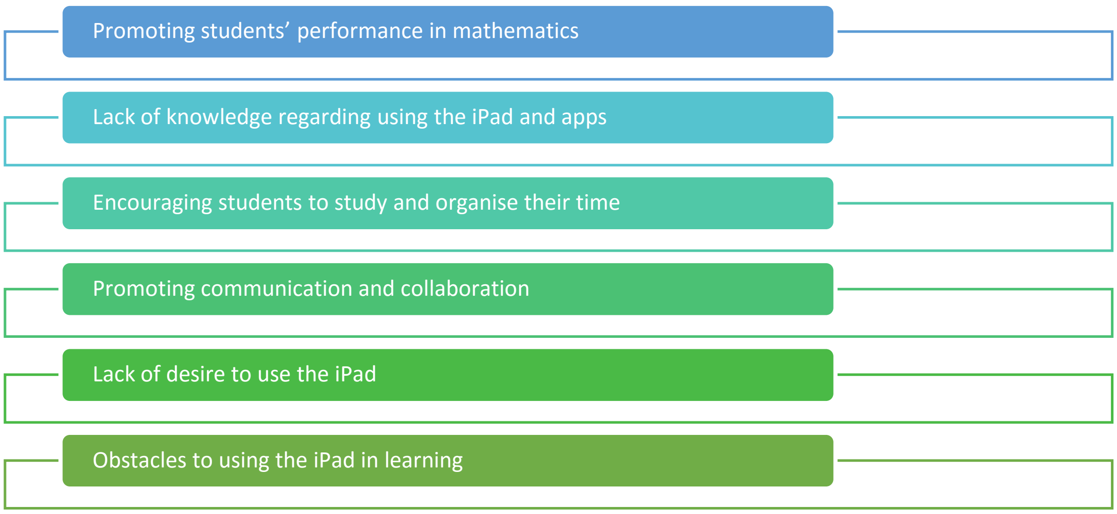


Figure 6-1. Themes derived from students' focus group interviews.

6.1.1 Promoting Students' Performance in Mathematics

Incorporating tablet devices and apps in learning can provide the opportunity for students to improve their performance in mathematics. The primary objective of evaluating the effectiveness of iPad use in this research was to improve students' performance, enabling them to achieve the lesson goals, and to identify how using iPads and apps would influence students' performance in mathematics. The first theme of the student focus group interviews was promoting students' performance. Four sub-themes were identified under this theme, namely: using iPads and apps assist in improving students' mathematical skills, iPad apps help students study and prepare for tests, using iPads provides immediate feedback for students, and using iPads assists students in searching for information and understanding the content.

6.1.1.1 Using iPads and apps assist in improving students' mathematical skills

One of the significant influences of using iPads and apps, as identified by the students, was that their mathematics skills improved. In particular, there was some evidence of students' ability to choose the right app to support them in solving mathematics problems and graphs, as teachers reported that in section 6.2.4. In contrast, when solving problems or equations using paper and pencil (traditional methods) in the first month of the quasi-experiment, students in class B struggled with some of the answers. Group B1 reported *"we faced difficulties and a big challenge for some questions"*. Similarly, other students in class B who also used traditional methods for learning mathematics faced difficulty in answering some questions and they believed that the extent to which mathematics is difficult depends on students' understanding of mathematics and ability to think through problems to solve mathematics activities. Group B2 stated *"There are some complicated maths problems, and some of them are not. These complicated maths problems defy us, such as mathematical equations, because they depend on your understanding and thinking".* The difficulties faced by Class B when doing mathematics indicate the need for more support to improve their proficiency and skills besides having the teacher. In this regard, iPads offer various applications that can support students with difficult mathematics equations, such as GeoGebra.

Meanwhile, the students in class A who used iPads during the first month of the experiment were encouraged to perform well and solve difficult problems through the iPad's apps; this increased the competition among them and mathematics became easier through using the apps. For instance, the students sometimes had a competition among themselves to see who could complete an activity the fastest and be the first to submit the answer via iPad. Group A1 said *"If we encounter a difficult question, we have to answer it quickly to be the first student to solve this question in the class".* Group A4 felt more confident when they used supporting apps, saying *"It makes mathematics easy and is an exciting class; for example, mathematics was complicated, but now it has become easier because we can download any app which can help us. Apps help us a lot".* The students found the iPad a beneficial tool to raise their mathematics grades because it provided a variety of apps to support their studies.

Also, the students believed that this device and the various apps allowed them to arrange their study time, which was reflected positively in their performance. They also discovered that using several challenging apps encouraged them immediately, thereby increasing their achievement. A relevant illustration of this was offered by group A2, who firmly stated *"We think our performance has increased after the use of the iPad because we can organise our time to study. Also, there are many applications which have improved our overall grades".* The iPad device and apps deliver information faster to students and make mathematics learning easier than teacher instruction. Likewise, group A1 said *"We see that our percentage in mathematics has become very high after the use of the iPad because it is easy to study in terms of homework, studying, organization, arrangement, and faster delivery...".* There is a clear need for students to access a method which enables them to understand the essentials of mathematics in a faster and more straightforward way, without the need to expend any additional mental effort doing an extremely hard equation. Currently, iPads offer a wide range of apps that can be accessed to organise study time and benefit students in terms of improving their performance.

In general, most mathematics students know how to draw a plot or graph manually, but it is not easy for a student to draw a diagram manually as fast and accurately as technology does. The findings suggested that iPads contain beneficial apps which enhance students' performance by helping them with graphs and solving challenging mathematics questions, reviewing the answers prior to submitting them, and offering the simplest means of presenting work to the teacher. Group A3 commented *"It contains many programmes which helped us to solve maths questions, such as applications that helped us with graphs and measurements".* Students also reported that they liked using various apps for activities such as drawing graphs, as they enabled them to do excellent work while also being time-efficient and not requiring additional effort. A pertinent illustration of this was offered by group A4, who used iPads in the first month of the quasi-experimental phase. They preferred to draw graphs using the GeoGebra app rather than by hand because they got a perfect scale for the graph or triangles. Group A4 said *"…some apps help us draw triangles or graphs with an excellent design, better than when we draw by hand, such as the GeoGebra app".* Similarly, group B3 found it difficult to draw graphs by hand, based on the coordinates, because they needed some essential tools, such as a ruler and a protractor, and the graph might not be accurate in its measurements. Group B3 commented "*some applications are helpful, such as graphs; as soon as we enter the coordinates X, Y and Z on the iPad, it will create an accurate drawing, unlike what happens in the case of a paper book. It takes time to draw one graph, and there are some tools which must be available to draw, such as a ruler, a protractor, and a pen; thus, the drawing may not be accurate".* Students can experience excellent graph drawing techniques using an iPad app, allowing them to perfect their measuring skills. The app also permits the presentation of 3D pictures, representing a clearer approach to learning than the hand drawing method. Graph drawing requires a specific set of skills and many students lack one or other of these.

6.1.1.2 iPad apps help students study and prepare for tests

The iPad contains some applications that have practice components; for instance, students can take practice tests and access pre- and post-test elements for each lesson. Group B1 reported *"The teacher provides us with exercises for every lesson and pre-tests & post-tests. These tests confirm information that is corrected directly".* Thus, students can evaluate their pilot tests level prior to taking an official class test. They can also choose the level of difficulty of their practice test, which encourages and motivates learning and cultivates an understanding of the test styles and the skills required to pass. Students had the ability to choose which apps they needed to practise individually and prepare for their tests at home or in lessons because they required several specific skills to raise their performance. Group A3 commented *"Sometimes, our teacher assigned exercises in which we could get extra scores or test links. Likewise, in the Achievement Test, we practise directly on the iPad as a preparation for exams, so our grades have improved from previous Achievement Tests".* The benefit of doing practice tests is that some students increased their percentages from previous tests to a greater extent than when the iPad was not used. One of the students in group B4 said *"I used to get 92% in the tests but after using the iPad I got 98%".* The iPad made study and preparation for the tests easier than looking through old exam papers. A teacher can save old tests in a system such as Marefah for students to review and prepare well for a new test.

In this study, the school used a Blackboard-style learning management system called Marefah, as mentioned in previous chapters. The students had access to this system to review the lessons and previous tests, and to upload and download homework through the iPad. Group A1 mentioned "*... it helped us in terms of tests as we can review previous tests in the Marefah system".* The system was an excellent way of students increasing their grades by getting extra points from the extra exercises and activities in their free time at home. The teacher supported the students by uploading worksheets that summarised a chapter or a specific lesson as a review for the exam. Group A4 found that Marefah had supportive documents, such as worksheets, which were uploaded by the teacher to help students review and practise for tests. In the test practice, they faced challenging activities to improve their preparation. Group A4 said *"our achievements have increased whilst using the iPad through the Marefah system; We find challenges and exercises that help us to achieve higher grades. It contains programmes from which you can acquire skills. As for the worksheets, the teacher downloaded four worksheets that were useful in the test as sources for it".*

Although the students can access this system using any technological device, the school uses iPads, which have been given to all students since 2015 (see section 4.7.1). Moreover, the Marefah system app has features such as extending the deadline of the submission for homework or the test. Students sometimes found it difficult to answer or finish a project in a certain time and they needed more time or they would lose the marks. Thus, the students became more interactive with this app and they did their best to attain full marks. Group B1 reported *"When the deadline for delivering the homework has passed, we will chat with the teacher to extend the time so that we can submit the homework. In the extra time, we try to do our best and be more active by chatting among ourselves in our chat group".* The Marefah system enables students to complete tests or homework assignments via a desktop computer or any other device. However, when this system is accessed using an iPad, students can answer and move through the assignment by manipulating the images on a high-quality screen with either their fingers or electronic pen. Moreover, the iPad version permits students to contact teaching staff or classmates rapidly to pose queries regarding their work, while simultaneously continuing with their given assignments.

In addition, in the Saudi education system, students who graduate from secondary school must take an exam called the GAT to apply for university or a job in SA. Group A4 talked about how practising using the iPad and different apps affected their GAT results positively, stating *"Also, our achievement has increased in the general abilities test, because we learned the necessary skills through the iPad apps; thus the percentage on our general abilities tests increased and became a few points higher than before".* The Qiyas app can be downloaded onto iPads or any tablet device and used both to help students understand the content of any tests and to assist them in achieving high grades in these tests. The iPad and other tablet devices are tools that have many apps (see section 3.3.4) and let students access these particular apps and areas of the learning management system. However, the iPad itself has a different feature, as discussed in section 3.3.4 such as a large screen 10.2" retina display and weighing just 1.03 pounds with a thickness of 0.29. Also, the school in this study gave all students iPad devices. Thus, the iPad facilitates access to a plethora of apps, which help students prepare for and pass a range of examinations.

6.1.1.3 Providing immediate feedback for students

Immediate feedback was one of the significant impacts on students' performance. There were several apps on the iPad, such as Marefah, that provided immediate feedback after submitting tests or homework, giving comments and information related to their answers from the teacher. The students received the result of homework or a test promptly after they submitted it. Group A1 mentioned "*Once we submit the homework or the test, it will be reviewed automatically"*. Similarly, group B1 said *"we know our mistakes and grades immediately"*. Thus, students could learn from their mistakes directly and avoid making similar mistakes in the next test or homework; meanwhile, they improved their grades. Group A1 stated *"we will get the feedback immediately so that we can know our mistakes. The system sometimes is opened to resubmit the homework, which encourages us to resolve the homework correctly to obtain a better degree and avoid previous mistakes".* Similarly, group A4 reported *"if we have any test or exercise, we will upload it to the Marefah system and get the grade directly. We will know our mistakes instead of waiting for a day or two to for it to be corrected by the teacher, unlike the previous method where the correction of* *the test took a week or two weeks".* Also, group B4 compared getting feedback from the iPad and the previous method, mentioning that *"It is better than the traditional way of getting feedback because it gets the result immediately. The iPad also shows your grades, your correct answers, and your mistakes".*

With respect to homework assignments and tests undertaken on the iPad, the Marefah app can both provide the content and help students submit their answers. Once work has been submitted, students can receive direct feedback in several different ways. For example, it is possible for the system to mark and correct student papers because it allows teachers to input both questions and answers. Alternatively, teachers can upload answer sheets to the system, only permitting students to access these resources once they have submitted their tests or assignments. Group A2 said that the feedback is sometimes shown immediately and is sometimes uploaded on the Marefah app by the teacher. They stated that the *"iPad app corrects the homework, or the teacher uploads the correct answer to an app such as the Marefah app, so you can know the right solution and compare your answer with the typical explanation. It is helpful, especially when we are at home. For example, when we would like to find out if our solutions are correct or not, it is available via iPad and we can know the typical answer after submitting the homework with grade markers".*

The Marefah app gave students a great opportunity to enhance their performance on homework. For instance, group A1 discovered the advantage of doing homework through the Marefah app, namely that it allowed them to resubmit the homework, which motivated them to raise their performance level. They noted that *"The system sometimes is opened by the teacher to resubmit the homework, which encourages us to resolve the homework correctly to obtain a better grade and avoid previous mistakes".* Students also used the Enjaz website through the iPad's Safari app to submit homework, which encouraged them to improve their grades. Group B3 stated *"There is an option to deliver some projects through the Enjaz website. So, using the iPad, there is no need to wait for the teacher to correct our projects; the app gives us feedback immediately, which is a reason for our increased achievement".* Like the Marefah system, the Enjaz website can be used through any technological device.

The students expressed a preference for completing their homework and solving problems on the iPad over the conventional method of handing a sheet to the teacher. The teacher sometimes corrected homework or tests at a later stage, so students did not get feedback or grades promptly as they did when they submitted by iPad. Group A1 stated that *"better than* *ever, we believe that solving tasks and files will be facilitated by a much better Marefah system than traditional regular files. Once the files are uploaded, the teacher can review them and give feedback".* Moreover, the ability of iPads to organise student files means that teachers can more easily and frequently access and review them before offering feedback. This surpasses the normal functions associated with regular files because it avoids situations such as the student losing files or leaving assignments at home in error.

The immediate feedback enables students' strengths and weaknesses in mathematics to be pointed out by identifying correct and incorrect answers and providing additional explanation of incorrect answers. Also, they can compare their solutions with typical answers shown in the feedback. This helped the students in the study to improve their mathematics performance. Group B1 said that *"By solving the exercises or the comprehensive questions of the course, after answering these questions we get an automatic direct correction and we know the correct solution and mistakes, so we can review the solution again until we get the whole correct answer. As for feedback, it made it so easy for us to realize our strengths and weaknesses. Also, it presents the solution of the wrong exercises with an explanation of how to solve it correctly, showing our GPA".*

Also, the students become more active and interactive when doing homework and providing feedback to each other. Some students reviewed other students' homework and gave them feedback because they wanted to ensure that their answers would achieve high marks in the assignment. Group B4 stated *"We cooperate when doing homework, and we feel more comfortable before submitting it because we review it to get the best marks. It saves time and effort as well".* Traditional methods tend to require teachers to collect answer sheets from the students. Thus, correcting the papers can be a time-consuming process. By the time corrected tests or assignments are returned to students manually, there is a risk that the students will have lost interest in that piece of work and will fail to review the corrections. Hence, they will not learn from their mistakes and may continue to repeat them. In contrast, the feedback received through tablet apps can radically alter the way in which students regard feedback, encouraging them to review the corrections and learn from their errors.

6.1.1.4 Assisting students to search for information and understand the content

Searching for new information and engaging with learning resources through the internet is essential for students to increase their understanding of mathematics. With the iPad, students could look for information online, which was reflected positively in their performance. Group A1 stated *"we are very happy to use the iPad in the maths lesson because if we face* *a difficult question or new knowledge, we can search for it on the internet".* Similarly, group B2 mentioned that searching on the internet helped them find additional explanations of the lessons put in different terms than teacher teaching. They reported that the *"iPad is better than the book in terms of searching for information, for example, if the teacher talked about a new theory, we could search on the internet to understand it in a way that is different from that of the teacher".* Also, group B2 talked about how the iPad and printed books were similar in terms of content, but the iPad was much better because they could find what they were looking for with less time and effort. They recounted that *"the iPad is like an electronic version of a hard copy book in terms of the scientific knowledge, so it has made it easier for us to do things like upload assignments, find an answer quickly, and organise lessons and files".* The use of apps on iPads expands the range of opportunities available to students who can seek information on a multitude of topics. Furthermore, this approach helps learners to appreciate the concepts they encounter during the learning process to a greater extent. Hence, iPads now comprise an essential learning tool.

A useful application for increasing the information available to students is YouTube. Students can watch experts on YouTube discussing any specific area in mathematics. If the teacher did not explain the lesson very well, they could instead understand it through YouTube clips. Sometimes, the teacher uploaded useful video clips in the Marefah system for those students who found it difficult to understand the lesson or who were absent. Group B1 stated that *"…many of the exercises offered by the teachers in the Marefah system increase our knowledge and understanding of the subject. If we do not understand something during the class, the teacher will download a video clip explaining this exercise from YouTube".* Likewise, group A4 found that iPad apps supported them in solving mathematics activities and helped them understand the content explained in a new way. They mentioned that *"Definitely, the iPad helps us. If we are solving a math question, we have to have a calculator to support us, and it is available on the iPad. In case we did not understand a math question, YouTube helps us to understand it or any other website to understand the explanations of lessons in different ways rather than our teachers' method".*

There are now numerous apps that can be employed to explain lesson content to students who have been absent or have failed to grasp the essentials of any lesson they have attended. The use of YouTube is a classic example, providing a resource for students to search for clips which might have been shared online by their teachers. Alternatively, they might search through other clips posted on YouTube by teachers who have explained the relevant material more clearly than their own teacher. YouTube is accessible using multiple devices, including mobile phones. However, iPads have the benefit of a larger screen, which permits students to watch video clips in higher quality (cf. section 3.3.4).

In addition, the teacher sometimes recorded the lecture using the smartboard and iPad, uploading the file into the system, as some students did not understand a part of the lesson. Hence, students had the opportunity to review the lesson in their own time at home and students who were absent from class did not miss any information. Group B3 mentioned that *"Sometimes the teacher has already summarised the object on the blackboard and recorded it; then uploaded the video on the Marefah system. Thus, it became easy to review and study clearly. It helps us to understand the lesson better and not to forget the its objectives".* Another major feature of iPads is that they allow teachers to connect their own devices to smartboards, which means that lessons can be recorded and uploaded using a cloud app or Blackboard. Thus, lesson clips become a reference tool through which students can review past lessons, irrespective of absences or their failure to understand the content at the time.

The best feature of the iPad apps is that there are hugely valuable mathematics applications that can help to increase students' information and understanding, consequently enhancing their accomplishments. If students had difficulty understanding a lesson or the solution to an equation, there were several applications that could support their learning with a full explanation of the steps. Group B1 said *"Definitely, it helped us to solve mathematic questions, especially the difficult ones".* For example, students used the MathPapa app to find solutions to difficult equations by having the answer explained step by step. Group A4 stated *"If we did not understand the lesson, there were specialist applications which explained the solution step by step for mathematics equations, such as MathPapa".*

Moreover, there were other apps used by students when they encountered a difficult question, such as GeoGebra or Photomath. Group B2 stated *"It is possible to know the answer to any hard equation because of the availability of the calculator, GeoGebra, and Photomath in our devices".* In addition, there was an application called Holol. Students used it as a source of mathematics ebook solutions, which increased their knowledge of all possible answers to any question. Group B4 mentioned that *"In the case of facing a difficult mathematical question, we use the Holol application; it has all the mathematics solutions".* Moreover, the students interacted with some apps (e.g. Photomath) that gave them a full step-by-step breakdown of the solution with additional explanation, such as a video clip. They liked to use these apps when they encountered a difficult equation and they wanted to understand how to answer it. Group B1 stated *"It also helped us by showing the steps of the mathematic equations; once you write the equation, you see the solution with the full steps. Also, some apps have a video or sound explaining the full steps for the solution, such as the Photomath app".* Similarly, group B2 mentioned that *"In the Photomath application, we can take a picture of any equation and it gives us a full solution".* There are already a number of mathematics apps which can be purchased from the Apple store and downloaded onto iPads. These apps can be employed to render more comprehensible any number of complex mathematical concepts. Moreover, there are also specific apps designed for use in the classroom by a teacher or a member of the school management, which can supplement those apps available for use at home.

6.1.2 Lack of Knowledge of how to Use the iPad and Apps

However, some students preferred to do their homework via paper and pencil (the traditional method), even though the teacher asked them to submit their homework online, because they faced difficulty using iPad and apps. Thus, they did the homework by hand and then scanned the homework and uploaded it via an app, such as the Marefah system. *"When the teacher gives us homework, we do it using pen and paper. Then, we take a photo of it with a scanner application and send it to the teacher using the Marefah app on the iPad".* One student from group B2 did not like doing mathematics activities on the iPad, preferring to do them by hand. He believed that writing by hand was faster than the iPad and saved time. He reported *"I think that my achievement is decreased because I prefer to solve the equation quickly using the traditional method and the iPad takes more time".* Also, students in group B4 liked using paper and pencil rather than apps on the iPad to solve equations or draw graphs, saying *"…but to solve the equation or graph we prefer to write on paper".*

Moreover, lack of knowledge in the use of technology may affect students' performance in mathematics. Some of them said that their performance was worse when using the iPad. An issue was that they were not trained to use this device or apps for their learning because previously they had been taught to use printed books. Thus, some students faced challenges using the iPad to study and preferred use the textbook. Group B2 said *"It was very difficult to use the iPad in mathematics because we were not trained to use it, as throughout the previous period, we used the book only. The use of the iPad was difficult".* Moreover, some students reported that their achievement was not improved by using the iPad. Group A3 declared *"We use the iPad to access the Marefah system, but we think our achievement has not increased. Nothing changed for us because of the iPad being used".*

Also, some students have encountered difficulties using the apps and preferred to solve problems by hand. Group B2 mentioned *"We think that our achievements are incomplete because we prefer to solve the formulas quickly using the traditional method, whereas the iPad takes more time".* Students still need basic training in iPad usage so that they can more effectively benefit from its potential, developing the necessary dexterity to use sophisticated mathematics apps, such as GeoGebra. Thus, teachers must instruct students for at least five or ten minutes before any new app is employed in the classroom context.

Moreover, the students stated that in terms of memorising the knowledge learned by working through a mathematics equation, the conventional method of paper and pen enabled them to remember the information for a much longer period of time than when they solved the problem on the iPad. Group B2 stated *"A book is better than an iPad in other aspects such as solving equations. We prefer to answer equations using paper, not the iPad, because the knowledge and the information will be memorised for much longer by writing".* However, iPads can be used with electronic pens (Apple Pencils), which enable students to write as if by hand, solving equations, or inputting and storing new data. Apps such as the notes app are already available for downloading onto iPads that support writing via e-pen. Furthermore, the e-pen permits learners to quickly append notes to eBooks or files.

In addition, some students believed that the iPad screen affected their marks because they thought they could not solve any equation correctly, especially if it was a long equation or had complex mathematics symbols that needed to be written using the iPad keyboard or with an e-pen. Group B1 said that *"when solving some of the long mathematical questions, the students find it difficult to write on the iPad, so some of them bring their own keyboards or electronic pen".* Similarly, group B2 preferred solving long equations by hand rather than using the iPad and apps. They said that *"it is difficult to write long equations on the iPad, but hand-writing on paper is easier".* Also, group B4 mentioned *"we cannot solve problems correctly because the screen space is small, and it is also challenging to write maths symbols".* Similarly, Group B1 faced difficulty use mathematics symbols such as roots. They said, *"some symbols, such as roots, are not available in some of iPad applications".* While the current dimensions of the iPad are satisfactory, there remain problems in relation to generating appropriate mathematical symbols. However, this issue can be resolved by using specialist mathematics apps, such as MathPad.

6.1.3 Encouraging Students to Study and Organise Their Time

Analysis of the student interviews revealed that the iPad and apps enhanced students learning of mathematics in a range of ways, demonstrating that they were able to increase their time on task when studying and organise their study time, and that they were encouraged to solve mathematics activities. First, the students could use the iPad to summarise the lesson with clearly organised information, which made their learning much easier as the lesson could be reviewed without any extra effort. Group B1 mentioned *"…the iPad helped us to do many things such as study and review the material".* Similarly, group A3believed that the iPad helped them organise their studies and encouraged them to study more by summarising the lesson better than previous methods. They said *"We think the iPad is organized, it helps us to study more and more. Sometimes, the lessons are much more complicated, but the iPad contains some summaries and graph trees, which allows us to summarise lessons with no big effort".* Similarly, group A2 said *"it also organises your time and shortens things, making it easier for you; meanwhile, the book may be a little more stressful to study than the iPad".* Students could not only organise their files on the iPad using a cloud app, but they could also summarise a lesson via the comments function. Thus, the iPad allowed the students to refer to their comments or files at a later date in an easy way, something which would not have been feasible using traditional paper-based methods.

Moreover, the iPads enabled the students to study and do their homework at any time or anywhere. The students could upload their homework through this device, and they also had the option to do their homework online without any effort. This could even be done at school in their free time, on their way home after school, or at home. The teachers in this experiment used the Marefah app to upload the homework for all students who used the iPad as a learning tool. Group A1 maintained the benefits of doing and submitting the homework online through the Marefah app, stating that they could send the assignment from anywhere and at any time before the deadline: *"We prefer the iPad to solve the exercises at home and also to upload the homework via the Marefah application. The iPad allows us to upload homework at any time and anywhere…".* Moreover, the students could exploit the free time in the car to do their homework on the iPad and upload it directly. For example, group B3 said *"When we are traveling with our parents, we can use the travel time to do homework instead of a paper solution and fear the paper being damaged or lost until we can hand-deliver it to the teacher".* Also, the students started to save money instead of having to buy papers or worksheets for homework. Group A1 noted that using the iPad *"…also saves us the cost of printing homework, as the homework is uploaded as files only".*

Likewise, the students were motivated to do their homework, on their way home after school or in their free time at home, because uploading it was easy using the iPad. Group A2 said that *"it also supports the students by making doing the homework easier than before".* Group B1 mentioned that *"Currently, 90% of the homework could be uploaded via the iPad. It facilitated many things; especially at home, if we were not busy, we would solve the questions and upload it directly anywhere and anytime. Even if it is late at night or even if we are outside of the home. The iPad makes it easy for us, and we prefer doing the homework via iPad than with the book. Moreover, during the bus journey home from school, we do some of the homework and make the best use of this time".* The use of iPads can prompt learners to study during their free time rather than merely chatting online or playing games. Moreover, they can boost levels of student motivation and encourage them to pursue their studies outside of the school environment in their free time by participating in activities related to their studies and homework.

However, some students believed that submitting homework via the iPad was more beneficial for the teacher than the students, because it helped them collect the homework files electronically and the homework was corrected directly after submission via the app. Therefore, the teacher would not have to expend additional effort or time arranging homework for their students and recording their grades. Group B4 stated that *"it helps the teacher more in correcting and arranging assignments".* Also, it enabled the teacher to know who had not submitted their homework on time or at all, and who had low grades. Group A2 said that *"sending the homework through the iPad allows the teacher to see each students' grade, the submission deadline and the level of the students".* Not only do iPads and the many available apps support students' learning, they also concurrently support teachers in their work (for more details, see section 6.2). The manual collection and correction of homework is time consuming. Moreover, it occupies time that would be better spent planning other lessons.

To sum up, the iPad encouraged students to learn as they could study anywhere and at any time, especially when they were doing homework because it was easy for them to submit it. Moreover, they received direct feedback (for more details about immediate feedback, see section 6.1.1.3) and could have an opportunity to resubmit the homework. Finally, the students summarised lessons using an iPad application, which made it easy for them to study and review lessons with little effort.

6.1.4Promoting Communication and Collaboration

Most of the students said that the iPad and its various apps offered continuous communication and collaboration among students. Thus, the students passed information and understanding of the mathematics concepts among them when they communicated with each other. Also, the students liked to communicate with each other individually or as groups to discuss mathematics problems using social media applications such as Telegram, WhatsApp, Snapchat, and Adobe Connect, or the Marefah system, when they were at home. Group B3 reported *"some students create groups in Telegram to communicate with each other in terms of assignments and lessons".* Group A3 said "*A student communicates with them via iPad apps such as Telegram, WhatsApp and Snapchat or the Marefah system. Students can enquire about homework or other things with other students or teachers when they are online on the website or an app".* They used either their mobile phones or the iPad to use these social media apps to discuss their learning. Group A1 said *"We have social networking groups; we often use mobile phones or iPads for communication".* Similarly, students could communicate among themselves to discuss a project or research before submitting their assignment, and they preferred this to a physical meeting. Group B4 mentioned *"we communicate with each other to enquire about assignments and participate in research using Adobe Connect. When we solve the assignment, we need to make sure that the answer is correct. So, we do not need to visit a colleague at home anymore because, through applications, we can enquire about that, and we can also communicate with the teacher through the Marefah System".*

Thus, they created groups in the Telegram app as well in WhatsApp to discuss various subjects, either among themselves or with their teachers. Group B1 stated *"Absolutely, there are Telegram groups in our devices; we communicate to discuss and understand some questions and lessons. In addition, we use WhatsApp which is available in our mobile, to make a connection between us and the teachers".* Similarly, Group A1 mentioned *"We use the iPad during the group discussions to communicate with each other; it is wonderful, we reach a solution and cooperate to solve questions until we understand the issue".* Also, this device and the apps promoted communication among students and their teachers. Group B1 said *"we can communicate with the teacher through using the Marefah system".*

Likewise, the students shared their ideas and knowledge, supporting each other. Group B1 said *"we can share some things between us, such as sharing solutions or ideas".* Group A3 stated *"Honestly, it is a beautiful thing that you communicate with your colleague through* *the iPad. It facilitates communication and helps you to understand and also to share ideas with colleagues".* Thus, one of the benefits of iPad use is that it encourages students to learn cooperatively via a range of communication apps which can be used outside formal education, thus enabling learners to share a wealth of information, knowledge, and experience with each other. Similarly, within the classroom environment, iPads comprise the most effective tools for collaboration with others due to their large screens, which enable students to present their work and information with clarity and then share easily via apps such as AirDrop.

The most beneficial aspect of the communication among students using the iPad and mobiles was that no-one missed lectures anymore. A student could use any social media app to connect with their classmates to clarify any aspects necessary if they had missed something the teacher said during class, misunderstood something during the lesson, or were absent from the class. As group A3 mentioned, *"When one of us was absent, he would miss many things, and he would not know about it, so he had to communicate with one of our colleagues to help him".* It is possible for students to use any technological device, not just the iPad, or app to communicate with fellow learners. However, using social media apps, for example, might raise issues in relation to the sharing of files or the use of lesson slides. Hence, the preferred option remains the use of iPads and the apps associated with them.

Also, group A3 mentioned that colleagues sometimes explained the lesson using easier methods than the teacher via a communication app, reporting *"…sometimes, some students can explain the lesson better than our teacher".* For example, group B3 said that *"a student sends a specific question to ask colleagues to help him understand the math problem, double-check if the solution is correct, send a link explaining a similar problem, or share a beneficial educational link to explain some lessons to enable him to understand the lesson in an easy way".* When students understand the content, they can explain it to their colleagues, which is more easily done through a communication app than making a home visit.

Therefore, some students prefer to use communication apps that have video calling, such as FaceTime, rather than having regular meetings with classmates at home or in a public place. The reasons for this include that it is time efficient, and it requires less effort for them to get an explanation of the lesson or problem, as when they are online, they can share video clips or links to clarify the issue, or make video calls to see each other's reactions. Group B1 said *"We prefer to communicate using the iPad because it reduces the time and effort. We can* *explain things via video between us and send it to each other better than in a face-to-face meeting. So, we can all connect online at the same time in the same group. Or two students can talk in a private chat via any social media apps or through video calling such as FaceTime, which is the best way".* Students sometimes need a video call rather than voice call to see the facial expressions when communicating with colleagues, which they can do using the free call app Facetime.

During school time, students also used the iPad to communicate and share files, even when they were not together in the same room. The iPad provides an excellent opportunity to communicate via an app, such as AirDrop, with a classmate or friend in school rather than excuse themselves from class to deliver a sheet or message to a friend. This avoids wasting time or missing a lecture. Group B3 said *"we communicate with each other inside the school through the AirDrop application, which enables us to share worksheets. Anyone who receives a worksheet will get a notification to accept or reject it".* AirDrop is an Apple app that can only be used to share information between Apple devices. However, it is a valuable app because it permits users to share files without the need to register, supply contact numbers, or comply with any other conditions. In addition, it enables users to decide whether to accept or reject files which other users attempt to share with them. Thus, the students were motivated during the quasi-experimental phase by using the iPad, because it enabled them to study mathematics and enhance their learning without wasting time. In addition, the iPad encouraged them to make more positive efforts during activities through the use of interactive apps. Furthermore, the iPad allowed students to communicate with each other through social media apps or the Marefah system to discuss their studies. Also, the students became more collaborative with their peers, sharing their information and understanding of mathematics.

6.1.5 Lack of Desire to Use the iPad

However, while most of students believed that the iPad and apps encouraged them to study mathematics, some mentioned that they had no wish to use this device and preferred using their regular traditional methods (book, paper, and pencil). Some of them believed that there was no difference between learning from a book or using an iPad. Also, they found that there were some challenges in using the iPad (for more details about the obstacles, see section 6.1.6) and they did not like doing their homework or assignments on it. The students mentioned some reasons for their motivation not being increased through using the iPad in learning mathematics. First, there was no major difference between using an iPad or a book to study mathematics. Group A3 stated *"We see that there is no difference, but the iPad* *sometimes help us with some equations".* Also, some students preferred the traditional methods to learn mathematics over using the iPad as a learning tool. Group A3 said *"we used it during the experiment, but it was not efficient for us, and we think the book is better".* Some students needed extra help from teaching staff to realise the full benefits of iPads and apps. Teachers should identify such learners early and ensure that they receive the necessary support and encouragement to guarantee that these students are capable of using iPads and are motivated to do so.

The second reason was that the students preferred to write notes or do activities in class by hand rather than using the iPad. Group B2 said *"The disadvantage is that it is difficult to write long equations on the iPad, but hand-writing on paper is easier".* While e-pens are available for use with iPads, most students expressed the opinion that purchasing a quality e-pen was not an option for them. Group A3 mentioned that *"It is more complicated than a book, and we need an electronic pen, and a high-quality e-pen is so expensive. The iPad is not considered a bad device, but the book is better because it is quicker and easier for me to write a note, and I can easily understand my own handwriting".* These students were not trained well to type fast or write on the iPad using an e-pen, so they needed more time to become familiar with iPad usage.

The third reason was that the students did not like to do homework through the iPad because they felt it wasted time. The students believed that they spent enough time using an iPad at school and therefore they did not want to spend more time at home facing the iPad screen. Group B4 reported *"We do not feel comfortable if the teacher asks us to do the homework on the iPad, because it takes time to solve. …we cannot work on iPads at home as well. We think that solving homework using the iPad is no different than using paper".* However, when the students used iPads for home-based study, the fact that they were watching learning videos as part of the learning process could make the entire experience feel somewhat effortless. Hence, this could encourage them to spend more time on homework assignments without regarding it as an unwelcome use of time and effort.

The fourth reason was that some students reported that the iPad made them less focused and affected them negatively while they were studying. Group A2 mentioned *"the iPad is harmful and may cause poor concentration".* Students need to know how to control the time they spend using their iPads to study. This is the function of special training, which must incorporate issues such as time management. In the classroom context, it is the duty of the teacher to manage the amount of time devoted to iPad use. Teachers might also be able to control the time spent on apps at home by employing remote controls and timers such as Classroom App.

However, the students in this Saudi secondary school encountered several obstacles during the intervention using the iPad as a learning tool. In the next section, these obstacles are explained in detail and the solutions proposed by the students in the focus group interviews are discussed.

6.1.6 Obstacles to Using the iPad Device in Learning

The intervention of technology, specifically in this case, using iPads in a secondary school in SA, faces some obstacles which decrease its effectiveness and lead to lack of willingness of use such devices as reported by students in the focus group interviews. Students faced four obstacles in particular, i.e. lack of internet connectivity or a weak connection, battery issues, technical problems with the apps, and broken screens or technical problems.

6.1.6.1 Interrupted or slow internet connection

The major obstacle was interruption to the internet connection or a weak connection, which can be detrimental to the educational process. This is one of the defects of the iPad and other tablet devices, as most apps must be used online, or they are not beneficial. The students could not use the apps without an internet connection and had difficulty accessing apps such as the Marefah system. Even if the internet connection was there, but weak, it was challenging to reap the full benefits of these apps. Group A1 mentioned that *"Usually, we face some problems such the internet interruption. Also, sometimes the weakness of the internet connection could make it problematic for us to access the internet, especially the Marefah system".* For example, group B3 faced problems with a weak internet connection during a routine short test on the iPad, so they had to do the test again on paper. Group B3 said that *"One of the problems we faced is also the weakness of the internet connection. Sometimes we have been asked to do a short test within the class, but the internet connection was very bad, so we had to do it in writing".* Similarly, Group B4 found that they had to re-sit an exam because of the internet connection dropping out. They might then get low marks when retaking the test because it became harder after the first attempt. They mentioned that *"Sometimes the internet is an obstacle, especially during tests. So, if the internet is interrupted, we have to re-sit the test, and we were surprised that the test became harder the second time".* Furthermore, the students reported that the teacher sometimes delayed the test to another day when the internet disconnected, even though the students were prepared for the test, and it could be difficult for them to study again if they were occupied with other studies. Group A3 reported that "*If the internet was lost during the test, the teacher delayed the test to another day".*

Furthermore, a weak internet connection led to students delaying downloading and registering a new app, preferring to do that at home rather than in school. Group B4 said that *"downloading new apps and registering was the biggest obstacle in school because of the weakness of the internet connection, so we delayed downloading new apps until we were at home".* Furthermore, group A4 stated *"Also, it is a challenge to download any new apps at school because of the bad internet services and all applications do not work except by activating them from admin control in school. Thus, we delay downloading applications and registration until at home".* All iPads used by students should be equipped with the necessary apps to facilitate learning in relation to any given school term or unit of study.

However, the students found that there were some solutions for interrupted and weak internet connection during the experimental phase: the students asked the school administration to solve the problem. However, students did not like to use the Wi-Fi service in school because there was a weak signal in some areas. Thus, some students brought in their internet modems and shared the service rather than dealing with the weak signal and being disconnected. Group A3 said that *"Some students bring their modem, so if the internet is weak or disconnected, they turn it on".* Similarly, other students mentioned facing the same issue during tests, so they used their own internet connection. Group A4 said that *"The internet is our biggest problem, but we bring our personal modems and share internet service".*

Personal internet routers were offered as a possible solution for students, a possibility which was raised on a test day. However, this is not a universal solution because some telecom companies have poor signal and coverage. Internet connection speeds tend to be slow in SA. However, the Saudi Telcom Company (STC) has begun to lay fibre optic cables, especially in big cities, to resolve internet connection difficulties. Schools need these connections, and it is therefore essential that universal coverage of educational institutions is achieved to avoid the problem of schools enduring weak or interrupted signals.

However, other students from group B1 said that the technical problems of the internet service were not a real issue for them because the school administration or the teacher resolved them. Group B1 mentioned that *"It is rare to face technical issues such as internet disconnection. For example, when we were uploading homework, the marks were not registered on the system. There was an issue with the internet, and the school administration solved this problem".* Also, group B4 said that the teacher was responsible for fixing the internet issue, either by bringing a new modem or changing the seating location of students in class to find a stronger connection to the school's internet. Group B4 said that *"If the internet is disconnected or weak, the teacher will bring alternative devices or ask us to change our seats in class until we find a good Wi-Fi signal".* However, it should be the responsibility of school management rather than teaching staff to secure a reliable internet connection. Specifically, management should implement a reliable Wi-Fi system to make sure the internet covers all classes in the school. The most useful action management can undertake in this respect is the sourcing of a trustworthy internet provider which offers fast internet and a strong signal. However, if the internet signal or service is good, there can still be difficulty connecting to the Wi-Fi service because of technical glitches with the iPad itself. For example, the students had difficulty connecting to the internet even when there was a strong signal. Group B2 reported *"There is a technical problem in the iPad itself, and it takes time to connect to the Internet, this is a defect in some devices".*

6.1.6.2 Battery issues

The second obstacle encountered by the students concerned the iPad batteries. Some students forgot to recharge the iPad at home until the battery was at full power, even though they used the iPad all the time at school, not just in mathematics class, which affected their power levels. Sometimes, they were unable to recharge the battery at school because they had forgotten to bring their charger, there were no sockets available, no power banks to use in class, or those that were available were situated too far from their desks. Group A1 stated that *"The unavailability of charges is an obstacle because there are no electric sockets or power banks".*

However, one of the advantages of the iPad's battery life is that it can last a long time. The students believed that if the battery of their device was fully charged, it would be enough take them through the school without recharging. Group A1 mentioned that *"if the battery is full, it will last for 7 hours without the need for a charger".* However, if the battery was not full, it would be insufficient to cover a full school day. As group A4 stated, *"we may go to school with a battery charge of 10% or 20%, but it is not enough for the whole day".* Also, even if the battery was full, it could deplete rapidly. Group B2 mentioned that *"the battery of the iPad goes quickly".*

Nevertheless, the students had some counter-measures if they encountered battery problems, such as using power banks. Group (A4) said that *"Some colleagues bring power banks".* Relatedly, group A2 stated that *"Sometimes the iPad is forced to turn off because of the low* *battery every day at school, so I had to buy a power bank".* So, some students brought a power bank, some brought their chargers to school, and some borrowed chargers from their friends. Group B1 said that *"The iPad battery goes quickly. Some students avoid this problem by bringing a charger with them".* Similarly, group A3 mentioned that *"As well as the low battery, some colleagues bring an extra charger for the iPad or power bank or borrow the power bank from a classmate. It is a rare problem because we charge our device at home".* A useful additional provision would be the installation of multiple sockets throughout the classrooms. This would mean that students would not need to move their seats to be close to sockets for the purposes of recharging their iPads. In addition, since students are prone to occasionally leaving equipment at home, it would be useful if schools could have a supply of spare batteries and chargers on hand to cover such eventualities.

6.1.6.3 Apps freezing during use

The third obstacle students encountered concerned technical problems with the iPad apps. Some mathematics apps froze during the activities in class and deleted all of their work, meaning that they had to start over. Also, students sometimes found it difficult to register in a new app which would be used in class. Another issue was that students could not download a new app in school due to the previously mentioned internet connectivity problems. Finally, after downloading a new app, students found using it to be challenging.

The students developed solutions to these problems. The first was that the teachers trained them in how to use a new app downloaded in school. So, in the Marefah app, students learned how to use it in the right way to avoid it hanging during usage, or they asked the IT department in school to fix the suspension issue. Group B3 said that *"The Marefah system is suspended sometimes".* Also, group B4 mentioned that "*When applications are suspended, we reboot the program to repair it".* However, some students believed that the issue of apps freezing is related to the expertise of the use of this app that they should be trained well on how to use it to avoid buffering during use. Group A4 said that *"In the beginning, we did not know how to use some of the math apps, so our teacher explained and trained us in how to use them, so we can use them without them freezing, because we suffered from the Marefah app freezing if we did not use it correctly".* The best way to avoid this is through the provision of appropriate training. Courses should be organised collaboratively by the school management team and the teachers and presented to the students in a way that encourages them not to misuse apps. In this way, freezing can be averted. Therefore, it is also essential to provide students with the training needed to use the apps. This must be done promptly so that students are ready to use their iPads in class at the start of any term or course of study.

Some students used an alternative app or website as a temporary solution in place of a frozen app or one that had not yet downloaded. For example, students used email to share files with others instead of a sharing app such as AirDrop. Group A2 stated that *"sometimes we send a file or sheet through AirDrop, but it does not work very well, so we need to send the file through email and upload it, which is not easy with low internet service".*

6.1.6.4 Fragile screens breaking easily

The fourth obstacle students faced was the screen of the iPad breaking. Some students broke their iPad screens in school, and these could not be fixed by the IT department. Consequently, they had to visit a repair centre. They mentioned that there was an arrangement between the school and a nearby repair centre to give a student discount. Group B1 mentioned that *"sometimes the screen is broken, so there is a service centre close to school which gives us a 50% student discount".* School management must collaborate with teachers to educate students with regard to safety issues, including the need to protect their devices with screen protectors. In addition, school management and teachers should encourage students to register for AppleCare product protection or take out other insurance to cover issues such as product defects, technical issues, loss, damage, and theft.

In conclusion, the primary obstacle encountered by the students was dropping of the internet signal or weak connectivity; however, the students developed their own solutions to address this, including brining their own modem from home, asking the IT department in the school to fix the issue, or requesting a change of seats from their teacher. Another problem for the students was the iPad battery, as some forgot to charge their iPads at home. However, students brought a power bank and charger to school to avoid this problem. Finally, technical problems with apps, broken screens, and other technical issues were encountered by some students during the experimental phase. The students dealt with technical problems downloading and registering for any new app at home. Also, broken iPad screens and technical issues were resolved at the repair centre next to the school, which offered a 50% discount for students.

6.1.7 Summary

The results showed that students held largely positive views regarding the use of iPads and the various apps, such as education platforms and communications apps. There was an increase in their motivation and engagement, which was positively reflected in their mathematics performance. In particular, students reported that using the iPad apps enhanced communication and collaboration with their classmates regarding their studies. They also reported that they become more interactive in learning mathematics and the iPads supported them in achieving the goals of mathematics lessons.

However, some students reported encountering several obstacles, such as interrupted internet or slow connection, low battery and difficulty recharging, some apps hanging during use, and the screen breaking easily. Also, some mentioned that they lacked focus during lessons and they considered the iPad a waste of time for carrying out activities, preferring to write by hand. Moreover, some of them believed that their mathematics performance was negatively affected because they were not well-trained in how to use the apps. In addition, they had difficulty memorising the solutions to long equations because some equation apps gave them the full solutions broken down step-by-step. Finally, they also found it problematic to write certain symbols on the iPad, which negatively affected their motivation to complete the answer.

6.2 Teachers' Interviews

The research was conducted with the primary aim of analysing the effectiveness of using iPads and applications in teaching and learning mathematics in a secondary school in SA. Thus, the goal was to understand whether such technology would be a useful tool to enhance student performance in the classroom and establish the factors influencing iPad use among mathematics teachers in teaching mathematics concepts. This section reports on interviews conducted with four teachers working at Alrowad Secondary School in SA, identified as T1, T2, T3, and T4. As previously mentioned, thematic analysis was used to analyse the data. This approach was beneficial in understanding teachers' perspectives about the use of iPads. Eight final themes emerged, namely: facilitating teaching and learning; assisting in achieving the lesson objectives; lack of technological skills in using the iPad and apps; selecting appropriate apps; helping improve students' performance in mathematics; helping motivate students to learn mathematics; lack of willingness to use the iPad in teaching mathematics; barriers facing the use of the iPad and apps in learning. These are summarised in Figure 6-2.

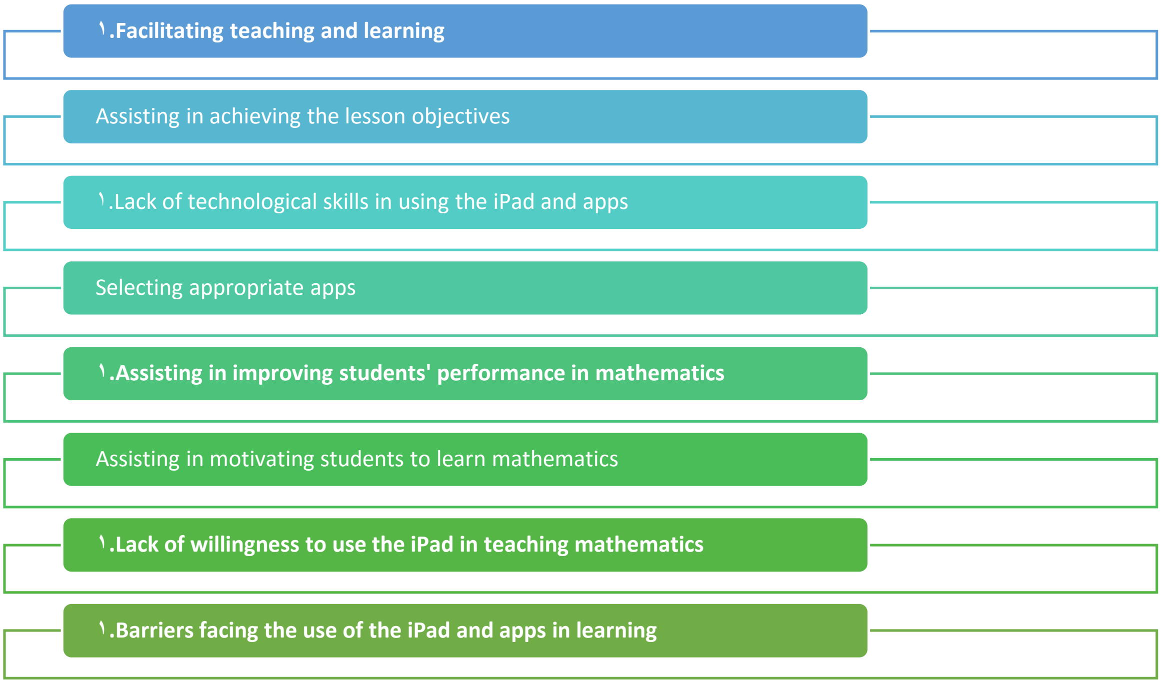


Figure 6-2. Themes arising from teachers' interviews.

6.2.1 Facilitating teaching and learning

The first theme from the thematic analysis was that the iPad and apps facilitated the teaching and learning of mathematics methods in the classroom. Teachers strive to use technology to teach content and be a part of a new community using technology in their lives and they would also like to keep pace with this new generation. Teachers want to get students' attention in lectures when they are teaching new mathematics objectives or skills. They can do so easily through using technology such as iPads as teaching tools. Based on the teachers' interviews, it was apparent that teachers would like to use technology to support teaching mathematics in the classroom, essentially to keep up with modern life and their community. T1 said that *"Technology has become a modern and essential tool for us. The whole community is keen to use technology, so we have to keep pace with this development"*. Teachers sometimes used the word "technology" in the interview to refer to iPads, smartboards, computers, and other devices. Also, teachers used the term "Marefah system", which is a Blackboard-type learning management system, employed in the school, as previously mentioned. T3 reported *"I prefer to use technology in teaching maths; the school has many basics which help to use the technology, such as smartboards, laptops, and iPads, as well as a specific website, the Marefah system, which can be used both in and out of school"*. Similarly, T2 mentioned that *"As for the types of technology I use; the smart electronic blackboard, which is considered a basic element in every grade, then the iPad,* *which stands in importance next to it, then the paper book, sometimes I use the iPad without the paper book because I rely on the PDF version of the (e-books)".*

The iPad and its apps supported the teachers by facilitating the teaching of mathematics concepts to students and also supporting students in learning mathematics easier than through prior learning methods. The teachers contended that the use of technology as a teaching and learning tool was more beneficial to education than other approaches. Also, they explained why they preferred to use technology rather than other methods to teach mathematics. First, the teachers used technology to make teaching mathematics concepts easy to understand in less time than the regular class time and with less effort. Technology supported them in attracting students' attention when they faced complex content and making it clear to students. T3 stated that *"I often use technology to explain a complicated subject, because it makes it easy for me to deliver the information to them".* Similarly, T2 said that *"I used technology in teaching for several reasons: first, to save time, and also to convey information to students more clearly than other traditional methods".* Also, T1 said that *"In maths, when we explain a particular lesson, such as triangles, angles, or inclinations, I find it difficult to explain them in traditional ways so I use technology to research and explain directly to the students so that they can easily understand quickly."* This device facilitates the explanation of mathematics content in a way that is clearer and quicker than previous methods.

Second, the teachers used technology to appeal to their students, particularly in challenging areas of mathematics. T1 mentioned, when asked about the reasons for using technology in the class, that it was *"to keep up with times, to attract students' attention, to explain the concepts which are hard to explain to them".* Technology such as the iPad and apps support educators when they teach content through attracting students' attention. It is possible, for example, for teachers to connect their iPad t a smartboard for presentation purposes (students can do the same), thereby making the lesson clearer and enabling easier explanations of complicated mathematical equations, as well as being more time efficient.

6.2.2Assisting in Achieving the Lesson Objectives

There was a general consensus among the teachers interviewed that the iPad was effective in achieving the goals of the lesson and encouraged teachers and students to make greater efforts. T4 talked about how the iPad could support the delivery of knowledge and achieving lesson goals faster than other methods. Moreover, it promoted the students' understanding of the lesson objectives. T4 stated *"Yes, it is helpful to achieve the lesson goals because it* *delivers information quickly and supports student understanding".* Also, T1 discussed how the iPad supported teachers in delivering the objectives of the lesson clearly and easily to the students. For example, during a geometry or algebra lesson, he would use the iPad to explain and the images helped the students to understand better than with conventional hand-drawn methods. T1 stated that *"the iPad gives you the simple details clearly to help achieve the objectives of the lesson, unlike the traditional methods used in topics such as geometry or algebra. Using the iPad achieves most of the objectives of the lesson, unlike the conventional method".* Similarly, T2 strongly agreed that the iPad supported him in achieving the lesson goals and he gave an example about the real direction, and the horizontal and quadrilateral. He said that it was difficult to explain these topics for students via the traditional method. It took time to draw each object. However, using the iPad, he could explain three objectives in one picture instead of three separate images. T2 stated that *"Yes, it helps in achieving the objectives of the lesson, for example, if you want the student to express trends, you explain the first way: the real direction. The second is the horizontal one. And the third is the quadrilateral one. When he presents these three drawings through the iPad, it will be better than the book, because he can present it in one picture, unlike the paper book which needs three pictures".* The findings suggest that the iPad and apps supported the teachers in delivering different objectives in one image, displaying a single picture on the board by connecting the iPad to a smartboard or projector. Thus, they could compare objectives and make them clear to the students, unlike the traditional methods using a regular board.

In geometry lessons, the iPad could assist students make accurate geometry drawings, thus supporting them in understanding the goals of the lesson immediately. T3 mentioned that it was easy to make a graph on the iPad and the students understood the objective of the lesson directly, unlike the paper approach, in which it took time to draw a chart or graph. Teacher T3said that *"Yes, it helps to achieve the objectives of the lesson; for example, if I have a graphing lesson, the student will find it easy to understand when using iPad, unlike the traditional method which wastes time".* T4 also reported that *"using the iPad in drawing is useful and has a positive effect".* It is evident that sketching geometric shapes through conventional methods (such as with a ruler or protractor) is a time-consuming process for teachers and the outcome may be imperfect. Conversely, the iPad and apps support 3D drawing and perfect measurement; hence, the students can see accurately what the sketches would look like in real life. Thus, the iPad helps teachers achieve the lesson plan and can merge different goals at the same time, quickly and easily improving the students' understanding.

6.2.3 Lack of Technological Skills in Using the iPad and Apps

To integrate technology in the classroom, the teachers must be educated in how to use it, especially tablet devices such as the iPad, based on the teacher interviews. The iPad has numerous educational applications and every day new apps are uploaded in the Apple store. Thus, even if the teacher knows how to use the iPad, they still require technological skills for any new application so as to ensure beneficial use and have traction in learning and teaching. As noted by T2, "*teachers need training courses".* Also, T2 mentioned that *"There is no shame in establishing technology courses for teachers because every day there are new programs and applications. Thus, a teacher needs specialised training in the same programs because most teachers are familiar with using an iPad or mobile in their daily routine, but it requires training courses just on how to use applications".* Similarly, T1 talked about how teachers should receive general training on how to use iPads because some will have never used them before. He said *"They are trained in general on the iPad. Second, they are trained on the apps and how they develop to benefit them in the future".* Even though there are some apps that are easy to use, the teacher still needs training in how to use difficult apps. T3 said that "*there are some applications which teachers are unaware of how to use. So, training courses are helpful to understand these applications. Some applications are easy to use, and do not need training, but some are difficult to use and you need the training to take advantage of this application as required"*. For example, GeoGebra was one of the primary apps used in this quasi-experimental phase and T3 had experience of using it, but through independent actions. He attended a private education course to improve his technological skills, reporting *"I participated in the training session on how to use GeoGebra via online training courses, this was a personal effort".* This suggests that teachers need training courses in the usage of iPads and apps, especially those to be used in the classroom to offers benefits for students. Thus, the school management or the education sector in the district should organise training course for teachers on app utilisation, rather than expecting them to undertake personal training.

Furthermore, the teachers mentioned that if they have completed a course on how to use a new app, they could sometimes share and transfer their knowledge and experience with their students through a short introduction at the beginning of class. T3 said that "*I learned how to use this application to inform my students how to use and benefit from it"* and *"After I* *understood the application and could use it properly, I established a training course for my students".* Similarly, T1 talked about teaching the students to use a new app after being trained in its use, stating that *"they [teachers] will be trained and become a trainer at the same time".* Also, T4 taught his students how to use a new app, noting that he would need to *"…explain to students how to use it"*. The most important aspect of teacher training is ascertaining how best to teach students in the usage of the app to be used in class prior to explaining the lesson, as this avoids losing time during the lesson.

Most of the teachers had not studied how to use an iPad in teaching methods at university. However, they had completed a few classes on the use of technology in general, such as using a computer. The iPad is a new generation tool and most of the teachers were already teaching prior to its introduction. Thus, the teachers mentioned that most of them lacked the technical knowledge for using iPads and apps and would needed to develop their professional learning. T4 mentioned that *"Absolutely, teachers need training courses to know how to use the iPad and its applications because we did not study how to use them in the university as you know, we studied how we used a computer as a technological tool in class but not iPads. So, teachers need courses to refresh their knowledge in teaching using technology, especially on the iPad and applications".*

The teacher interviews highlighted that the teachers needed training courses to learn about iPad use in order to keep up with advanced technology. Typically, the teachers lacked technological experience and found it difficult to obtain the relevant knowledge independently. This suggests that the professional development department in the MoE should look at the materials addressing technology in the universities and include the new technologies in the training content, specifically adding use of tablet devices and apps to the curriculum. It is essential to prepare teachers to use different new technological devices, especially iPads and relevant apps, at all educational levels. To sum up, the teachers suggested that school administrations should arrange training courses for all teachers on how to use iPads in general and also each app that would be used in the classroom.

6.2.4 Selecting Appropriate Apps

According to the findings, the teacher is the one who typically chooses the appropriate app for the lesson and they must know how to use it prior to introducing it to the students. After the teacher chooses an app, he or she will train the students in its use, as mentioned in section 6.2.3. T4 stated that *"Of course, a teacher who has experience in the use of applications through training courses in how to use them will select the appropriate application".* The reason is that the teacher needs to focus on the optimal app to achieve the lesson objectives. T3 said that *"The teacher usually selects the applications for each lesson; he believes that this app will help a student to understand the lesson and to achieve the lesson goals".* However, some apps do not deliver knowledge to students correctly, simply, or effectively. T2 mentioned that *"some applications do not deliver information as required"*. Thus, the teacher should be careful of the choice of the app to ensure the full benefits of its use.

One of the key apps used in this research was GeoGebra, chosen by the teacher. GeoGebra is a specialist app for graphics, plot functions, and parametric and polar curves, and is the best in this area, as well as for solving equations. T2 said that *"The teacher often selects the appropriate applications for the lesson, he searches for the best application that is helpful, such as GeoGebra which is one of the best graphics applications".*

However, even if the teacher chooses the appropriate app to be used in the classroom, the students will not know how to use it without instruction from the teacher. T1, also discussing the GeoGebra app, said that he told his students to use an online video to independently familiarise themselves with how to use the app: *"GeoGebra, for example, I recommend it. Also, I advise them to watch YouTube channels such as the Khan channel, which is helpful for them".* Thus, the best person to choose the apps is the teacher and he or she should choose the appropriate app for students to be used in the lesson. In addition to GeoGebra, MathWay is appropriate for basic mathematics, pre-algebra, and algebra, and the Fraction Calculator app is appropriate for fraction problems. However, some of the mathematics apps are not fit for student use, being complicated and suitable only for specialists, such as Math Graphing app.

However, the app choice is not entirely dependent on the teacher as the teachers mentioned that students could also choose apps, presenting their choice to the teacher who would then decide whether to use it. As noted by T3, *"Also, a student can inform the teacher about a useful application he has used before, and the teacher decides if it's helpful to all students".* In the same vein, T4 said that *"the student can choose the application and show it to the teacher, and if approved, it can then be distributed to all students for use".* However, if students download apps without consulting the teacher, they could affect his studies and understanding. To sum up, the app choice is dependent on the lesson goals or objectives and the effectiveness of the app in helping students to meet these goals or objectives of the lesson. Thus, the teacher has the primary responsibility for the app choice in each lesson.

6.2.5 Assisting in Improving Students' Performance in Mathematics

Technology such as iPads and related apps assist teachers in improving their students' performance in mathematics, identifying the academic level of their students immediately, giving their students flexibility in their learning, assisting them in preparing their students for tests, and supporting their students in mathematical operations. They considered the iPad to be a means of changing students' performance in mathematics for the better.

6.2.5.1 Assisting teachers to identify the academic level of students immediately

A teacher conveyed that the iPad contributed to improving students' performance in terms of achieving mathematics tasks individually through the pre-test for each lesson. Also, due to the daily pre-tests, the teacher was aware of the strengths and weaknesses of each student. Thus, he liked to support his students' performance individually and collectively through the results of the pre-tests. T1 stated *"I get the results of the pre-test directly, I know the strengths and weaknesses of the students in this lesson, which helps me to influence the rapid achievements, unlike the past, the evaluation was just individual. With the iPad, education became collective, and we can clearly know their achievement levels".* Similarly, T3 said *"I can see all the scores of the students and their levels in this test".* For instance, the teacher compared the test results in the Marefah app for each lesson and found that students' knowledge improved, which positively affected the students' achievement. T1 talked about implementing the short test using the iPad and how it affected students' knowledge. T1 stated *"I have a lot of evidence to show the extent of the change in their educational achievement and the most important of it is the student's knowledge in short quizzes and comparisons with all the results of short exams in all periods. Thus, I found there is an increase in students' performance in mathematics".* This suggests that the quick tests at the beginning of each lesson not only encourage students to improve their performance. These quick tests undertaken through an app also allowed the teacher to check his students' mathematical skills, competence to solve math problems, and prepare them for the new mathematics lesson.

The iPad, and other tablet devices, have different mathematics apps that support the teacher in determining individual differences in the students' academic performance in the tests. Prior to beginning the lesson, it is an excellent opportunity for the teacher to quickly and efficiently establish the students' levels using the iPad. The apps allow the teacher to collect students' tests more quickly, gain information on the students' performance using auto-correction, and thus shape pedagogical decisions. However, this could be done by collecting the pre-test papers at the beginning of teaching in just the same way as using the iPad, but the teacher would lose lesson time to correct them to check the students' performance levels. Furthermore, leaving corrections until the end of class does not help the teacher to ascertain the student's individual levels of comprehension of the explanation.

6.2.5.2 Giving students flexibility in learning

Using iPads gives students flexibility to learn mathematics at any time and anywhere. The teachers asserted that traditional methods alone are inadequate to improve students' achievement, as opposed to the introduction of teaching through technology. For example, students can use apps which support their learning to improve their performance in specific mathematics skills and they can practise these skills using different apps at school or at home at any time, which basically enables them to learn everywhere, even in their free time. As mentioned before, the iPad offers various supportive educational apps to make learning easier and student can refer to them readily. T2 stated *"I think that the traditional way is not enough for a student to have the knowledge, unlike using technology in learning. First, the student is given most of the applications that will be used in the class in the form of files, and the student can go back to the applications anytime and anywhere. Unlike using paper, when a student had to sit at home and do the homework, but with the iPad a student can do the homework in any place and save time and effort".* This is in contrast to working from books; the student would have to carry around all the books needed for the day and spend time reviewing them and searching for information to understand the lesson objectives. With technology, all the students' books can be available on one device as eBooks, which are easy to search and time-saving. T4 noted that students prefer using iPads because they can have all their books in one device, allowing them to source information and prepare for test or lessons: "*it has all the books in one device".* The iPad gives students the opportunity to enhance their performance in mathematics to complete their tasks through different educational apps whenever they wish and wherever they are, which is better than the traditional learning method using paper and pencil, which requires students to work in a specific place and at a particular time. Student might have little time to do homework or not do it at all, negatively affects their achievement.

6.2.5.3 Assisting teachers in preparing students for tests

Besides the findings of students' interviews in the previous section, a teacher reported that the iPad devices and apps could assist them in preparing students for tests. T2 pointed out that the iPads could be used for particular assessments using certain apps besides being used for learning. Students could practise using apps and prepare for assessments such as the

GAT. Thus, they achieved the highest grades in the measurement test in SA and the school reached the highest school ranking in SA. As T2 said, *"It is certainly clear through the superiority of the school, it obtained the first level of the Kingdom in the measurement test (achievement), and this is evidence that the percentage of achievement of students has become higher than in other schools".* The main issue for secondary students is the GAT and they are worried about how to pass it with a high grade as it is a requirement for acceptance at a university in SA (cf. section 2.5.1). One of the benefits of using the iPad is that students can prepare for the tests using the Qiyas app, which has all previous examinations, the explanation of the solutions, and mock tests.

6.2.5.4 Potentially affecting students' skills in basic mathematical operations

Using iPads can improve the students' skills in basic mathematical operations. T4 talked about how the students' performance might be affected positively or negatively based on how they used the iPad. For example, a student might depend on the calculator app for multiplication activities, negatively affecting their knowledge: *"It may affect the student both positively and negatively, depending on the way that the student uses it. If a student does not memorise the multiplication tables, he will use the calculator app in the iPad, which is detrimental. The student must memorise the multiplication table and not depend on the iPad calculator".* Conversely, T4 that a positive way of calculating mathematical operations was to use an advanced calculator app that could support students through a set of functions, such as calculating functions and space: *"the developed calculator app is a perfect choice for functions and spaces".* Addition, subtraction, multiplication, and division are all mathematics skills and a student should know them from the beginner level. Thus, a student in secondary school should already have acquired these skills and the calculator app is to support him/her in doing simple mathematics quickly to answer the complex equations.

6.2.6 Assisting teachers in motivating students to learn mathematics

Using iPads can assist teachers to motivate their students to learn mathematics and support them in understanding the content easily with greater focus. According to T2, technology such as iPads are popular with students at school or at home. Technology motivates them to try to understand the lesson, especially when the lesson is linked with a game: *"the technology affects students either inside or outside school, the use of technology such as mobiles, iPads, or laptops has become the talk of the modern world these days. It motivates* *them when it links a game to a particular lesson in one of the applications to increase their focus with regard to understanding the knowledge and information".*

This theme has six sub-themes: improving student engagement, assisting in increasing interaction, facilitating collaboration and communication among students, developing creative skills and critical thinking skills, improving self-reliance, and assisting teachers by providing immediate feedback to students.

6.2.6.1 Improving student engagement

Teachers see that iPad use positively promotes students' participation and improves engagement with other classmates in the classroom as they do the activities using the apps. T1 pointed out that certain activities have specific deadlines for completion, which motivates students to be the first to finish. Also, some activities can be done outside class, so the student can use the iPad anywhere to complete the lesson activities through his/her student account: *"There are activities in the iPad applications with a deadline at a specific time using a username and password for each student"*. In contrast, taking notes by hand when the teacher is explaining could mean that students are too busy to engage with the teacher and others in the classroom. Thus, it is better for teachers to record and upload the lesson directly as a reference for students so that they can engage with the teacher and other classmates in the class. T1 highlighted that there is no need for students to take notes, because the lessons are uploaded directly onto their iPad devices at the end of each class. Thus, they could focus on the teacher's explanation, not taking notes: *"After the end of the explanation of each lesson, the student finds the lesson fully explained on the iPad, so there is no need to write during the lesson".* This suggests that when students take notes using paper and pencil, they may miss some points of the teacher's explanation. In contrast, when the teacher uses the iPad during the class and records the lesson, the students do not need to take notes because they know the lesson will be recorded and thus can pay full attention to the teachers' explanation. However, note-taking by hand can be a powerful tool for some students who prefer this mode to understand the concepts, but it is better to take notes using the iPad as it is a useful organisational tool; if they wish, they can use e-pens, which are similar to regular pens.

Furthermore, iPads are useful for active learning, encouraging students to be in charge of their own learning and get involved in the process. T2 mentioned that students' engagement with other classmates can be driven through active learning with the iPad: *"Yes, the iPad contributes to the participation of the students with each other through active learning".*

T3 talked about an extra point regarding class activities. There are additional activities with extra points in the Marefah app and students will do all they can to achieve extra points and improve their performance. This increases their focus and motivates them to practise. He said that *"In the Marefah system, we have some activities which help the student to participate and accomplish his task; a student who completed his task quickly will get more points than one who completed in later to encourage them to do so".* This suggests that the iPad encourages teachers to give students more mathematics activities during the lesson through the iPad and the different apps, which positively affects their engagement as they receive extra points from the additional work. Furthermore, I consider that the traditional method of doing activities on paper does not encourage teachers to assign additional activities for students, as it increases the time necessary for correcting their work. Teachers would have to take time to correct students' work in class which would negatively affect their willingness to provide extra activities. They need to check the outcomes of their students' understanding of their explanation to make decisions about pedagogical approaches. This can be done through iPads and the various educational apps as it is faster correcting these activities rather than correcting them manually.

6.2.6.2 Assisting in increasing interaction

Using iPads can assist the teacher in increasing student interaction in the classroom. The teachers mostly expressed a sense of satisfaction associated with iPad use regarding students' interaction. The students interacted with the iPads during the activities. According to T1, students like to do activities such as integrals through apps, which help them understand: *"There is no doubt that the student interacts with the iPad; it is essential for him. For example, a specific drawing or space or integrals in which the student participates and understands clearly".* Similarly, T2 mentioned that students interact during the activities and endeavour not to make any mistakes by using the app. They would present their work through the smartboard, which is connected to students' devices to enable them to discuss the activity with others: *"Certainly, the student reacts and engages using the iPad more than not using it. In the Marefah system, the student will do preliminary activities, and this is much better than the teacher posting a paper test. The student will be informed of his grades, and the solution will be assessed, and he will be careful to get the answers correct because he has to present it to his colleagues through the smartboard using the iPad".* This suggests that when students do mathematics activities using an app in class, they try to do their best to answer correctly. Students become more interactive undertaking these activities as they need to display their answer by connecting their iPad to the smartboard or projector and subsequently share answers with their classmates. In contrast, doing mathematics activities on paper makes it difficult to share their answers with all their classmates and they just hand it over to the teacher. Thus, students might not learn from their mistakes immediately when they use paper as they do when they share their work on a big screen, such as a projector or smartboard.

As mentioned in section 6.2.4, the iPad has various educational apps, each of which has different features. The choice of app is essential to increase students' interaction in the classroom. T4 referenced this, saying that *"students interact with the iPad, but it depends on the teacher and his choice of applications".* It is important that teachers become familiar with the apps and their various functions so that they can effectively choose the most appropriate app for each specific lesson, as this will increase students' interaction, thereby enabling them to learn better and understand the lesson objectives.

6.2.6.3 Facilitating collaboration and communication among students

Collaboration and communication among learners can occur inside or outside the classroom through a formal platform or informal platform, such as social media apps. This can be accomplished through various technological tools, such as the iPad. All the teachers conveyed their opinion that the iPad supported students in collaborating and communicating with their classmates to a greater extent than previous methods. The experimental phase provided an excellent opportunity for students to cooperate with others and share knowledge when they used the iPads and different educational apps in collaborative learning.

Collaborative education supports students in sharing their experiences with others, solving equations or activities, and comparing the solutions. When T3 switched the class to a collaborative learning mode using iPads, he stated *"This collaborative participation is very useful; it helps them to share their ideas and know the correct answer".* In addition, T1 commented on the exchange of knowledge between students engaging in collaborative learning through their devices, finding that they focused on individual activities within class activities then sharing and comparing their results with others: *"…the student can compare his achievements with others when he solves the questions and compares them with the answers of the other students. They exchange knowledge between them until they reach the correct solution".* Furthermore, sometimes when the students collaborated on a mathematics exercise in a particular file, they found that there would be a certain equation they could not solve. Thus, they asked the teacher to explain how to find the answer. Subsequently, the teacher displayed it on the smartboard via his iPad to discuss and explain it, which was a beneficial activity for all students. T2 stated *"When the teacher asks students to open a specific file for activities, he discusses the file with them in case they have difficulty in solving these exercises. Thus, a student attempts the file, then the teacher opens it and presents it on the smartboard and explains it to the students".*

Collaborative participation among students through the iPad and apps supports them in sharing their knowledge, recognising their mistakes, and getting feedback from classmates. The findings show that there are excellent opportunities to integrate iPad use as a means of fostering collaborative *participation* as it is significantly more straightforward to share worksheets through different apps such as AirDrop than traditional methods using paper and pencil. T3 mentioned that "*a student solves a problem through the iPad's app and shows the solution for his colleague, so the collaborative participation between them begins by clarifying and correcting the solution and clarifying the steps of the solution correctly through cooperative learning".* Moreover, each collaborative group can display their answers on the smartboard or projector to discuss them with the teacher, thus increasing the competition between them. T1 said that *"there is an apparent communication because they share the same tests or homework and compete with each other for these lessons"*.

Nowadays, students are responsible for their own learning. If students miss something in class or are absent, they can connect with their colleagues or teacher through social media apps or the Marefah system to get the required information. If students find it challenging to understand their colleagues' explanations, they can subsequently ask the teacher for help. As T2 put it, *"Some students, if they missed a day or two, will communicate with the teacher and with their colleagues to look for lessons and information using the files described through the Marefah system".* Moreover, T2 talked about participatory online classes on the Marefah platform, which allow students and teachers to connect and participate to share their experiences outside social networking: *"The social networking programs are used outside the school, and we have a system in Marefah (participatory class). Through this, the teacher asks the student to participate, even from his home".*

As mentioned in section 6.1.1 concerning the benefits of the Marefah system, it is suggested that the MoE in SA should use a Blackboard-type system such as Marefah to activate participatory online classes outside school time to increase students' knowledge. The MoE could implement the Marefah system throughout the education sector as it is currently exclusively used for schools in the Royal Commission for the Jubail General Education

Department in SA. Although Future Gate was generated by the MoE, it is not actively used in most government schools in SA.

Furthermore, students could use informal platforms to communicate with their classmates regarding their studies, especially outside school. The students themselves created groups on social media apps, with WhatsApp being the preferred channel of communication for discussions about educational issues. Even if their discussions did not lead to an answer, they provided them with a clear pathway for querying a problem with their teacher in class. T4 stated that *"Students participate in an application such as WhatsApp as a group. They communicate with each other to discuss any questions. They gather new ideas, and it might be further questions, and perhaps they might not have the answer, but the issue becomes more apparent".* Social media is an effective means of communication among students or between students and the teacher to discuss tasks and activities. T1 said that *"there is a network between them; they communicate only by iPad through social media apps or Marefah system".* Thus, creating a group on an app such as the Marefah system in this school or on a social media app will allow students to connect with each other outside school to discuss their learning and support each other more informally.

6.2.6.4 Developing creative and critical thinking skills

Using iPads and apps can assist teachers in developing their learners' critical thinking and creativity skills. The teachers mostly expressed a sense of satisfaction associated with the iPad regarding students' critical thinking skills. For example, using the iPad helped improve their thinking skills by making the connection between reality and mathematics, which is essential to develop students' cognitive understanding in most areas of mathematics, rather than just focusing on procedural knowledge. T1 stated *"the iPad develops students' thinking skills because it connects the lessons to a live example of a picture through the iPad to clarify the lesson".* In another example, the same teacher mentioned that when students were drawing a square on a piece of paper, they could not imagine it in reality, but they could search via the iPad device for a picture or shape of a square in reality and then imagine the space in reality. T1 said *"In the past, I asked the student to create a square space on paper, but now, using the iPad, a student can begin to link reality with lessons".* This suggests that the iPad and apps help to connect students with reality, which helps clarify the lesson concepts and objectives, as well as potentially helping them to apply their learning in the classroom to reality, which would be challenging without using the device.

In terms of students' creativity, using the iPad and apps assisted students in sharing their knowledge and putting their information together to come up with solutions. T3 discussed students' search for new knowledge or ideas and the sharing of acquired knowledge with other students. This was found to foster greater creativity in the students, which improved their thinking skills. T3 said *"Through the iPad, the student can search for any information and share it with his colleagues as well as with teachers. Technology has helped to develop their thinking as well as creativity in terms of sharing the information".* Similarly, T4 mentioned that students could search for information related to the objective of the lesson, which increased their questioning about related information and positively increased their thinking skills: *"…it will increase students' questions and their thinking".* Technology such as the iPad allows students to think about a new idea, the teacher can allow them to search for more details on the internet, and they can subsequently share and discuss what they have learned with others.

6.2.6.5 Assisting in improving self-reliance

The iPad and its apps assist teachers in raising their students' self-reliance. The majority of teachers in the interviews said that the iPad contributed to increasing self-reliance in learning mathematics and other subjects. T1 mentioned that students became self-reliant and could use their prior knowledge to solve, reflect, and plan a new strategy for learning, especially with regard to their studying abilities for the GAT, being able to identify their weaknesses when preparing for the test, as mentioned in section 6.2.5.3. Also, in school, the administration organised a course on how to use iPads to achieve success in the GAT and Achievement Test for those unfamiliar with them (for more details about these tests, see section 2.5.1). T1 stated that *"the iPad has become the student library. I do not only speak about mathematics, but I also talk about the tests of a student's abilities and achievements. He can rely on himself using an iPad. For example, when a student is being tested in the abilities test, he can search for all the previous questions, exams and activities using the iPad. In our school, we were organising training courses, whether in the classroom or externally".* Using iPads and apps supports students in becoming more dependent in their own learning. T2 stated *"the students become more dependent on themselves in their studies."* In particular, iPad use encourages them to prepare for the Achievement Test, which is a requirement for all Saudi students to complete their education. Due to this school being classified as smart, as mentioned previously in Chapter 2, it has achieved top ranking among Saudi secondary schools for both the GAT and the Achievement Test (for more details about these tests, see section 2.5.1).

Therefore, using iPads and the different apps supports students in taking responsibility for their learning. For example, when they face a mathematics problem that is difficult to solve, they can ask their teacher or classmates to guide them through a communication app, as mentioned above (see section 6.2.6.3). As T2 said, *"if they face a problem, they can ask their teacher or colleagues".* Also, they can search for more explanations of the issue. This will help students who were absent or did not understand the objective of the lesson in class time. T4 mentioned that *"a student is responsible for teaching himself; …if he does not have information, he will use the iPad to search".* For example, students can search in YouTube for an explanation of any mathematics problem using their devices; using the YouTube app is straightforward and it is possible to find clips of good explanations of mathematics content. T3 noted *"Students became more self-reliant by using the iPad, especially social media apps such as YouTube. The student can use it to search for information".* Therefore, the students became self-reliant in their learning through using YouTube apps. As a researcher, I argue that students can use desktops or other devices to watch video clips on YouTube as this app is not exclusive to iPads. However, iPads and other tablets make learning easy because students can watch explanations of anything they require clarification on at any time, on a large screen, and in any place (for more details about the features of the iPad, see section 3.3.4). Moreover, I argue that teachers should control video clips by choosing those offering the best explanations for students and uploading them to an education platform such as the Marefah system. Also, the teacher should encourage students to use the Future Gate platform, which has explanation video clips for all Saudi curriculum content (for more details about the Future Gate platform, see section 2.10.3). One reason is that the content of some clips on YouTube may not suit students and YouTube itself also could distract students from learning, for example by playing advertisements.

Instead of watching video clips, some mathematics sites and apps provide definitions for all mathematics terms, along with explanations and examples, to make it easy for students to understand. As T3 stated, *"… [a student] can use mathematics sites to help him solve questions. It facilitates an understanding of mathematical terms and their definitions. There are also applications for mathematics that the student can use and rely on himself in these cases to understand the information or lesson".*

6.2.6.6 Assisting teachers by providing immediate feedback to students

Feedback encourages and motivates students to review their answers and study more. Technological devices such as tablets and different apps assist teachers in providing immediate feedback for their students. T3 discussed how immediate feedback also motivated students to increase their performance, explaining that posting a test online in the Marefah app assisted students in getting immediate feedback. Moreover, it does not matter which device is used to access this system, but using an iPad or other tablet makes it easy for students to answer the test in the system using the touch screen. T3 said *“when I post a test on the Marefah system, a student can answer it and get his score immediately. The student gets feedback via technology in the electronic tests”.*

Based on test feedback, the teachers discovered that incorporating technology and using e-tests provided students with better opportunities to achieve higher grades than with paper tests. The immediate feedback provided through technology enables students to understand their mistakes and avoid them in the next test or in the resit. Sometimes, the teacher allowed students to resit the test after getting feedback through the Marefah system, which improved their knowledge and achievement. T3 stated *“There is a positive impact on the level of students and their grades. Because there are ways to help the student to understand, the technology has become an auxiliary factor and has become better than the traditional tests”.* He also reported that the electronic test in the Marefah system has a feature enabling students to do resits, encouraging them to do better in the second round of the test: “*In the electronic tests the student gets the results and clarifies the mistakes at the same time”.* When students take tests using paper and pencil, they have to hand the paper over to the teacher and wait for the result, which can sometimes take a week to return. Thus, they lack the advantage of immediate feedback, which can be powerful for learning and self-regulation. Conversely, submitting tests via the iPad apps, such as the Marefah system, means that students get immediate feedback and know whether their answers are correct or not. Thus, they will learn from their mistakes. If there is an option to resit the task after getting the feedback, students will be encouraged and motivated to do their best on the second attempt, which will have a positive effect on performance.

The teachers conveyed that their students also have the option to upload their homework online through the Marefah system and receive immediate feedback. T4 said *“A student has the Marefah system, and through it, he can upload his assignments”.* T1 also mentioned that students could upload homework through the internet using the iPad or another device: *“Definitely, the student can upload his homework via the internet”.* Sometimes teachers will set a deadline for the homework, so then they can provide feedback after all the students have submitted their assignments. Alternatively, the teacher uploads an ideal answer sheet on the Marefah system, so the students can check the answers on the iPad and compare their answers with the ideal solution. T1 stated *“Sometimes I post a specific link with a specific* *time, and the student can follow this link and upload his homework. It facilitates everything; the student can know if his answer is in the correct or wrong direction. There are ideal answers which are uploaded after the students solve the questions to enable them to know the correct answer".* Similarly, T2 talked about feedback and how it is essential for the students because they are automatically assessed after submission, and the teacher knows who did not submit their homework: *"[the] student gets feedback immediately through the Marefah system, and immediate assessment, and the teacher can also observe a student who has failed to upload his homework".* It is a good practice for the teacher to upload homework every day via an iPad app because he will receive students' homework once it has been autocorrected, at which point he simply reviews it and is informed about his students' level and progress. In addition, it is beneficial for students to review their homework immediately to avoid making similar mistakes in their next homework assignment.

6.2.7 Lack of Willingness to Use the iPad in Teaching Mathematics

Aside from teacher training issues, the teachers interviewed mentioned that most of the teachers and students in the school did not use an iPad for teaching mathematics for several reasons. First, too few students had iPads and could bring them to school. Moreover, schools are not equipped to integrate iPad use in class. The teachers mentioned that schools in SA need to be equipped with technology such as smartboards, iPads, and the internet to be able to undertake interventions using technology. The internet is the most important factor; there must be an excellent signal that covers all areas of the school (for more details, see section 6.2.8.1). T2 reported that *"The lack of use of iPads in learning in general is due to many tangible factors. An insufficient number of students have iPads, …, and the school itself is not equipped with technology".* Similarly, T3 stated *"I think it is because the teachers in the government schools have to use paper books, and also it may be that the classrooms are not equipped with a smartboard and internet connection. This would be a hindrance for the teachers' use of the iPad as educational technology within the classroom".* This suggests that school management and educators should provide schools with technology if they do not already and classrooms should be equipped with the internet. Also, preparing before the integration of technology would save considerable amounts of money and time. Moreover, where possible, it is beneficial to provide smartboards to connect to iPads, displaying the work of both teachers and students to enable them to share their answers and knowledge, thus ensuring the successful integration of iPad use. As T2 said, "*the teacher opens it [the problem/answer] and presents it on the smartboard and explains it to the students".*

Moreover, the interviewees were asked why teachers do not use iPads in secondary schools in SA. They said that teachers tend to prefer to use traditional methods to teach mathematics because they do not like to change their methods or try new teaching approaches. Some of them were afraid to integrate the iPad in the classroom because of their lack of knowledge of how to use it as previously mentioned in section 6.2.3. However, some teachers would like to use it, but found iPads to be too expensive for them and their students. T1 reported that *"Some teachers are afraid to use iPads, because they lack information and some skills in how to use them and benefit from them. Second, the iPad may be somewhat expensive for some teachers. Third, most teachers prefer to use the traditional method and fear changing their method of teaching".* Similarly, T4 stated that iPads are too expensive for students or teachers, are susceptible to being broken easily, and need regular software updates: *"Teachers do not want to use iPads in general, due to the lack of availability and the high price. It is difficult to keep them for a long time without been broken or having a technical issue".* However, there are cheap computer tablet devices that have similar features and apps and are affordable for everyone.

Furthermore, teachers are disinclined to use tablet devices because their students need education in how to use them and the apps, as also mentioned by the student focus groups (see section 6.1.2). The teachers considered that having to educate their students in using the iPad and apps in teaching and learning mathematics was one of the issues. According to T1, students also require training in the maintenance of the iPad in addition to how to use an app itself: "*Training students entails learning how to use these applications and educating them about maintaining their devices, as well as dealing with their ignorance about using programmes or applications. They need an awareness of how to use them"*. Relatedly, T3 said *"the student still needs training in how to use math apps such as GeoGebra, which is a professional application"*. Thus, the teacher needs to spend 5 to 10 minutes explaining a new app at the beginning of the lesson to ensure students' understanding. Students will then have some knowledge of how to use it and can benefit from it. T1 stated *"Regarding the lack of understanding of educational applications, everyone needs training courses before using these applications, whether they are a student or a teacher. Before the student uses any new app, I spend five minutes explaining it to them".* The teachers, in cooperation with school management, should provide training for students in how to use iPads and the applications to be used in class at the beginning of the semester. This can also be done any time a new application is introduced.

The lack of willingness to use iPads in teaching and learning mathematics was attributed to not all teachers and students having an iPad and therefore not being able to bring it to school as an educational tool. Furthermore, schools in SA are not equipped to integrate the iPad in the education sector. Therefore, school management should provide iPads for students and schools should have an internet connection. Indeed, the internet connection is considered one of the greatest barriers that teachers face, as explained in greater detail in the next section.

6.2.8 Barriers to the Use of iPads and Apps in Learning

As with any technology used in education, iPads have some limitations. These reduce the use of such devices and apps by teachers in the classroom environment. Such limitations include the fact that internet service is essential in some cases, the battery life can limit the use of these devices in the classroom, and the huge number of non-instructional applications can hinder the process of teaching. However, there are no obstacles without solutions, as presented below.

6.2.8.1 Disruption of internet service

All teachers said the main obstacle in terms of using iPads and apps was lack of an internet connection during the teaching and learning process in the school environment. Indeed, this was also the main challenge that students reported facing, as discussed in section 6.1.6.1. In this regard, T1 cited *“the problem of the internet disconnection”* and T4 stated *“There are some obstacles such as internet disconnection”*. The issue of lack of connectivity or poor signal strength negatively affected learning and teaching. It was difficult to download or upload files or search for new information without the internet, or with a slow connection due to the signal. The students were upset when the internet connection dropped out during a test. This entailed repeating the test and the second version could be more difficult than the first attempt. As T3 stated, *“the internet is a big problem for me and my students; sometimes I have to re-explain the lesson or students do the test again because the connection fails”.* T2 also noted that *“Students face many obstacles… when there is a bad connection”.* This shows that a lack of internet connection or weak signal means that the iPad is of little or no use, which can seriously hinder the teaching and learning process, as well as causing students to become demotivated when they have to redo tasks or retake tests.

However, the teachers mentioned some solutions regarding internet problems. The first was that the school administrative staff could contact the IT department to fix the connection. Another solution was that the teacher could ask the school administration to supply an alternative internet router to avoid this issue arising. T2 recounted *"If the internet connection is bad, the school administration solves this problem".* Similarly, T1 said *"… we asked the school administration to bring an alternative router or wireless device so that it is easy for the student to access the internet".* Also, asked about solutions, T4 said *"an alternative internet router".* This suggests that the education sector and school management should provide an excellent internet server, full maintained, during the academic year to cover all areas in the school in order to reap the benefits of technology such as iPads.

6.2.8.2 Battery problems

The teachers frequently referred to battery charging and facing challenges recharging the devices in the classroom. For instance, when asked about particular problems with using iPads, T1 said *"the problem of … the charger or the battery"* and T4 also said "*There are some obstacles such as …the battery".* They mentioned that students sometimes neglected to charge their devices at home and they would forget their chargers; thus, they would have insufficient battery power to last the school day. T2 said that *"Students face many obstacles such as forgetting the iPad charger".* However, the students found it problematic to recharge their iPads in class even when they brought their charger because there was no electric outlet near most of the students' seats. As noted by T2, *"There are no chargers or enough charging sockets in the classrooms".* However, teachers found solutions to this obstacle, namely to carry a power bank (a portable battery charger) or bring an extra charger. Students were able to use the power bank from their seats. Thus, T1 stated *"Regarding the charger, we provided them with a power bank"* and T4 reported making *"extra chargers available in class".* Similarly, T2 said *"We have an extra charger for students who forgot their charger to borrow".* This suggests that school management should provide electrical outlets, a power bank, and cables for chargers in different areas of the class to enable students to recharge their devices.

6.2.8.3 Forgetting the iPad device

Another main obstacle that teachers faced was students forgetting to bring their iPads to school. Indeed, according to T2, *"forgetting…the iPad itself"* was the most common obstacle encountered during the quasi-experimental phase. T4 also noted this issue: *"…sometimes a student forgets his iPad".* However, the teachers resolved this issue by bringing an extra iPad to class provided by the school administration for use in this instance. Also, students could borrow an iPad from a colleague who did not need it at the same time. As T2 said, *"We have an extra iPad that can be borrowed"* and T4 reported *"…a student who forgets his iPad, can* *borrow one from their teacher or colleagues",* as did T2: *"Any student can borrow an iPad from his colleagues".* T4 suggested that there should be an extra tablet device with every teacher in the classroom to cover forgotten devices: *"the teacher should have at least one extra iPad device in the classroom".* Thus, it is suggested that school management should provide some spare devices for students who have forgotten theirs.

6.2.8.4 Using non-instructional apps in the classroom

Teachers believed some students were distracted by using non-instructional apps when studying. For example, some students used game apps while the teacher was explaining the lesson. T3 said that *"There are obstacles which face students such as some students' use of non-instructional applications while the lesson is being explained. For example, games apps distract students and they do not listen to the teachers' explanation".* Moreover, some students chatted with others using one of social media apps. Thus, these non-instructional apps distracted students from listening to the teacher during the lesson. T3 said *"The communication between the student and his colleague during the lesson may distract each other by using social media such as Snapchat, which can distract students from following the explanation".*

T3 went on to highlight that these distractions can be averted by motivating the students with extra activities on an iPad app that gives them the opportunity to earn extra points: *"These obstacles are overcome. First, the students should be motivated by giving extra grades and encouraging them. The student is focused on the subject and not on anything else by giving them exercises and collecting points for their work".* This indicates that the teacher should endeavour to keep the students busy by continuously assigning extra work to be done via apps on the iPad. The teacher can also allow the students to search online for information associated with the lesson objective of the day and should discourage the use of non-instructional apps that distract them.

6.2.9 Summary

The results of the teacher interviews showed that, overall, using iPads and apps had a positive effect on both students and teachers. They were found to be useful tools for enhancing and facilitating the teaching and learning process in the classroom. The teachers considered that using the iPad facilitated more rapid accomplishment of the objectives of the lesson than other methods previously employed. This device and the apps also assisted them in improving their students' performance in mathematics and equipped them with immediate knowledge of their students' academic levels. Their students also had more flexibility in their learning time and were better supported in their test preparation. The iPads and apps helped teachers motivate their students to learn mathematics. The teachers reported that the use of the iPad and apps also contributed to improving students' levels of engagement and interaction. The findings demonstrate that the introduction of iPads facilitated collaboration and communication among students and developed their creativity, critical thinking skills, and self-reliance. The teachers also found that this device and apps allowed them to provide immediate feedback to their students.

While the teachers willingly embraced the introduction of iPads and a range of apps in their classes and recognised the opportunities offered to education, they nevertheless experienced several obstacles and limitations when employing iPads in their classrooms. These obstacles were mainly associated with technical issues, such as internet connectivity or battery life. The battery-life of an iPad is relatively short and thus chargers are necessary; when students forgot to bring their charger cable to school, they found it difficult to recharge their devices. Teachers also mentioned that the iPad has various non-instructional apps and they believed that their students were distracted due by using these applications during study time. In some cases, these obstacles were compounded by a student forgetting to bring the device to school, which hindered the educational process as the student had to borrow a device from a colleague.

6.3 Combining the Results from the three approaches (intervention, students focus group and teacher interview)

The findings of this study contain an amalgamation of the results obtained from the three approaches of the quantitative and qualitative data collected over the course of this study, the main results from collected data using quantitative instrument (chapter five: quantitative findings), where data was analysed descriptively based on SPSS software, and collected data using qualitative instruments (this chapter six: qualitative findings), where data were analysed according to the thematic analysis. In this section, these findings are addressed and synthesised, with a view to linking both the quantitative and qualitative data analysis.

The results of the quantitative data (pre-tests, first post-tests, and second post-tests) for class A and class B showed statistically significant differences in students' levels of achievement, with increases in mathematics performance for students using the iPads in learning mathematics against learning without using the iPad. More specifically, in month 1, the achievements in learning and receiving instruction in mathematics of the class A students (using the iPads and its apps) surpassed those of the class B students (using the book, pencil and paper, with no access to the iPads or its apps): M = 18.56 and M = 15.36, respectively. Interestingly, the results showed that after switching the treatment, the students in class B (M = 18.64), who used the iPad and apps in the second month of the quasi-experiment, outperformed the students in class A (M = 15.32), for whom the iPad-based intervention was switched for paper and pencil. Therefore, both classes (A and B) demonstrated better outcomes immediately after the intervention with the iPad and apps, while the effect was slightly less obvious once the intervention was removed. Moreover, qualitative data analysis of both students and teachers revealed that the iPad has a variety of applications that could be a beneficial tool to raise students' math grades, support their studies, and motivate them to increase their performances in mathematics. However, some students believed that the iPad screen affected their marks negatively because they felt that they could not solve any equation correctly, especially if it was a long equation or had complex mathematics symbols. They reported that their performance was worse after using the iPad and its applications because they were not trained in or familiar with using the various apps. In general, though, the comparative analysis of the quantitative statements indicates a positive agreement about the academic achievement of both classes which showed that the intervention integrating iPad usage in class had a significant positive impact on students, improving their learning and levels of achievement. The overall findings from the quantitative and qualitative data support the proposition that interventions using tablet devices and apps assist students in improving their mathematical achievement. Both teachers and students believed that the intervention was positive due to the numerous benefits offered; for instance, helping students to solve challenging mathematical equations, supporting their learning, and improving their mathematics skills.

The teachers reported that usage of the iPad and its apps is highly effective in increasing students' motivation to learn mathematics, in helping them to more easily understand the content, and in improving their focus. Concurring with this, students mentioned that the iPad and its apps motivate them to learn the mathematics lessons in a range of diverse situations, and how they can increase the task time for studying and be more encouraged to solve math problems. Both teachers and students perceived the iPad to be useful in their learning due to its role in supporting communication and collaboration with other students and their teachers via different apps, such as Telegram, WhatsApp, Snapchat, Adobe Connect, and the Marefah system. Furthermore, both teachers and students expressed that receiving immediate feedback via different apps encourages and motivates students, and this factor was one of the most significant in terms of impact on students' performance. Both teachers and students agree that the teacher typically chooses the appropriate app for the lesson, and they must know how to use it prior to introducing it to the students. This is a better approach than the students choosing because the teacher will know how to use the app and can transfer this useful knowledge to the students. However, as reported by the teachers and students, there are several challenges associated with the use of iPads and apps in education, limiting their use in teaching and learning. These main challenges confronting students and faculty members in the use of the iPad and its apps for educational purposes are summarised in the below table, along with some solutions to overcome these issues, see Table 6-2.

	Obstacles to using iPads in learning		Solutions
	Students	**Teachers**	
1	Interrupted or slow internet connection The biggest obstacle was the interruption of the internet or a weak internet connection, which both teachers and students highlighted as being detrimental to the process of teaching and learning.		**Students brought their own internet routers and shared their internet service with their classmates to avoid connectivity issues**, or they asked the schools' IT department to fix it.
2	Low battery level and difficulty recharging Students and teachers reported that some students forgot to recharge their device at home. This is a disruption to the learning process as iPad batteries generally do not last until the end of the school day, and recharging devices in the classroom can be problematic.		Students generally bring their chargers to school, and some borrow chargers from their friends to recharge their devices in the classroom
3	Apps freezing during use Students encountered technical problems with the iPad apps because some of these apps were suspended during the activities in class, which deleted all of their work.	-	Students proposed that a solution to this issue would be to temporarily use an alternative app or website
4	Fragile iPad screens breaking easily Some students broke their iPad screens in school, and these could not be fixed by the IT department.	-	It would be preferable for the school IT department to develop the capacity to fix broken screens, as this would be more efficient and cost-effective for both students and teachers.
5	-	Forgetting the iPad Teachers reported that students sometimes forget to bring their iPads to school, which negatively impacts the learning process.	The teachers interviewed in this study suggested that the issue of forgetting the iPad could be resolved by ensuring that extra devices were available for students who forgot theirs.

6	-	Using non-instructional apps in the classroom Teachers believed that using non-educational apps in the classroom had the potential to distract students.	The teachers suggested that to avoid students accessing non-instructional apps for games or chatting, it would be beneficial to give them extra work on an app or task them with searching for new information about the lesson.

Table 6-2. The main challenges confronting students and faculty members in the use of the iPad and its apps for educational purposes

Overall, the results indicated that there is high positive agreement toward engagement in using the iPad and its apps in learning and teaching mathematics. Teachers and students agreed with benefits of the use of this device and highlighted that students need support from the school management and teachers. The comparative results revealed that there are statistically significant differences in the students' levels of achievement, with increases in mathematics performance for students using the iPads in learning mathematics against those without using the iPad and its apps.

6.4 Conclusion

This chapter has outlined the results of a qualitative evaluation of the effectiveness of iPad use at a secondary school in SA from the perspectives of both teachers and students. The qualitative data were collected from students and teachers and the results of data analysis were discussed in two sections. The first concerning the focus group interviews with students and the second was related to the teacher interviews. Thematic analysis was used to analyse both the focus groups and semi-structured interview data (cf. section 4.12.1). The results of the focus group interviews were presented under five main themes and several sub-themes. The main themes were as follows: (i) promoting students' performance in mathematics; (ii) students' lack of knowledge regarding use of the iPad and apps; (iii) motivating students to learn mathematics; (iv) lack of desire to use the iPad; (v) obstacles to utilising iPads in learning.

The results of the teacher interviews were presented under eight themes and several sub-themes. The main themes were as follows: (i) facilitating the teaching and learning of mathematics using the iPad; (ii) assisting with achieving the lesson objectives; (iii) assisting with improving students' performance in mathematics; (iv) assisting with motivating students to learn mathematics; (v) selecting appropriate apps; (vi) teachers' lack of technological skills in using the iPad and apps; (vii) lack of willingness to use the iPad in teaching mathematics; (viii) barriers to using iPads and apps in learning.

In conclusion, it is evident that the qualitative data from both sources agreed in several respects related to the research issues, such as the iPad and the various apps being beneficial for both teachers and students in the teaching and learning of mathematics, although some obstacles limited their use. The discussion in Chapter 7 considers the data and provides a summary of the results in order to determine answers to the associated research questions. It presents the discussion of the findings from the qualitative and quantitative data, addressing all the research questions to evaluate the effectiveness of iPad use for learning and teaching mathematics in secondary schools in SA.

Chapter 7 Discussion

7.1 Introduction

This study endeavoured to assess the effectiveness of implementing the use of iPads and relevant apps for teaching and learning mathematics in a Saudi secondary school. The study adopted an embedded mixed methods research model, in which quantitative data were obtained from a pre-test and two post-tests with 50 10th grade students and qualitative data were acquired from interviews with 4 teachers and from focus group interviews with 8 groups of students. The primary quantitative approach followed a quasi-experimental design and the secondary qualitative approach was carried out during the quasi-experiment. Statistical analysis was conducted for the quantitative data collected from the students' tests and thematic analysis was undertaken to explore the interview data from both the teachers and students, helping to develop a deeper understanding of the extent and nature of the use of tablet devices and apps for educational purposes in SA.

This chapter presents a discussion of the study findings. It includes the results of the data analysis for each research question. These findings are also discussed in light of the literature reviewed in Chapter 3. The three main questions addressed in this study were as follows:

1. What are the effects of iPad use on students' mathematics achievement?
2. How does iPad use affect the motivation of students in learning mathematics?
3. What are teachers' perceptions of the effectiveness of iPad use in the teaching of mathematics concepts?

In this chapter, the findings are briefly presented in tables, followed by more detailed discussion with reference to the existing literature and the relevant logic model (section 7.2).

7.2 Research Findings

The following sections discuss the findings drawn from both the quantitative data (Chapter 5) and qualitative data (Chapter 6) in further detail with regard to the effectiveness of iPad use in promoting students' achievement (section 7.2.1), the effectiveness of iPad use in terms of promoting students' motivation (section 7.2.2), and the effectiveness of using iPads based on teachers' perceptions (section 7.2.3). The purpose is to evaluate the outcomes of the intervention integrating iPad use in two classes in tenth grade at Alrowad Secondary School in SA (cf. section 4.7.2.

7.2.1 Effectiveness of iPad Use in Enhancing Students' Achievement

The first research question sought to evaluate the effects of iPad use on students' achievement in mathematics in 10th grade mathematics classrooms. At the beginning of the quasi-experimental study, the students were assessed by means of a pre-test to determine the average performance level in mathematics in two comparable classes. Students in class A used the iPad and its apps as a learning tool in the first month, while class B continued to learn without using the iPad (using books, paper, and pencil). At the end of the first month, both classes were assessed with a post-test. After the first post-test, the treatment was switched, with class A returning to learning without using the iPad and apps, while students in class B used the iPad and apps as learning tools for the second month of the quasi-experimental period. At the end of the second month, a second post-test was given to both classes to assess mathematics performance. Having checked the data were normally distributed, t-tests were used to compare any differences in academic achievement between students who used the iPads and those who did not in the different periods and whether such differences were statistically significant.

This section discusses the effects of iPad use on students' achievement, summarising the results in three different tables to aid discussion, and compares the main findings with those in the literature. The tables are used to avoid repetition and to allow easy reference. The first compares the pre- and post-test means of class A (see Table 7-1), the second compares the means of class B (see Table 7-2), and the third compares the means of class A with those of class B (see Table 7-3).

Table 7-1. Comparison of means for class A.

Class A	Mean	Mean Difference	Sig. $p < 0.05$
Pre-test	13.12	-5.440	0.000 Significant difference
Post-test 1	18.56		
Pre-test	13.12	-2.200	0.036 Significant difference
Post-test 2	15.32		
Post-test 1	18.56	3.240	0.000 Significant difference
Post-test 2	15.32		

Table 7-2. Comparison of means for class B.

Class B	Mean	Mean Difference	Sig. $p<0.05$
Pre-test	13.18	-1.480	0.222 No significant difference
Post-test 1	15.36		
Pre-test	13.18	-4.760	0.000 Significant difference
Post-test 2	18.64		
Post-test 1	15.36	-3.280	0.005 Significant difference
Post-test 2	18.64		

Table 7-3. Comparison of means for class A and class B.

Class A & B	Mean	Mean Difference	Sig. p<0.05
Pre-test A	13.12	-0.760	0.389 Significant difference
Pre-test B	13.88		
Post-test 1 A	18.56	3.200	0.002 Significant difference
Post-test 1 B	15.36		
Post-test 2 A	15.32	-3.320	0.000 Significant difference
Post-test 2 B	18.64		

The first phase of the quantitative analysis involved comparing the means of class A's test results after using the iPad as a learning method in the first month with those produced after using the traditional learning methods (paper and pencil) in the second month. The results strongly suggest that using the iPads in the first month had an effect on the students' achievement, with a subsequent decrease in performance after removal of the iPads during the second month, as shown in Table 7-1.

The second phase of quantitative analysis compared the test means of class B, who used traditional learning methods (paper and pencil) in the first month and the iPad as a learning tool in the second month of the quasi-experimental period. The results show that students' achievement was not affected in the first month, which is unsurprising, as they were not using the iPads. However, iPad use during the second month made a positive difference to the students' mathematical performance, as shown in Table 7-2. This supports the idea that student achievement in class B was positively affected by the adoption of the iPad as a learning tool during the second month of the quasi-experimental period.

The third phase of the quantitative analysis compared the test means of class A and class B for the first month, when class A used the iPads and class B used traditional learning methods. The final tests occurred after the switch in the treatment, with class A using traditional learning methods and class B using the iPads. The purpose of comparing the two groups was to investigate whether students' achievement was affected by using the iPad as against traditional methods (paper and pencil) to learn mathematics. The results confirmed that there was no inherent difference in the mathematical levels of these groups prior to the quasi-experimental phase. One month later, when students took the first post-test, the results illustrated that better performance on the part of class A students who used the iPad than for class B students using the traditional methods. At the beginning of the second month, the treatments were switched, with class A using the traditional methods (book, paper, and pencil) and class B using the iPads. At the end of the quasi-experimental period, the results confirmed that iPad use made a positive difference in the level of the class B students' performance in the mathematics test and they scored better than the class A students (see Table 7-3).

The findings of the study support the proposition that using iPads and different apps aid students' achievement; thus, both classes showed better outcomes immediately after the intervention using the iPad and educational apps. Although the students in class A then performed worse than those in class B in the second post-test following removal of the iPads, the class A students still performed better than prior to having access to the iPads. This result is in line with other research studies showing that using technology offers opportunities to improve students' skills development rates and achievement (Kebritichi et al., 2010; Lamb & Johnson, 2012; Pannabecker, 2004; Tüzün et al., 2009). Other studies have focused on tablet integration in various parts of the world, based on several different classroom formats and used for various topics to enhance students' learning (Carr, 2012; Green & Hartley, 2010; Holcomb, 2009). Al-Fabian et al. (2016) found iPads to be more helpful than other educational technological tools, affecting the academic learning of students' and associated achievement more positively. In addition, they mentioned that most of the teachers involved in their study said that the iPad supported students by keeping them focused on their tasks. This finding is supported by the results of the current study, which suggest that using iPads increases students' performance compared with the use of traditional methods of learning. Similarly, the findings are in line with Clark and Luckin (2013), who found that teachers and parents generally agreed that iPad use had a beneficial impact on students' grades, as well as enhancing and improving their academic performance.

Furthermore, the findings showed that when students use iPads and specific apps, their achievement increased more than that of students who did not use the iPad. This result is in accordance with other research studies showing a significant difference between the treatment group and the control group in terms of post-test results and noting that using iPads positively affects students' achievement more than traditional teaching methods in Jordanian schools (Al-Mashaqbeh, 2016; Alsalkhi, 2013). Likewise, Riconscente (2013) also found an increase in students' achievement using iPads, although the students in that study were allowed to use only one app for 20 minutes over just 5 days. In this work, I allowed the teacher to select a range of appropriate apps from a list designed to support a wide range of students in increasing their mathematics performance over a long period of usage (see Appendix 3). Thus, the teacher had time to train students in how to use the apps and they became familiar with the ways in which these apps could have positive impact. The effect of iPad application on students' performance was thus shown to include improvements in fundamental mathematical skills, such as solving equations and similar foundational activities. Also, the benefit of using different apps is that it can enable students to find the easiest app for them to use personally, helping them develop an understanding of concepts under the teacher's control.

The results of this research are also in line with other research studies in SA that offer a positive view of the effects of iPad use on student achievement (e.g. Alzannan, 2015; LaBelle et al., 2016). Such studies reinforce the findings of this research in terms of the importance of integrating iPad use in learning more generally to increase students' performance. An example of such a study is that of Alzannan (2015), who found a positive effect on students' achievement in an Arabic language class in kindergarten. The findings are in line with other research in a Saudi school showing a statistically significant difference between the reading and cognitive skills of students who used iPads and those who used pencil and paper learning methods based on post-tests in one class of first graders separated into two groups (LaBelle et al., 2016). In this study, I measured the performance of students in a mathematics class rather than a language class, and selected students in 10th grade at secondary school to provide results with more statistical confidence.

However, some other studies did not find any difference in the performance of students whether they used the iPad or traditional methods to improve their learning (Carr, 2012; Stattel, 2015; Singer, 2015). This study's findings contrast with those of Stattel's (2015) research, which took place in elementary mathematics classrooms and reported no significant difference in students' achievement during the treatment week, when the students used iPads, and the non-treatment week, when they used traditional methods. It is entirely possible that there was lack of impact from using the iPad. Stattel's experiment involved just a single set of students in one class and the set of students using the iPads were given them only for one week at a time, using traditional methods the following week until the end of the semester. This could have been a more conclusive study if the author had used two different, equal groups and allowed the treatment group to use the iPads for a longer continuous period of time before switching the treatment between the groups, as in the current study. Having the opportunity to use the iPad for a month meant that the students had time to familiarise themselves with the iPad and applications.

Carr (2012) also reported no significant differences between fifth-grade students using iPads and those not using them in two elementary schools in Virginia. In that study, students' mathematics achievement was not affected at all, with that of those students using iPads being similar to that of students who used traditional methods. However, the researcher did not encourage students to use the iPad outside school time; they used the iPads only in the classroom (Carr, 2012). This study was done in one school and overseen by one teacher with two groups, which might have positively affected the reliability of the study. Moreover, the significant differences found may perhaps be because students in the treatment group were encouraged to use their iPads at home, including to keep in touch with their peers. Thus, they spent more time studying mathematics at home with iPad access, enhancing the development of their mathematical problem-solving skills, which in turn positively improved their mathematics achievement.

Furthermore, Singer (2015) also found no significant effect between two groups of students in terms of achievement on a pre-test and post-test; however, the researcher allowed the teacher and students in the treatment group to use only specific apps, which may again have affected the findings. In this study, I suggested a list of apps before the experimental period started (see Appendix 3), but the teacher retained the right to use any beneficial apps, even those not on the list; this included the Marefah app, which was not on the initial list, but was included by the teacher. The quantitative findings showed a definite increase in students' performance after the use of apps such as GeoGebra and the Marefah system, with such iPad apps found to be significantly better in terms of impact than traditional methods (paper and pencil).

The literature review suggests that almost no previous studies on the integration of iPads in the classroom have conducted comparisons by switching the treatment (iPad access) between groups. Most such studies have made comparisons between two groups with no treatment switching, with the exception of Stattel (2015), who compared the means within a single group in which the students had iPad access for one week followed by a week without, alternating until the end of the semester. In this study, a further comparison was made by switching the treatment between the two classes after a one-month period to check that any differences in performance were the result of iPad use rather than random group effects. This additional comparison confirmed that the students' academic achievement in mathematics increased when they used the iPad more than when they learned using paper and pencil methods. Moreover, class A's performance still slightly improved in the second month, when their iPad access was removed, based on studying the material.

As mentioned in section 3.2, there is an issue about the low level of students' achievement in mathematics, according to the results of TIMSS and other international assessment tests. The findings of this study suggest that using iPads and educational apps can support students' achievement in mathematics and this might be reflected positively in the future in the results of international assessments. Overall, the findings support the view that the intervention introducing tablets devices and apps had a positive effect on students' achievement. Based on the statistical analysis, it is reasonable to conclude that the aims of the evaluation programme were met.

7.2.2 Effectiveness of iPad Use in Enhancing Students’ Motivation

The second research question sought to evaluate the effects of iPad use in terms of promoting students’ motivation in learning mathematics in a 10th grade mathematics classroom, as perceived by the students. To develop these findings, 8 focus-group interviews were conducted with a total of 48 students, each group containing 6 students. The students from class A formed the first four focus groups and the students from class B the second four. Interviews were conducted in both the first month and second months of the experiment, after the treatment was switched, in order to determine the effect of using the iPad and apps before and after the treatment for both groups. Subsequently, the student focus group interviews were thematically analysed to gain a comprehensive understanding and identify essential themes relating to use of the iPad and apps.

Qualitative data were collected in this study to evaluate 10th grade students’ motivation regarding learning mathematics. Motivating students to learn mathematics through the use of the iPad and apps featured prominently in both the students’ focus group interviews and the teachers' interviews (for more discussion of the teachers' perceptions regarding students' motivation, see section 7.2.3). The existing literature widely supports the assertion that tablet devices increase students’ levels of motivation through the learning process. Murphy (2016) argued that technology positively affects students and raises their motivation levels when learning mathematics. Similarly, Singer’s (2015) study found that when students use iPads and apps, they become more motivated, feel more supported, and have better concentration than when using paper and pencil in the learning process. Kyanka-Maggart (2013) contends that increasing students' motivation via the use of technological devices depends largely on their knowledge of technology, which is reflected in their effort to learn mathematics in lessons. However, in this study, some students reported that they had no desire to use the iPad as a learning tool and that it did not increase their motivation to study. This finding is consistent with previous findings in the literature, which reveal that no difference in students' motivation whether they use iPads or pencil and paper in the learning process. For instance, Karsenti and Fievez (2013) argued that there is no clear evidence to confirm or deny that technological devices such as iPads could foster students' motivation to learn (for more details on these discussions, see below).

The second aim of this study was to identify whether and to what extent the use of iPads might affect students’ motivation levels in 10th grade secondary classrooms in SA. Despite there being a consensus among the students related to this aim, their reasons for being motivated to learn mathematics using iPads and related apps differed. The findings are discussed in relation to key themes.

7.2.2.1 Promoting students’ performance in mathematics

A prevailing theme that emerged from the students' focus group interviews in this study was the positive role of iPad use in facilitating learning and promoting students’ performance in mathematics. The interviews revealed that using the iPad and apps enhanced students' learning in several ways: (i) it assisted in improving students’ mathematics skills; (ii) it helped students prepare for tests and supported studying; (iii) it provided immediate feedback for students; (iv) it helped students to search for information and understand the content. Each of these is addressed in turn in the following paragraphs.

First, the students reported that using the iPads motivated them to enhance their performance and increase their mathematics skills. The teachers also stated that their students’ performance improved due to using the iPad and apps (cf. section 7.2.3). The students mentioned that the iPad offered a variety of applications which could be beneficial for raising their grades and supporting their learning. In particular, the apps helped them with graphs, solving challenging mathematics questions, and allowing them to review the answers prior to submitting them to the teacher. This result is in line with other research studies showing that iPad use enhances students’ academic performance, positively affecting their overall performance level by increasing their independent study time in mathematics, written language, and reading (Clark & Luckin, 2013; Flower, 2014). Riconscente (2013) found that students' performance on a fraction test rose 15% after practising with the Motion Math app. However, this result is not in line with the study by Raut and Patil (2016), which found that during study time, students were potentially accessing their social media accounts (such as Facebook and Twitter), which was detrimental to their overall performance.

The overall findings support the proposition that interventions using tablet devices and apps assist students in improving their mathematical skills which could aid the MNSCD Project in achieving its purpose, which is to improve students’ skills (for more details, see section 2.9) through integrating tablet devices and their apps. Based on the findings of the students' focus group, it is reasonable to conclude that the outcome of the evaluation programme was met.

The students reported using the iPad apps, specifically the Marefah system, to aid them with studying and test preparation and review (for more details about the Marefah system, see section 6.1.1). For instance, students can take practice tests and access all test elements for each lesson. Group B1 stated that *"The teacher provides us with exercises for every lesson and pre-tests and post-tests. These tests confirm information that is corrected directly".* The students also felt that the iPad apps played a role in facilitating planning, studying, and practising for the GAT (for more details about this assessment, see section 2.5.1). According to the National Centre for Assessment (2018), the test training and preparation programme for the GAT was established online by Education and Training Evaluation Commission (ETEC) to provide free assistance to students.

Students expressed that receiving immediate feedback encouraged and motivated them and this factor was one of the most significant in terms of impact on students' performance. Students reported that when they submitted their homework or completed a test via an app (for instance, the Marefah app), their teachers were able to provide feedback on their work, which they found beneficial for improving their performance. In addition, both teachers and students reported that immediate feedback allowed the students to see whether their answers were correct or incorrect, and in the case of incorrect solutions, an explanation was provided through comparison with the correct answer or automatic correction. Thus, the students expressed a preference for completing their homework and solving problems on the iPad because it allowed them to receive feedback immediately. Similarly, the students were encouraged to complete more mathematics exercises due to receiving instant feedback on the various iPad apps (Kyanka-Maggart, 2013). The immediate feedback increased the students' engagement and built their confidence as when they made mistakes, the apps allowed them to attempt the tasks again (Attard & Curry, 2012). Based on the immediate feedback provided and the possibility of checking answers against the solutions, iPad use can increase the probability of students producing correct answers the next time (Haydon et al., 2012). In this way, students can consolidate their own knowledge, without having to wait for the teacher to tell them the correct answers (Singer, 2015).

In contrast, using the conventional paper and pencil method, students had to wait to get feedback on homework or a test. The students would hand worksheets in to their teachers and it could take up to a week to have them returned. Group A4 said using an app, "*We will know our mistakes instead of waiting for a day or two to for it to be corrected by the teacher, unlike the previous method where the correction of the test took a week or two weeks".* However, teachers could prepare instant feedback using cards or paper presenting appropriate answers as well as using peer and self-assessment, which could make the application of conventional methods in the classroom less time-consuming. Furthermore, peer- and self-assessment can permit students to assess each other and themselves. Depending on the approach adopted by the teacher, the traditional method may give students the opportunity to redo a task or retake a test. Hence, they can learn from their mistakes, but not immediately, rather after the time needed by the teachers to review and correct their work; doing the homework or taking a test on the iPad is different, as teachers sometimes provide another chance to resubmit the homework or the test after immediate feedback. Thus, it could positively affect students' performance and make them more motivated to achieve a better result than in their initial attempt. The students in group A1 noticed that *"The system sometimes is opened by the teacher to resubmit the homework, which encourages us to resolve the homework correctly to obtain a better grade and avoid previous mistakes".*

The results of the student focus groups also indicated that as the apps enabled students to search for new information, their understanding of mathematics increased and their overall learning improved, which was reflected positively in their performance. The findings of this current study are consistent with those of Buck et al. (2013), who suggested that the integration of mobile devices supports the education system by allowing students to search for new information and knowledge. The students viewed YouTube as one of the most important apps that could enable them to increase their information and knowledge by watching video clips in which experts explained the lessons. Students can access YouTube via any technological device, but using tablet devices has the benefit of a larger screen, which permits them to watch video clips in higher quality (for more details about the features of tablet devices, see section 3.3.4). However, Verhoeven et al. (2014) found that the entertainment offered by YouTube could distract students from their learning. The findings of the students' focus groups suggested that the teacher could upload useful video clips in the Marefah system for those students who found it difficult to understand the lesson. The likelihood is that the use of this educational platform would reduce concerns about the use of YouTube for non-educational purposes.

The ability to access educational apps and search for a solution was noted as a useful contributory factor for enhancing students' understanding of the content. Students reported that tablet apps allowed them to find the solutions and understand content by having the answer explained step by step (MathPapa, Photomath), using a specialist mathematics calculator (GeoGebra), or providing a source of mathematics e-book solutions (Holol). The convenience of tablet apps is well reported in the literature. For example, Arbain and Shukor (2015) established that GeoGebra can be used to enhance students' learning. Similarly, Riconscente (2013) found that Motion Math assisted students in understanding fractions and ratios. In another example, Swicegood (2015) argued that students who use puzzle-solving apps to learn, such as Splash Maths, were more likely to succeed in their learning than students who use conventional paper and pencil to solve mathematics problems.

7.2.2.2 Students lack knowledge regarding the use of iPads and apps

While a majority of the students believed that the iPad and apps helped to improve their mathematics performance, others were sceptical about the benefits of these devices. Some students in the study mentioned that they were struggling in mathematics and that they found it difficult to understand mathematic concepts. They reported that their performance was worse after using the iPad because they were not trained in or familiar with using the various apps. From their perspective, using the iPad more than conventional methods for learning, study, or homework tasks actually demotivated them. They did not believe there were any significant benefits to using the iPad over traditional books to study mathematics and found it challenging to do so (for more discussion about the challenges, see section 7.2.2.5). In addition, they preferred the traditional handwritten approach over iPad use as they considered using iPads in school and at home to be a waste of time. However, this study suggests that it would be possible to reduce the gap between these students and their peers by providing training on how to use the iPad and apps. This training would help students to address the issue of lack of technical knowledge and allow them to focus on improving their performance in mathematics. The findings of this study therefore agree with the view that some students struggle with technology use and require an intensive course to familiarise themselves with it (Mudaly & Fletcher, 2019).

7.2.2.3 iPad use can encourage students to study and organise their time

Another theme that emerged from the discussions in the students' focus group interviews in this study was that iPad use could encourage them to study and better organise their learning time based on certain apps. They believed that this developed their ability to summarise the lesson, filing clearly organised information on their devices, which consequently facilitated an enhanced learning process. For instance, they could summarise a lesson using the comments function and refer to their comments or files at a later date. In addition, the students stated that using the iPad allowed them to study at any time and in any place, which they found particularly advantageous for their homework tasks. This outcome is in line with the findings of Al-Mashaqbeh (2016), illustrating that mathematics apps support students to submit their homework online and make their learning easier. Furthermore, the students in Ali's (2015) study reported that iPads can be used any time and anywhere for the learning process, for example b watching educational video clips, browsing the internet, chatting with classmates, or sending emails to teachers.

Regarding doing homework online, some students in the study believed that submitting homework via the iPad was actually more beneficial for the teacher than the students. For instance, the tablet device assists the teacher to collect homework online easily and the homework is corrected directly after submission, rather than collecting papers from students and manually correcting students' homework (for more discussion of teachers' perceptions, see section 7.2.3). Fundamentally, using the iPad and apps benefitted students in several ways, such as enabling them to learn and study anywhere and at any time, making it easy to submit their homework, and providing instantaneous feedback on their work. It also makes it easy to study and review lessons with little effort.

7.2.2.4 Promoting students' communication and collaboration

One of the major themes in the study findings was that the use of the iPad and apps was reported to be beneficial for offering continuous communication and collaboration between students. Students expressed that they liked to collaborate during mathematics activities using the iPad apps, working together until they established the correct solution, which they then shared with other classmates, thereby acquiring a more in-depth understanding of the mathematical concepts. Students mentioned that they preferred the use of certain apps to communicate and collaborate among themselves, such as social media applications (Telegram, WhatsApp, Snapchat, Adobe Connect) or the Marefah app. These apps facilitated communication among themselves to discuss their assignments and mathematics problems, them to exchange their knowledge through discussion groups or individually with a classmate. This result was generally consistent with similar results reported in the literature, which have shown that using iPads and apps can encourage communication and collaboration among students and instructors in the classroom and outside school time (Dhir et al., 2013); therefore, communication apps promote relationships among students as well as with teachers (Karsenti & Fievez, 2013) and students develop their knowledge in a more creative way when they are connected with each other (Kyanka-Maggart, 2013). Through technology students can share ideas, debate, and search for and present outcomes within task limits (Falloon, 2013).

The overall trends and tendencies in the findings support the view that the intervention introducing the tablet device and apps promoted communication and collaboration among the students. Based on the findings of the students' focus groups, it is reasonable to conclude that the outcome of the evaluation programme was met.

7.2.2.5 Obstacles facing use of iPads in learning

The students highlighted several challenges associated with using iPads and apps for learning purposes, which negatively impact levels of achievement and motivation. These include the interrupted or slow internet connection, low battery levels and difficulties recharging, some apps handing during use, and the iPad screen breaking easily. However, they also provided solutions to these obstacles. Each is addressed in turn.

One of the major obstacles reported by students concerning the use of the iPad and apps in the learning process was related to interrupted or weak internet connection, which can be detrimental to the educational process. This obstacle was also reported by the teachers (for more discussion, see section 7.2.3.9). The students reported problems accessing apps (such as the Marefah system) when there was a weak or no internet connection. This caused difficulties in doing examinations or downloading and registering in a new app. They could not use an app requiring an internet connection in school. Previous studies have shown that technical problems such as lack of connectivity is a major challenge for an effective learning process that entails using tablet devices and apps (Alsufi, 2014; Dhir et al., 2013; Williamson-Leadley & Ingrams, 2013).

Students also disclosed that if the internet disconnected during a test and their teacher allowed them to resit it, they preferred not to do so as they feared achieving low marks in the second sitting. Group B4 said that *"if the internet is interrupted, we have to resit the test, and we were surprised that the test became harder the second time".* The students also reported that if their teacher delayed the test to another day, it required them to study and prepare for the test again. However, some students stated that lack of internet was a rare occurrence because the school administration always resolved the problem. Indeed, these students did not find the internet connection to be an issue because the school was rated a smart school in SA (for more details about the school, see sections 2.2.1 and 4.7.1). However, connection issues remain a problem for many other schools in SA, as they have inadequate infrastructure that would require significant development to bring them up to the same standard as the school in this study.

The students reported overcoming any issues with the internet disconnecting by asking the school administration to resolve the problem. Moreover, they brought their own internet routers and shared their internet service with their classmates to avoid connectivity issues or a weak signal. Tablet devices require an internet connection to operate optimally in the classroom as many apps can only be used online. A recommendation of this study is that the MoE should provide schools with strong internet services and rebuild school infrastructure where necessary by adding a Wi-Fi service that covers all classrooms.

Another issue that causes problems when using an iPad for learning is low battery levels accompanied by difficulties recharging. Students pointed out that the battery would not last a full school day if they had forgotten to recharge it at home (as discussed by teachers in section 7.2.3.9). The students believed that if the battery had been fully charged at home, it would be enough to last the entire school day. As reported by group A1, "*it will last for 7 hours without the need for a charger".* Previous studies have shown that iPads and tablets have up to 10 hours of battery life, which is sufficient to cover the school day without needing to recharge the devices at school (Stattel, 2015; Sinelnikov, 2012).

The students also reported that if they forgot to recharge their devices at home, they faced difficulty recharging their devices at school because sockets were not readily available in the classroom and were situated too far from their desks. Henderson and Yeow (2012) argue that recharging devices at school should not be an issue for students because this can easily be done by moving around the school or by collecting all students' devices and recharging them at the same time. This study contends that moving around the school to recharge devices can affect students' education in terms of lost time, so better solutions should be found.

The students' focus groups suggested some solutions for this issue, such as using power banks. This would mean that students would not need to move their seats to be close to sockets to recharge their iPads. Students generally bring their chargers to school and some borrow chargers from their friends to recharge their devices in the classroom. However, some have to move around the classroom to find the nearest available socket. This study suggests that school management could possibly provide electrical outlets throughout the classroom with charger cables, or a power bank for anyone still situated away from the electrical outlet. It would be useful if schools could have a supply of spare batteries and chargers on hand to cover such eventualities.

Another obstacle that negatively impacts the use of iPads in the learning process is technical difficulties with the apps, such as hanging during operation. This negatively affected students' work and they had to delete what they had done and restart the problematic app. Peel's (2019) study argued that the technical problem is the device freezing by itself.

The students proposed that a solution to this issue would be to temporarily use an alternative app or website. This study suggests the provision of appropriate training for students on how to use an app as the optimal way to avoid apps being overloaded and freezing. Moreover, the school management team and the teachers could collaborate to organise courses for any app that will be used in the classroom, encouraging them not to misuse apps and avert freezing issues.

Another obstacle described by the students was the iPad screen breaking and the school IT department being unable to repair it. An issue such as this necessitates a visit to a repair centre, which does not fix the problem immediately and therefore the student requires an alternative device in the interim period. According to Henderson and Yeow (2012), iPads are susceptible to various kinds of damage within the school environment. This study suggests that school management and teachers educate students on how to keep their devices safe by using screen protectors and that they encourage students to register for AppleCare protection to cover against issues such as product defects, technical issues, loss, damage, and theft. Moreover, it would be preferable for the school IT department to develop the capacity to fix broken screens, as this would more efficient and cost-effective for both students and teachers.

The overall trends and tendencies in the findings show that students minimise the possible obstacles to iPad use in the learning process by developing some solutions. In general, the findings support the view that the intervention introducing the tablet device and educational apps had a positive effect on students' motivation in the classroom. Based on the findings of the students' focus groups, it is reasonable to conclude that this outcome of the evaluation programme was met.

7.2.3 Teachers’ Perceptions of the Effectiveness of iPad Use in Teaching Mathematics Concepts

The third research question sought to evaluate the effects of using iPads and various apps in terms of the perceptions of teachers regarding the implications for the teaching of mathematics concepts. To develop these findings, four mathematics teachers gave in-depth insights into their own perceptions of the use of iPads and apps for educational purposes through interviews. These were subsequently analysed thematically to gain a comprehensive understanding by identifying key themes relating to teachers’ perspectives on iPad use.

Ninth major themes were identified as reflecting the perceptions of teachers on iPad use, namely: (i) facilitating the teaching and learning of mathematics, (ii) assisting in achieving the lesson objectives, (iii) lack of technological skills in using iPads and apps, (iv) selecting appropriate apps, (v) assisting in improving students' performance in mathematics, (vi) potentially effects on students' skills in basic mathematical operations, (vii) assisting teachers in motivating students to learn mathematics, (viii) lack of willingness to use iPads in teaching mathematics, and (ix) barriers to using iPads and apps in learning. These themes are discussed in turn.

7.2.3.1 Facilitating the teaching and learning of mathematics

One of the dominant themes revealed in the teachers' interviews was that the iPad and apps had positive effects in facilitating mathematics teaching and learning in the classroom. The teachers reported that they preferred to use such technology to support their teaching in the classroom and to keep pace with modern life, as this gave them and their students the opportunity to benefit from innovations and developments in education. They noted that using iPads and various applications facilitated the teaching of mathematics concepts and the delivery of lesson objectives, requiring less time and effort to ensure students understood the lesson (for more discussion on achieving lesson objectives, see next section 7.2.3.2). In addition, they like the appeal to their students' attention, primarily when they were teaching a challenging aspect of mathematics. These findings are in line with other research showing that the integration of iPads in the classroom provides an excellent opportunity for teachers to develop different teaching methods (Amin, 2010). Appropriate technological resources could be used to transform traditional classrooms into more progressive learning environments (Herro et al., 2013). The findings of this study are also consistent with those of Haydon et al. (2012), which suggested that use iPads benefitted both teachers and students in class. This study suggests that the integration of iPad and its diverse applications could make it easier for teachers to monitor their students' attention, which is of utmost importance during the teaching process. Moreover, it provides clarity for the lesson and gives straightforward explanations for complex mathematical equations; therefore, from the teachers' perspective, it is more time efficient.

7.2.3.2 Assisting in achieving the lesson objectives

The teachers reported that the iPad and apps were a motivating factor for them to achieve the lesson plan. The technology aided them in conveying complex lessons and also improved their lessons so that their teaching had a positive impact on students' learning. Using iPads can support teachers in merging different goals simultaneously so as to increase students' understanding; consequently, it supports the teacher in delivering knowledge and meeting lesson goals faster than when employing other methods. These findings align with the research of Starkey (2011), who found that teachers can deliver lessons effectively incorporated with the iPad, which influences students' learning more than conventional methods. However, Alharbi (2013) found that some teachers do not like to use technology in the teaching process in SA because they view it as a waste of their lecture time. They contend that the 45-minute duration of their class is insufficient to convey all of the necessary information to their students via a technological device such as an iPad (Alharbi, 2013).

A teacher interviewed in this study was of the opinion that it was difficult to explain three related topics – the real direction, the horizontal, and the quadrilateral – simultaneously without using the iPad, which could explain them in a single picture. Thus, the findings suggest that tablet devices and apps can support the teacher to deliver different objectives readily by connecting the tablet with a smartboard or projector.

The teacher interviews revealed that the adoption of the iPad and apps in the mathematics classroom could assist students by demonstrating accurate geometry drawings and supporting their immediate understanding of the goals of the geometry lesson. In contrast, using the conventional paper and pen method to draw a graph or chart is very time consuming. Thus, the iPad and apps helped the teacher to merge different goals concurrently, quickly, and easily, leading to improved understanding of the lesson objectives. In this regard, the findings of the study conflict with those of Alabdulaziz (2017), which reported that teachers preferred to use a traditional blackboard to explain mathematics activities rather than using technology. He mentioned that writing by hand on the board allowed teachers to explain the solutions step by step, which was more beneficial for their students (Alabdulaziz, 2017). This study holds the position that instead of depending heavily on technology, teachers should still draw certain geometric shapes by hand in order to provide students with step-by-step explanations. In addition, it is beneficial for students to learn how to draw geometric shapes by hand.

7.2.3.3 Lack of technological skills in using iPads and apps

The teachers who participated in the interviews were of the opinion that some teachers lack the technological skills to use iPads and apps. They need to improve and develop their technical skills, especially on how to use apps because new apps are uploaded every day, as well as requiring general training in how to use the tablet device itself, and how to teach using these devices. Some teachers expressed hesitation about using the iPad and apps in the classroom due to their lack of knowledge. This result is in line with other studies showing that teachers need professional development concerning how to use technology (Attard & Curry, 2012). Similarly, Schembri (2015) suggested that learning will not improve when using technology unless teachers have been appropriately trained in its use prior to implementing it in the teaching and learning process. Thus, the integration of these devices without previous training was a significant barrier to the majority of the teachers, which negatively affected both their teaching and their students' learning (Singer, 2015). Moreover, Sankar and Abdallah (2015) report that if the teacher is not trained in the use of technology before integrating it, educational progress may not be significant.

One of the interviewees maintained that GeoGebra is one of the key apps used in mathematics. Whilst this teacher had experience of the app, it was solely because he independently undertook an online training course to acquire skills in its use. Nevertheless, even when the teacher is trained on how to use an app (whether independently or through a private training course), it will still be challenging for first time users in the classroom. For instance, with apps such as GeoGebra, which is viewed as a beneficial mathematics by teachers, they will have to train the students in its use before they can employ it in class. Teachers reported that students require training in every new app that is intended for use in a lesson. T3 mentioned "*I participated in the training session on how to use GeoGebra, this was a personal effort. I learned how to use this application to inform my students how to use and benefit from it"*. The findings show that teachers spend a minimum of 5 to 10 minutes at the beginning of a lesson training students, explaining the functions and operation of a new app to ensure understanding and thereby enable them to optimise its use and reap the benefits. In this regard, the findings of the current study differ from those of some previous research. For example, Beauchamp et al. (2015) argue that spending time training students in this manner could affect lesson planning due to loss of time. Moreover, teachers in Peel's study (2019) reported that they spent time educating their students on how to use the iPad device at the start of the semester, which negatively affected their plans by creating new layers of distraction.

During this research, the teachers commented that they did not study how to use new technology such as iPads during their university studies in SA. Therefore, they require courses and short training sessions in the use of technology, particularly concerning apps to be used in the classroom. This paper suggests that school management or the education sector in the district should organise training courses for teachers on how to use tablet devices and different educational apps rather than the teachers having to learn independently. Moreover, once the teachers are trained, they can pass this knowledge on to their students prior to using the apps in lesson time, for example through activity classes, as this will avoid wasting time later. Furthermore, the study suggests that it would be beneficial for improving the teachers' technology knowledge if the MoE updated and amended university curricula to include such knowledge at all university levels. Indeed, teachers not only need technological skills to use the device in the classroom, but also other additional skills. According to Mishra and Koehler (2006), teachers need the skills to merge knowledge of technology, pedagogy, and content in order to successfully integrate in the teaching process.

7.2.3.4 Selecting appropriate apps

Tablet devices can operate a wide range of applications, some of which are suitable for educational purposes and others not. Thus, it is essential to establish which applications can be used in the classroom and who is in charge of making the selection. The teachers interviewed in this study reported that they were responsible for selecting appropriate apps for each particular lesson, as some apps would not deliver knowledge to students correctly, simply, or effectively, particularly if the students were unfamiliar with them. These results are consistent with those of Henderson and Yeow (2012), who determined that schools must oversee app selection as it could be challenging to establish the suitability of a particular app for the classroom given the massive availability of diverse apps from which to choose. In contrast, the findings of this current study conflict with those of research conducted by Khalid et al. (2015), who asserted that teachers were ill-equipped to select an appropriate app to fulfil the lessons' goals.

However, the findings of this study revealed that to ensure that the benefits of an app can be fully reaped, students' familiarity with the app must be taken into consideration prior to introducing it in class. For example, as previously mentioned GeoGebra is a leading specialist graphics app, but students cannot reap its benefits without receiving initial training. In addition, some apps can increase student attention whereas others do not. However, the choice of app is not always entirely dependent on the teacher. The teachers noted that students could present their app choices to them and the teachers would then decide which were most beneficial for students' comprehension and promoting study. Nevertheless, it might be better for the teacher to choose apps to avoid problems such as the mathematics app not being fit for student use in the classroom, perhaps because it is too complicated or more suitable for mathematics specialists. Also, each app has its properties for delivering information to a student by providing detailed explanation of the steps to the solution, such as Cymath, GeoGebra, MathPaPa, MathWay, and PhotoMath. Thus, teachers should consider the various apps and their suitability for learning purposes before choosing one for use in the classroom.

7.2.3.5 Assisting teachers in improving students' performance in mathematics

One of the dominant themes revealed in the teachers' interviews was tablet devices and different apps assisting teachers in improving their students' performance in mathematics. The teachers interviewed in this study agreed that the incorporation of the iPad and apps in learning had the benefit of giving their students the opportunity to develop their performance, innovation, and flexibility in education. The teachers considered that the iPad and apps worked to change their students' mathematics performance for the better. Four sub-themes were identified, each of which is addressed in the following paragraphs.

One of the key sub-themes that emerged from the teacher interviews was that the technology afforded them the opportunity to learn the academic level of their students immediately. They reported that the pre-test for each lesson delivered via an app, such as the Marefah system, helped them to establish concept comprehension and determine each students' strengths and weaknesses, as well as supporting students' performance both individually and collectively (for more details about the Marefah system, see section 6.1.1.2).

This study maintains that these pre-tests at the beginning of the lesson should not be included in the final semester grades; instead, they should simply be used to ascertain the strengths and weaknesses of each student related to each new lesson objective. Hence, the students will be more comfortable undertaking such tests, reducing performance anxiety and providing superior insights into their comprehension.

The teachers also perceived using the iPad and apps as enhancing the educational process by giving students the flexibility to learn mathematics at any time and anywhere (cf. section 7.2.2.3). The teachers believed that traditional methods (books, paper and pencil) did not improve students' performance to the same extent as incorporating tablet devices. They felt that the iPad played a role in facilitating students' learning by allowing them to practise different activities at an appropriate time through using various apps that improved their skills. Furthermore, these apps essentially make all books and materials available to students through e-books and the fact that they can easily search for knowledge and information is highly beneficial to their learning. The general perception shared by the teachers was that tablets were a useful and essential tool in the learning process and that they enhanced their students' performance in mathematics as they could be used any time and anywhere. Thus, they were superior to the traditional learning methods of using paper and pencil, which require students to sit in a specific place and work at a particular time, as well as carrying all books and materials with them.

Consistent with the findings of this research, a teacher in Peel's (2019) study stated that one of the benefits of using iPads is that a student can study anywhere quite easily. Jahnke and Kumar (2014) note that mobile devices furnish students with easy access to information any place, which can then be shared with others. Similarly, Takahashi (2011) states that the iPad allows students who have missed a lesson or need additional explanation to study at their convenience. Foote (2012) established that when students have a tablet device in their hands, learning anywhere and at any time becomes truly real for them.

Another subtheme that emerged from the teachers' interviews was the role of iPad and apps in assisting teachers with preparing students for tests. The teachers viewed the iPad and different apps as contributing to expediting preparation for the most important test (GAT) for students at secondary schools in SA (for more information about this test, see Saudi context, section 2.5.1). The teachers highlighted that students can use the Qiyas app to practise mock tests, review solution explanations, and explore previous exams. Thus, students in the school involved in this study (Alrowad Secondary School) achieved the highest grade in the measurement test in SA and the school attained the highest school level in SA. In this regard, the findings of the study do match those of Jaciw et al. (2012), who found that a tablet-based algebra program containing printed textbook content and a series of interactive tools had no impact on students' performance in the California Standards Test. However, consistent with the findings of this study, Riconscente (2013) established that students could practise for the fraction test using the Motion Math app, which helped them to improve their results by 15%.

7.2.3.6 Potentially effects on students' skills in basic mathematical operations

The use of the iPad and various apps was found to improve students' skill in basic mathematical operations. T4 generally believed that using an advanced calculator app could support students with a set of functions such as calculating functions space. One mobile graphing calculator app is GeoGebra (cf. section 6.2.4), which was a key app in this study (see section 4.7.1). This graphing calculator app, as suggested by the findings, supports students in understanding graphs and challenging problems more easily with real-life examples. The convenience of graphing calculator apps is well reported in the literature. For instance, Balantes and Tonga (2020) demonstrate that using graphing calculator apps such as Mathlab, Graphing Calc (GeoGebra), GraphCalc 2, and Desmos enhanced students' mathematical processing skills and their conceptual understanding. Moreover, these apps were found to potentially encourage their interest in mathematics. Similarly, Kramarenko et al. (2020) argue that GeoGebra prompts students to discover new mathematical facts.

However, T4 suggested that some students might always depend on the calculator app for basic mathematical operations, such as multiplication, negatively affecting their operational skills. This study contends that students should already have acquired basic operational skills in addition, subtraction, multiplication, and division prior to commencing secondary school. Thus, students can save time by using these calculator apps in doing simple mathematics quickly as a component of solving a complex equation.

7.2.3.7 Assisting teachers in motivating students to learn mathematics

One of the dominant themes revealed in the teachers' interviews was that using technology assisted teachers in motivating their students to learn mathematics and support their understanding of content. The teachers interviewed believed that incorporating iPads and apps in class had the benefit of motivating students in the learning process. As noted by the teachers, mobile devices have become a popular type of technology with students, both at school and at home, and these can be used as learning tools. Moreover, the teachers noted that the apps could potentially motivate students, particularly when the lesson could be linked to a game, thereby better enabling them to understand the concept. The teachers generally perceived that the iPad and apps improved students' participation during the lesson. They also believed that using the iPad and made interacting with students easier. The potential for collaboration and communication among the students was thought to be greater using different communication apps. Developments in the students' creative and critical thinking skills were also evident through the connections made between reality and mathematics skills, which is essential for developing students' understanding. The teacher interviews also revealed that the tablet devices and apps assisted them in promoting their students' self-reliance and allowed them to provide immediate feedback to their students.

The theme of improving students engagement featured prominently in the interviews with the teachers. They considered the iPad and apps played an important role in enhancing the teaching and learning process. The students focus on the mathematics activities and tasks involving the iPad and apps improved. The teachers also believed that the students could focus on their explanation with no need to take notes, because the lesson was uploaded directly onto their devices. Consequently, as they were able to focus without this distraction, students' levels of engagement increased, both with the teacher and among themselves. Furthermore, the teachers viewed the iPad as useful for active learning, leading students to take charge of their own learning and become more involved in the learning process. For instance, a teacher could provide supplementary activities with extra points for students during the lesson via an app, positively affecting engagement.

There is broad consensus across the existing literature that using such technology is largely beneficial for the teaching and learning process. According to Murphy (2016), technology plays a critical role in enhancing students' learning by enabling them to comprehend mathematics lessons fully, which in turn increases their engagement in the learning process. As found in this study, the teachers interviewed in Swicegood’s (2015) study reported that students’ levels of motivation and engagement could be enhanced by using apps which allowed them to spend more time on the tasks.

However, Atallah et al. (2015) found that iPads were not necessarily an appropriate means of increasing students' engagement and teachers should not use them in class without a clear pedagogical strategy established by experts in the educational field. This means that teachers should have a definitive plan to integrate tablet devices in the classroom based on explicit learning goals so as to achieve increased engagement. Similarly, Alkaabi et al. (2015) reported that using iPads could cause a distraction for students through their use of non-educational features, such as social media apps, in the classroom.

In this study, the teachers mentioned that they could engage their students with extra activities enabling them to earn additional points via an app. This result is in line with Riconscente's (2011) study, which determined that students could collect a larger number of points by using certain iPad apps. This study suggests that tablet devices and apps encourage teachers to give students more activities during the lesson, which positively affects their engagement as they receive extra points from the additional work. Furthermore, it is also suggested that the traditional methods of doing activities on paper do not encourage the teacher to do more activities as it increases the time required to correct students’ work (cf. section 6.1.3). Essentially, teachers’ time in class is expended on correcting students’ work, which hinders them from assigning extra activities. Furthermore, they need to know the extent of their students' understanding when they are providing explanations in order to make decisions about their pedagogical approaches. Using tablet devices such as the iPad and various educational apps facilitates much faster correction than the conventional method.

The overall trends and tendencies in the findings support the view that the intervention introducing the tablet devices and apps in the classroom fostered students' engagement. Based on the findings from the teachers’ interviews, it is reasonable to conclude that this outcome of the evaluation programme was met.

During the interviews, the teachers expressed a sense of satisfaction associated with using iPads and the various apps in relation to students' interactions with mathematics activities. The teachers believed that an advantage of using such technology in terms of enhancing the educational process was that the students could connect their devices to a projector or smartboard to present their solutions to their classmates. This increased interaction by enabling students to see and understand how the correct answers were reached. In contrast, this study suggests that if students do mathematics activities with paper and pencil, they are likely just to hand the worksheet over to the teacher without sharing their work with their peers. The teachers' comments demonstrated their general opinion that iPad apps are useful learning tools, particularly in increasing interactivity among students and helping them focus on completing the activities individually, especially challenging activities. One teacher specifically pointed out that choosing an appropriate app is key to raising students' interaction levels in the classroom.

In this regard, the findings of the study differ from those of some previous research. For example, Erkan (2019) found that integrating tablet devices in education negatively affected interaction among students, ultimately leading to the failure of the learning process. Lim et al. (2011) believed that using technology in an elementary school classroom created an individualist environment that reduced the levels of interaction among students. Albadry (2018) argued that some students engaged in language learning at a Saudi university believed that working together via apps was less beneficial due to slow internet disrupting their communication, which made them reluctant to interact with other classmates.

Nonetheless, the general perception among teachers in this study concerning the role of iPad apps was that they helped increase the interaction among students in the classroom. This is in line with Jahnke and Kumar (2014), who established that using iPads and apps offers opportunities to improve students' interactivity through sharing their knowledge. It is also supported by other studies showing that students become more interactive by doing the activities individually then sharing their knowledge with others via the iPad and they report they would like to use iPad in their future studies (Clark & Luckin, 2013; Jahnke & Kumar, 2014; Preciado-Babb, 2012; Riconscente, 2011). This study suggests that teachers should be familiar with the apps so that they can select appropriate ones for a specific lesson in order to increase interaction among students and thereby enable them to learn better and understand the lesson objectives.

A prevailing sub-theme that emerged from the discussions with the teachers in this study was the positive role of iPads and apps in promoting collaboration among students. In addition, they held positive perspectives on facilitating collaborative learning and communicating with classmates. The tablet devices and apps allowed the students to share their experiences with others to a greater degree than previous conventional methods. The teachers observed that iPad use supported students in sharing their knowledge, recognising their mistakes, and getting feedback from classmates. Thus, the teacher in this study reported that he adopted collaborative learning using the iPad and apps when students were doing mathematics activities and found them to be useful for students to share their knowledge via different kinds of apps such as AirDrop. Moreover, the teachers highlighted that in the event that a student was absent from or misunderstood the lesson, using technology afforded them the opportunity to connect with their teacher or fellow students using social media apps (for example, WhatsApp or the Marefah system) to acquire the information or clarity they needed.

These findings are consistent with previous research showing the positive role played by technology in enhancing communication and collaboration between students in educational settings. For example, Falloon (2013) reported enhanced collaboration between students who used iPads, as they allowed them to present their outcomes, debate, negotiate, and search within task limits. In another study, Preciado-Babb (2012) reported that iPads enhanced communication among students by facilitating and diversifying means of communication. In particular, the capability for creating a group on a social media app or Blackboard app provides students with an avenue for direct communication and informally discussing their learning.

The teachers’ perception was that the iPad and apps improved students' creative and critical thinking skills making connections between reality and mathematics. Moreover, teachers expressed satisfaction with the ability of students to reap greater benefits and become more contemplative from using the internet in the classroom regarding their questions about new objectives. Using iPads can make students' learning easier by allowing them to search on the internet within the classroom environment, rather than having to go to the computer laboratory in the school. Furthermore, the teachers expressed the opinion that when students’ search for information about a lesson, it leads to them asking additional questions, which builds their critical and creative thinking abilities.

These findings conform with those of Cubelic and Larwin (2014), which suggest that using technological devices such as the iPad could support students in enhancing their creative thinking skills. In a recent study, Bagdasarov and Wu (2017) demonstrated that the dimensions of students' critical thinking could be affected positively by using tablet devices to explain their thoughts, deliver their findings, and organise their data.

The overall trends and tendencies in the findings support the proposition that the intervention developed students' creative and critical thinking skills. Based on the findings from the teachers' interviews, it is reasonable to conclude that this outcome of the evaluation programme was met.

The teachers interviewed in this study generally believed that the iPad and apps contributed to increasing students' self-reliance in terms of learning mathematics or other subjects by seeing explanations of the lessons in video clips or reading additional information online. The teachers in this study also mentioned that students became more self-reliant when studying the materials through files uploaded by the teacher using the Marefah app. This was also true for students’ test preparation, particularly in terms of using testing apps such as the Qiyas app. A range of beneficial apps can support students in their bid to achieve success in test of ability and general achievement and they are especially useful for those who are unfamiliar with the tests. The teachers reported that using iPads has the potential to encourage students to become more independent and responsible for their own learning, in particular prompting students to use apps to make a study plan and download related files through different apps such as the Marefah system. This can help them to understand the objective of the lesson, thereby reinforcing their motivation and is particularly valuable for absent students.

These findings complement those of previous studies that have shown students become more self-reliant in their learning when they use iPads and apps for learning. According to Pilgrim et al. (2012), mobile devices are essential to support students in building their confidence to realise learning objectives and promote independent learning. Similarly, Al-Rafi et al. (2013) determined that when students use a range of apps, their self-reliance and level of involvement in mathematics class increases, thereby boosting their independent learning and engagement. This finding is similar to that of Clark and Luckin (2013), who reported that the iPads foster independent learning for students, which gives them a sense of autonomy and control over their learning. Likewise, Al-Mashaqbeh (2016) found that iPad apps can assist students in improving their skills independently through different educational videos, sounds, or pictures. This study asserts that the content of some clips on YouTube or other apps may not be suitable for students and YouTube itself also could distract students when advertisements are displayed during the clips. A suggestion is that teachers should encourage students to use educational platforms such as the Marefah system (cf. section 6.1.1.2), the Future Gate platform (see section 2.10.3), or iEN channels (see section 2.10.2), which offer explanatory video clips for the entire Saudi curriculum.

The overall trends and tendencies in the findings support the view that the intervention introducing tablet devices and apps in class helped the students to become more self-reliant.

Based on the findings from the teachers' interviews, it is reasonable to conclude that this outcome of the evaluation programme was met.

The teachers interviewed in this study agreed that the iPad and apps assisted them in providing immediate feedback to their students. They reported that posting a test online in the Marefah system gave instant results to their students that motivated them to increase their performance. Although the students could use any device to access the Marefah system to do the test, using tablet devices would be more convenient, making it possible to do so anywhere and at any time. The findings of the teachers' interviews revealed that using e-tests provided students with a better opportunity to achieve higher grades than with paper tests. Students received feedback immediately on submitting the test, thereby enabling them to understand their mistakes and avoid them in the future. The teachers also reported that using the tablets and apps helped them upload an ideal answer sheet for homework or to automatically assess submissions on the Marefah system, which allowed students to review their answers.

However, in contrast to this study some previous research did not find positive results in terms of feedback. For example, two teachers in Peel's (2019) study reported that written feedback via paper and pencil was better than electronic feedback provided through any technological device. They felt that written feedback was easier and faster than using technology, especially for low-level students, as it provided them with more explanation of the solutions (Peel, 2019). This study contends that providing written feedback is a lengthy process and it sometimes takes a week for students to receive feedback. In addition, for students with low grades, the teacher can offer extra feedback on their homework or tests through an app.

Consistent with the findings of this study, two teachers in Kyanka-Maggart's (2013) research reported that when students receive feedback through an app, they become more motivated, which prompts them to make extra effort in the mathematics exercises delivered through such apps. The two teachers also observed that providing written feedback on paper could take several days, which could reduce students' motivation (Kyanka-Maggart, 2013). Uploading homework or tests using a tablet app assists teachers to review and follow their students' performance and progress more easily and rapidly than other methods. Furthermore, it is beneficial for students to review their mistakes (cf. section 7.2.2).

7.2.3.8 Lack of willingness to use the iPad in teaching mathematics

Teachers noted that most of the teachers and students in the school had no desire to use iPads or apps in the learning process for several reasons. First, most government schools in SA are not equipped to integrate iPads or other technology due to issues such as lack of internet connectivity. Second, the teachers reported that most tablet devices are too expensive for them and their students; thus, they cannot bring them to school. Hence, they prefer to employ traditional methods to teach mathematics. Third, the teachers interviewed stated that both teachers and students lack knowledge of how to use iPads and apps in the learning process (as discussed in section 7.2.2.2).

Swicegood (2015) identified that teachers were hesitant to alter their teaching methods and found the integration of technology to be a particular waste of time due to the effort required to prepare devices at the beginning of class. Furthermore, with regard to the lack of knowledge, Iqbal and Bhatti (2020) suggested that a lack of technical knowledge and training is one of the most significant barriers in the adoption of mobile devices (as also discussed in section 7.2.2.2). Alghamdi (2015) found that public secondary schools in SA have a lack of technology and technical support. He recommends that schools should be equipped with classroom technologies such as a smartboard, a data projector, the internet, and a PC for the teacher. This study suggests that the MoE in SA should prepare for the integration of technology by equipping schools with appropriate means to use it, such as a reliable internet connection. It is also recommended that the MoE provide tablet devices for teachers and support them by offering educational courses on how to use such devices and associated apps. An area for further research is what these educational courses might entail.

7.2.3.9 Barriers facing the use of the iPad and apps in learning

The teachers identified several challenges associated with the use of iPads and apps in education, limiting their use in teaching and learning. These include technical challenges, such as lack of internet connectivity and issues with recharging batteries. These challenges also include forgetting the charger or the device itself and using non-instructional apps in the classroom. However, the teachers interviewed also provided solutions to these challenges.

One of the main obstacles reported by teachers concerning the use of iPads and apps in the learning process was related to lack of or a weak internet connection. This obstacle was also reported by students and could be detrimental to the educational process (cf. section 7.2.2.5). The teachers were actually dissuaded from employing technology in the classroom when there were issues with weak signal or lack of connectivity. They reported that when these issues arose, they were forced to explain the lesson to the students again, or arrange for resits of the tests. These findings are in line with other research showing that teachers faced the aforementioned technical problems, negatively affecting both the lesson and their students' motivation (Ali, 2015). Moreover, Parnell (2018) highlighted that when connection issues occur, it could result in data loss.

In addition, one of the disadvantages of using tablet devices is that most apps only work with an internet connection, as reported by the teachers and the previous literature. For example, Taylor (2014) states that iPad devices must be connected to the internet to access web resources and Al-Huneini et al. (2020) have also reported that tablet devices, especially iPads, are dependent on internet connectivity. In contrast, Karsenti and Fievez (2013) have argued that students' devices should not be connected to the internet in the classroom because it distracts them and reduces engagement (as discussed in section 7.2.2.5). Melhuish and Falloon (2010) also noted the financial costs associated with the technical requirements of Wi-Fi access for students' iPad devices as an issue.

However, the teachers interviewed reported that they overcame such obstacles by asking the school IT department to resolve interruptions to internet services immediately by bringing an alternative internet router or fixing the modem. Internet service should cover all areas of the school. This issue could be solved by school management or the general Department of Education. They could provide excellent internet service with full maintenance during the academic year. Thus, teachers and students would have the benefits of various technologies in the classroom, such as tablet devices and relevant apps. In this regard, the findings of the study do not support those of some previous works. Other research has emphasised the high costs associated with supporting internet connectivity in school. For example, Melhuish and Falloon (2010) report that there are financial costs associated with the technical requirements of Wi-Fi access for students' iPad devices. There are signs that school management is aware of this technical issue and is addressing it by connecting to the IT department in the school or the general Department of Education, which can resolve this issue for teachers and students. However, this study has identified that unlike the school participating in this quasi-experiment, most government schools in SA do not have an IT department. It is not feasible for the IT department in the general Department of Education to cover all schools simultaneously or instantaneously when issues arise and thus service may be delayed for days or even weeks.

A further issue arose in terms of battery power. The teachers interviewed reported that sometimes students forgot to recharge their iPads at home, which was detrimental for power levels. In addition, they sometimes forgot to bring their charger cable from home, making it difficult for their device to last until the end of the school day. They also noted that their students encountered difficulties recharging their devices in class due to insufficient electrical outlets (as discussed in section 7.2.2.5). This aligns with other research that has highlighted dying iPad batteries or loss of battery life as an obstacle (Kyanka-Maggart, 2013). Similarly, teachers in Ali's (2015) study reported that when students came to school without recharging their devices, it disrupted learning in the class. Thus, they preferred for their students to use textbooks rather than using iPads because printed books do not need to be recharged (Ali, 2015).

The teachers interviewed in this study found solutions to this obstacle, namely to provide a power bank in the classroom and bring an extra charger that would allow their students to use the power bank from their seats. Similarly, Henderson and Yeow (2012) argue that students could recharge their devices easily by moving around the school or giving their devices to their teacher to be recharged. As a researcher, I recommend that the school provide smart charging lockers for students in different locations in the building to allow them to recharge their device when they are not using it.

An addition challenge identified by some teachers was students forgetting their iPads. Indeed, this was identified as the most common obstacle negatively affect students' learning. In this regard, the findings of the study conflict with those of some previous studies. For instance, a teacher in Peel's (2019) study reported that students might forget their books frequently, but they did not typically forget their iPads. In contrast, another teacher in Peel's study reported that if a student or students forgot their iPads, it presented a challenge regarding management of the classroom (Peel, 2019). However, the teachers interviewed in this study suggested that the issue of forgetting the iPad could be solved by ensuring that extra devices were available for students who forgot theirs.

A teacher interviewed in this study believed that using non-educational apps in the classroom had the potential to distract students. For example, the teacher reported that some students chatted with other students via social media apps during class time. Giunchiglia et al. (2018) identified a negative correlation between using social media apps and students' academic performance in that they were distracted and it was detrimental to their learning. Similarly, Raut and Patil (2016) noted that the performance of students who checked their Twitter or Facebook accounts during study time was negatively affected.

To address this issue, one teacher suggested that to avoid students accessing non-instructional apps for games or chatting, it would be beneficial to give them extra work on an app or task them with searching for new information about the lesson. This study recommends using a specific education platform for learning and communication rather than allowing access to social media apps that can be a source of distraction.

The overall trends and tendencies in the findings support the view that teachers minimise the possible obstacles to iPad use by providing realistic and practical solutions. Generally, the findings support the proposition that the intervention integrating tablet devices and apps in class positively altered teachers' perceptions of the effectiveness of using technology in the teaching of mathematics concepts. Based on the findings from the teachers' interviews, it is reasonable to conclude that these outcomes of the evaluation programme were met.

7.3 Conclusion

This chapter has discussed the implications of the findings of this research focusing on the effectiveness of using tablet devices and apps in enhancing the teaching and learning of mathematics in a secondary school in SA. As mentioned in the introduction to this chapter, the study adopted an embedded mixed methods research approach. Quantitative research was conducted involving three assessment tests for 50 10th grade students. In addition, qualitative research was conducted using focus group interviews with 8 groups of students and semi-structured interviews with 4 teachers. Furthermore, the evaluation adopted a quasi-experimental design (for a period of two months) conducted as the primary quantitative approach and the secondary qualitative approach was carried out during the quasi-experiment. In addition, the treatment (iPad access) was switched between the two classes. The quantitative data were subjected to statistical analysis, while the qualitative data were analysed using thematic analysis.

The findings of this research show that using iPads and appropriate apps has an important role to play in the teaching and learning of mathematics in secondary schools. The quantitative findings demonstrate that the students' academic achievement in mathematics improved when using the iPads to a greater than using the traditional means of book, paper, and pencil. This finding also provides statistical evidence that one of the most important outcomes of the evaluation programme has been met.

Students are generally positive about their experiences with the intervention of the iPad and apps, such as GeoGebra, the Marefah system, and social media apps. Using tablets is broadly considered to improve the learning process and positively affect students' learning and performance in mathematics. The students stated that using iPad and the various apps was beneficial to their learning and allowed easy access to many educational resources. They also reported that using the iPad promoted their communication both with other students and their teachers. It also fostered a collaborative environment.

While substantial benefits were identified concerning the use of iPads for educational purposes, there was also some scepticism regarding the advantages. Some students reported that using iPads negatively affected their performance in mathematics as they had less motivation to study after using these devices due to their lack of knowledge of how to use them effectively. Furthermore, the students reported numerous challenges that they faced in using iPads and apps for learning. They detailed some obstacles such as interrupted or weak internet connection, as well as a low battery levels, facing difficulty recharging their devices, the hanging of some apps during use, and the iPad screen breaking easily. These obstacles could be detrimental to the educational process and limit the effective use of tablet devices for educational purposes. However, many such issues were actually related more to the infrastructure in the school than the nature of the device and apps.

Nonetheless, the obstacles identified in this research were important factors that were overcome by students during the quasi-experimental period. In terms of internet connectivity, they brought their own internet routers to school or asked the school administration to fix this issue. When their batteries needed to be recharged, they brought power banks with them, thus avoiding the need to find an electrical outlet. The students also reported a solution regarding apps freezing: they used an alternative app or a website. Finally, based on the findings from the students' focus groups, there is evidence that most outcomes of the evaluation programme were met.

From the perspective of the teachers, the findings show that using the iPad and apps both facilitated the teaching process and were efficient in terms of accomplishing the objectives of the mathematics lessons. Importantly, this technology also helped them to improve their students' performance in mathematics by providing immediate knowledge of their academic levels, giving them flexibility in learning, and preparing them for tests. The findings of this study also show that teachers had positive perceptions of using the iPad and apps in the learning process and that these devices played an important role in assisting teachers to motivate their students.

The teachers stated that the most significant benefits of using the iPad and apps were as follows: (i) improving students' engagement; (ii) increasing interaction among students; (iii) enhancing communication and collaboration among students; (iv) increasing students' self-reliance; (v) developing students' creative and critical thinking skills; (vi) providing immediate feedback to students. In contrast, a teacher in the study believed that while this device and the apps, such as an advanced calculator app, calculating functions space, and GeoGebra, supported students in a set of functions in understanding graphs and challenging problems, it could actually be detrimental to students' skills in basic mathematical operations.

Furthermore, the teachers reported that students should be familiar with an app before using it for learning. Thus, the teachers reported that it was their responsibility to select appropriate apps for the class. In addition, teachers needed to be familiar with the tablet and apps before using them for teaching. This study has shown that teachers have a lack of technological skills in terms of how to use the iPad and apps.

In addition to this lack of knowledge, there were several other reasons why both teachers and students expressed a lack of willingness to embrace the introduction of the iPad. Teachers reported that most public schools in SA are not equipped to integrate the iPad and other tablet devices, and students and teachers cannot provide these on their own due to the associated expense. Indeed, the teachers in this study faced obstacles that limited their use of the iPad and apps.

The main obstacles identified by teachers as limiting their use of the iPad and apps were interrupted internet connection or a weak signal and issues for students with charging iPad batteries or forgetting to bring the charger or devices. This study has also shown that using non-instructional apps in the classroom, such as chatting on social media apps, was one of the most significant barriers in terms of distracting students during the educational process.

This study has proposed several solutions to these issues, including refocusing students by assigning extra work on an app, providing a spare device, and keeping a power bank and extra charger in each classroom. Regarding the internet issue, the teachers mentioned that the school IT department fixed this issue or provided an alternative internet router as a temporary solution. Based on the findings from the teachers' interviews, there is evidence that most outcomes of the evaluation programme were met.

The obstacles identified in this study are important factors that current school management and stakeholders in MoE might want to address by looking at the proposed solutions to enhance the teaching and learning process. The school specialises in using technology for teaching and learning and so it is important that interventions using tablets are as reliable and flexible as possible. The iPads and apps were not explicitly designed to be effective in learning environments such as secondary schools in SA and thus it was necessary to evaluate the extent to which they were effective in enhancing the teaching and learning process.

Chapter 8 Conclusion

8.1 Introduction

This study has evaluated the use of the iPad device as a tool for enhancing the teaching and learning of mathematics at secondary school level in SA. A mixed methods approach was adopted in this evaluation study, utilising an embedded design that combined a quantitative approach (a quasi-experimental design) and a qualitative approach (a case study). The quasi-experimental study data were collected through mathematics tests from 50 students and a single case study was conducted using semi-structured interviews with 4 teachers and 8 focus group interviews with students at Alrowad Secondary School. The quasi-experimental design was conducted as a primarily quantitative approach for two months and the qualitative study was carried out during the quasi-experiment. In the first month of the quasi-experiment, class A was the treatment group and class B was the control group, while in the second month, the treatment was switched. This method was chosen to provide additional evidence of the effectiveness of using iPads in supporting mathematics learning among secondary school students in SA.

The study set out to evaluate the effectiveness of the use of iPads and various apps on the mathematics achievement of 10th grade students, together with the potential influence on their motivation, and compare it to conventional learning methods (i.e. using paper and pencil). The study also evaluated the effectiveness of iPad use from the secondary school teachers' perspectives of the teaching of mathematics concepts in SA. Thus, the aim of this study was to evaluate an intervention integrating iPads in class by assessing the programme outcomes. A logic model was implemented to facilitate this process. Figure 8-1 depicts the components of the model related to the intervention integrating the iPad and apps, and includes the outcomes measured in this study.

Following an in-depth review of the literature in this field, the findings were critically analysed. The primary aim of this study was addressed by distributing the research results in a logic model, along with related literature, to gain insights into the strategic utility and address potential reforms for the MoE and stakeholders in SA.

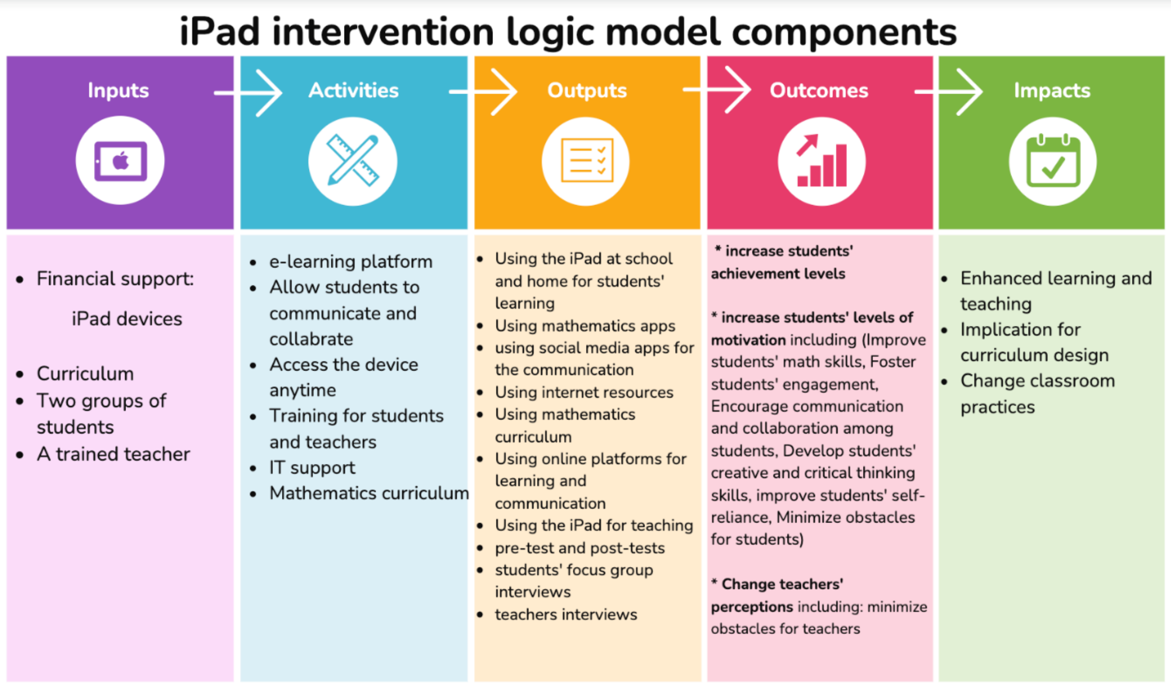


Figure 8-1. The iPad intervention logic model components, including the outcomes measured.

This chapter concludes the thesis with a review of the major research findings, along with a discussion of their contribution and implications. The chapter begins with a summary of the research findings, focusing on the three research questions addressed in the study, which were as follows:

1. What are the effects of iPad use on students' mathematics achievement?

2. How does iPad use affect the motivation of students in learning mathematics?

3. What are teachers' perceptions of the effectiveness of iPad use in the teaching of mathematics concepts?

This chapter also provides some recommendations presented based on the literature and the results of this research to enhance the learning and teaching of mathematics using iPads and associated applications. Also, it provides a section about the connection of the research problem with the general findings of the study. Finally, it also provides several suggestions for further research.

8.2 Summary of the Research Findings

This study addressed three research questions. The findings are based on an amalgamation of the results obtained from a variety of sources; namely, analysis of the data gathered from the secondary school in SA, quantitative results garnered from one pre- and two post-tests, and qualitative results from teachers' interviews and students' focus group. Data were collected to evaluate and understand how iPad devices and apps can be integrated in teaching and learning practices in Saudi secondary schools, with particular emphasis on mathematics education. This has wider implications for curriculum design, classroom practice, teacher education, and the understanding of learning and cognition in technology-enhanced learning settings.

The results of the pre-test and two post-tests for students reveal a significant impact on students' achievement using the iPad and apps. The study also provides statistical evidence that one of the most important outcomes of the evaluation programme has been met. In addition, the focus group interviews with students and the teachers' interviews helped to enhance understanding of the use of iPads and apps in the learning process and shed light on the associated obstacles. They also provided evidence that most outcomes of the evaluation programme were met. The results are summarised by providing a response to each research question individually.

8.2.1 RQ1: What Are the Effects of iPad Use on Students' Mathematics Achievement?

The first question of this study aimed to evaluate the effect of the use of iPads and different educational apps as a learning tool on the achievement of students in a 10th grade mathematics classroom. The findings confirm that the tablet devices and apps significantly affected students' achievement when used for learning purposes. Nine comparisons were made within and between classes A and B to determine the findings, evaluating pre-test, first post-test and second post-test data using t-tests. The purpose of the statistical analysis was to provide specific evidence related to the quantitative approach. The data assisted in providing further understanding of the integration of iPads and related apps in a secondary school in SA.

The results revealed that before the intervention, the two classes did not differ significantly (class A $M = 13.12$, class B $M = 13.88$), meaning that the outcomes would not be affected by any pre-influences in the sample. The results of the comparisons then revealed that the achievement of students in class A ($M = 18.56$), who learned and received instruction based on the iPad and apps in the mathematics classroom in the first month of the quasi-experiment, was better than that of students in class B ($M = 15.36$), who were exposed to conventional methods of education (i.e. paper and pencil). Interestingly, the results showed that after switching the treatment, the students in class B ($M = 18.64$), who used the iPad and apps in the second month of the quasi-experiment, performed better compared with the students in class A (M = 15.32), for whom the iPad-based intervention was switched for paper and pencil. Thus, both classes demonstrated better outcomes immediately after the intervention with the iPad and apps, while the effect was slightly less obvious once the intervention was removed.

Surprisingly, the level of performance of the class A students at the end of the quasi-experiment (second post-test M = 15.32) was still better than their performance before the start of the intervention (pre-test M = 13.12), even though they used the iPad device only in the first month and the technology was removed in the second month, although of course they continued to learn using the traditional method (book, paper, and pencil) in the second month, which would also affect their performance. However, there was a statistically significant difference between students who used the iPad and students who did not as a mathematics learning tool. Thus, most of the students in both classes displayed different mathematics achievement during the quasi-experiment, with increased performance as a result of exposure to the iPad and apps compared to exposure to traditional methods (book, paper, and pencil).

Moreover, the effectiveness of using the iPad in terms of the outcomes for the 10th grade students may have been affected by the use of specific apps, such as GeoGebra and the Marefah system, as well as the teachers' instruction methods; one teacher was selected to teach both classes and the same apps were used for both groups. Furthermore, the teacher had experience of teaching mathematics based on the above-mentioned apps and taught his students how to use the apps.

In general, the comparative analysis of the academic achievement of both classes showed that the intervention integrating iPad use in class had a significant positive impact on students, improving their learning and achievement. Moreover, these findings provide statistical evidence that one of the outcomes of the evaluation programme was met.

8.2.2 RQ2: How Does iPad Use Affect the Motivation of Students in Learning Mathematics?

The second research question examined the effectiveness of iPad use on students' motivation related to mathematics education. Analysis of the students' focus group interview data revealed five major themes relating to students' motivation arising from iPad use as a tool to learn mathematics. Overall, the students expressed positive sentiments and reported beneficial experiences regarding the intervention using the iPads and apps in the learning process. The students interviewed in this study considered the iPad and apps (such as

GeoGebra, the Marefah system, social media apps, etc.) to be key components of the learning process. The technology enabled them to access learning content at any time and anywhere. However, some students were unwilling to use the tablet devices and apps for learning purposes as they felt they did not have sufficient knowhow regarding its usage and they encountered other barriers.

One of the major themes that emerged from the student focus group interviews was that the iPad and apps promoted students' performance in mathematics and played a positive role in facilitating their learning. The secondary school students believed that the intervention was positive due to the numerous benefits offered, for instance helping them solve challenging mathematical equations, supporting their learning, and improving their skills. It helped them with test preparation, especially for the GAT, provided immediate feedback on tests or homework, which encouraged and motivated them to study, and helped them organise their study time. They also found the content easier to understand as using the iPad enabled them to search for relevant information online. However, in contrast, some students found their mathematics' performance declined with the intervention due to the additional time needed to become accustomed to using the educational apps.

The students perceived the iPad to be useful in their learning due to its role in supporting communication and collaboration with other students via different apps, such as Telegram, WhatsApp, Snapchat, Adobe Connect, and the Marefah system. Compared to other technological devices, iPads are more effective tools for communication and collaboration due to their large screens and ability to allow students to share their knowledge quickly.

Although iPads and apps can be considered educationally beneficial (as verified via the focus group interviews), the students nevertheless encountered many barriers. The obstacles associated with iPad usage were primarily identified through the focus group discussions with students. From the students' perspective, one of the major obstacles hindering successful use of iPads and apps in the learning process was an interrupted or slow internet connection. The students believed that lack of connectivity or a slow internet speed constituted a major challenge to the learning using the iPad due to the difficulty in accessing apps, sitting exams, doing homework, or downloading files without the internet. Indeed, students preferred to bring their own routers, which had a better signal and provided faster internet access than the schools Wi-Fi service, as a solution to this issue. Another issue identified by the students concerned battery life, both in relation to low levels and difficulty recharging at school. The students pointed out that when they forgot to recharge their devices at home, their batteries would not last a full school day. However, they brought a power bank or charger to use at school to resolve this issue.

Another obstacle that limited students' use of the iPads was the freezing of some apps during use and their work consequently being deleted. In such cases, students used an alternative app or website as a temporary solution in place of the frozen app. The students also reported another obstacle related to the iPad device itself, namely that the screen was fragile and easily broken. Students reported that this issue limited the use of the device for learning and it was also difficult to fix immediately at school.

Finally, the findings from the students' focus groups support the proposition that the intervention using iPads and apps had a positive effect on motivation in the classroom. Moreover, students were able to minimise the possible obstacles. Based on the findings, it is reasonable to conclude that the outcomes of the evaluation programme related to student motivation were met.

8.2.3 RQ3: What Are Teachers' Perceptions of the Effectiveness of iPad Use in the Teaching of Mathematics Concepts?

The perceptions of teachers at the secondary school concerning the effectiveness of iPad use in the teaching of mathematics concepts were evaluated. In general, teachers held positive perceptions of the role of the iPad and apps in education. Nine core themes emerged from the analysis of the teachers' interview data. The teachers interviewed in this study liked using technology to teach mathematics content, gain students' attention during lectures, and keep pace with modern life and their community. The teachers interviewed preferred to use technology to teach mathematics and they believed that the intervention was beneficial, having advantages over the conventional approach using book, paper, and pencil.

The first major theme that emerged from the interviews with teachers was that using the iPad and apps facilitated the teaching and learning of mathematics. The teachers believed that this technology made teaching mathematics concepts easy to understand for students, with less time and effort required. Also, the teachers mentioned that technology appealed to their students and supported them in explaining difficult concepts.

The second theme that featured prominently was that the iPad and apps assisted teachers in achieving the lesson objectives. The teachers found that when employing the iPad, the students were more motivated to achieve the lesson plans and did so faster than with other approaches. They maintained that the iPad devices supported them in merging different goals simultaneously and aided them in conveying complex lessons, which effectively improved their students' comprehension. Indeed, not only did the iPad and apps help make the teaching process easier, but also assisted students in understanding the goals of the lessons immediately, unlike the previous approach before the intervention.

The third theme that emerged from the teachers' interviews was that there was a lack of technological skills in the use of the iPad and apps. As noted by the teachers, new educational apps are uploaded every day; thus, they required continuous development of their technical skills in how to use these apps prior to integrating them in the educational process. Lack of knowledge about the use of these apps made teachers wary of integrating tablet devices in the classroom. In addition to requiring training on how to use the iPad and apps themselves, their students also needed instruction in their use. The teachers mentioned that they had to spend time at the beginning of the class training their students by explaining the functions and operation of a new app before integrating it in the learning process so as to obtain full benefits from its use. In addition to the issue of lack of knowledge, some teachers were unwilling to use the technology in the classroom because the majority of Saudi public schools are not equipped to integrate it, especially the iPad and other tablet devices, and there are difficulties in equipping all students and teachers with such devices.

A fourth theme that featured prominently was the need to select appropriate apps. Usually, the teacher is responsible for choosing an appropriate app for the lesson. This is a better approach than the students choosing because the teacher will know how to use the app and can transfer this useful knowledge to the students. While some apps are suitable for use in lessons, others do not deliver knowledge to students correctly, simply, or effectively. For example, in this study a teacher chose the GeoGebra app because it supported him in delivering the goals of the lessons and was particularly strong in terms of graphics, plot functions, parametric, polar curves, and solving equations. In contrast, the teacher avoided using some complicated apps that were not fit for student use. Some were considered to have the potential to disrupt learning by distracting the students, such as the Math Graphing app.

The findings of this study also indicated that the iPad and apps assisted teachers in improving their students' performance in mathematics. The fifth theme was that, overall, the teachers considered the intervention benefitted their students by giving them the opportunity to develop their levels of performance and innovation. Inside the classroom, the iPad and different apps assisted teachers in ascertaining their students' academic level and preparing them for tests, and afforded them flexibility in learning.

In addition, the sixth theme was that there was a potential benefit in terms of improving the students' skills in basic mathematical operations. For instance, using an advanced graphing calculator app (e.g. GeoGebra) could support students in applying a set of functions. GeoGebra helped students understand graphs and solve challenging problems. However, one teacher thought that the iPad and apps negatively affected students' skills in basic mathematical operations, such as multiplication activities, because they would depend on these apps and not be able to do the operations mentally.

The seventh theme that emerged concerned the influence in terms of motivating their students to learn mathematics. In general, the teachers believed that the intervention had the benefit of motivating students and played a role in enhancing students' learning by increasing their engagement in the classroom. The teachers were of the general opinion that the iPad and apps helped them to increase student interaction and facilitated collaboration and communication among their students, as also discussed by the students' focus groups, which is an essential element of the learning process. It is interesting that the students mainly focused on the communication aspects of the apps in the learning context, including checking homework, giving access to materials, and engaging in group discussions via different social media apps, including WhatsApp or the Marefah system, rather than using these apps for non-educational purposes, such as chatting or playing games. These apps also played an important role in promoting communication between teachers and students in that the teachers could respond to students' queries immediately or later depending on the circumstances. Furthermore, the devices were considered advantageous in terms of increasing student collaboration levels, enabling document sharing via apps or AirDrop in the classroom.

The eighth key theme that emerged was that teachers believed the iPad and apps were significant in terms of developing their students' creative and critical thinking skills, and especially connecting reality with mathematics skills, which is important for improving students' comprehension. The teachers also thought that the iPad and apps encouraged students to become more independent and responsible for their own learning. Whether outside or inside the classroom, the teachers believed that students benefitted by increasing their self-reliance in their learning through accessing information, watching explanations of the lessons on video, and accessing educational materials online. Furthermore, the iPad and apps assisted teachers by providing immediate feedback for their students. This not only enabled students to review their mistakes, but also aided teachers in reviewing and following their students' performance immediately in the classroom more easily and faster than with other methods, such as handwritten feedback.

While using the iPad and apps for educational purposes was seen to be beneficial (as evidenced by the teacher interviews), the teachers nevertheless still faced some barriers limiting implementation of the technology. The teacher interviews revealed that a weak internet signal or lack of connectivity and issues with battery charging or students forgetting to bring their devices (as also identified by the students' focus groups) were the main obstacles. The use of non-instructional apps in the classroom was also identified as one of the most important barriers that could negatively affect the educational process, as it could distract students.

The teachers highlighted that they developed several solutions to address the obstacles they encountered. For instance, they would give students extra activities in the classroom using an app through which the students could earn extra points to focus their attention so that they would not use the tablets for non-educational purposes. Having an extra device, a power bank, and an extra charger to hand was helpful in the case of low battery, difficulty recharging, or devices left at home. However, the school IT department should be made capable by the school management of fixing internet issues or supplying an alternative router as a temporary solution where necessary.

Finally, the teacher interviews provided evidence that most outcomes of the evaluation programme were met. These outcomes helped to evaluate the effectiveness of intervention using tablet devices in the teaching and learning process.

8.3 Summary of the Programme Evaluation

In school settings, programme evaluation is important to ensure that the stakeholders in education are satisfied with the status of the educational process. Thus, schools should develop strategies for effective evaluation considering school activities and desired outcomes based on data providing evidence by which the impacts of interventions can be measured.

This study used a logic model for programme evaluation to determine the effectiveness of the intervention using technology in terms of meeting the planned outcomes. The logic model provided a practical, clear, and easily understandable map to identify the programme's key measurable outcomes. Evaluation questions that captured the essence of the programme's impact were framed and identified. In addition, the logic model offered a platform for efficient communication and collaboration among students and between the students and their teachers.

One significant outcome of this study was the impact of the logic model for programme evaluation on Alrowad Secondary School. Resources and activities were in place to support the goals of the evaluation programme. Once this programme was established, the data outputs were created and outcomes evaluated. This valuable process can be replicated across the country.

8.4 The connection of the research problem with the general findings of the study

Mathematics as a subject is generally considered difficult and has become unpopular amongst many students (Yushau, 2006). Therefore, the MoE in SA has endeavoured to develop and enhance the mathematics curriculum for many years and following the NCTM's publication of the standards in 2000, it has been striving to meet these standards and enhance students' achievements in mathematics. However, according to the TIMSS results over the years, Saudi students' mathematics attainment remains behind most other countries. For instance, in most recent result (2019), Saudi students' achievement is significantly lower than the international average scores (mean = 500) in the examination in mathematics, with scores of 398 points for 4th grade students, and 394 points for 8th grade students (Mullis et al., 2020). Moreover, according to PISA, male students in SA had the lowest performance in mathematics among participating countries in the PISA 2018 (OECD, 2020).

Accordingly, the MoE has undertaken significant developments and made major amendments to the mathematics curricula in an attempt to resolve this issue. The MoE adopted one of the most significant educational projects in SA history in 2008 by adapting the McGraw Hill global series as the basis for a new mathematics curriculum for all educational phases (Khormi & Woolner, 2019). Despite this, Saudi students continue to underperform and underachieve in mathematics. Consequently, this has become an area of huge concern amongst the MoE and educational stakeholders, with the TIMSS and PISA results being a particular worry. Furthermore, Saudi students' unwillingness to learn mathematics and their low achievement levels continue to be a significant issue in the SA education system (Almaleki, 2010). A key problem is that Saudi students rely heavily on their teachers for learning and find it a challenge to be more independent and assertive in their own educational pursuits (Albadry, 2018). In a bid to address this, the MoE has established effective technology usage in the mathematics classroom to support the education process through different projects such as the King Abdullah bin Abdul-Aziz Project for public education development to provide high-quality solutions and implement the use of technology, technological solutions, and digital transformation in the education sector in SA (MoE, 2020). This study aims to encourage greater support for technology use, such as iPad and other tablet devices, to accomplish the goals of mathematics lessons at all school levels throughout SA, as well as in other education systems worldwide. Therefore, this study evaluated and sought to understood how and to what extent the use of tablets such as the iPad in the classroom can support the development and achievements of students in mathematics, enhance motivation levels, and support the practice of teaching mathematics concepts in SA secondary schools and other countries.

The academic achievements of 10th-grade students were measured for two classes, A and B. The achievement of students in class A increased with iPad use in the first month of the quasi-experiment in contrast to the students in class B who did not use the iPad in their learning process (used conventional book, paper, and pencil only). In turn, the performance of class B increased with iPad use in the second month, while the performance of class A decreased after the iPads were withdrawn. The results showed that both classes (A and B) demonstrated better outcomes immediately after the intervention with the iPad and apps, while the effect was slightly less obvious once the intervention was removed. Both teachers and students expressed the opinion that the iPad and its diverse apps could be a valuable tool in improving mathematics grades, supporting study, and enhancing motivation levels. Both added that receiving immediate feedback via different apps encourages and motivates students. This factor was one of the most significant in terms of impact on students' performance. Contrastingly, some students maintained that the iPad screen was a problem in that it did not allow them to correctly solve an equation, particularly if it was lengthy or involved complex mathematical symbols, thereby negatively impacting their marks in the subject. This highlights the necessity for both students and teachers to receive training in the intervention of the iPad and its apps in the learning and teaching process in order to show an impact on tenth-grade students in their academic achievement in mathematics. However, the effectiveness of using the iPad and its apps on the outcomes of the 10th grade students may be affected by the switching the treatment (the withdrawal of the iPad from group A students mid-way through the process and provided to group B students). It was also impacted by the change in treatment after the students had become accustomed to their learning methods in the first month of the quasi-experiment (Group A going from iPad to no iPad, and vice versa for Group B).

Saudi students' unwillingness to learn mathematics and their low motivation levels continue to be a major issue in the SA education system. The qualitative data from both teachers and students revealed that students held largely positive views regarding the use of iPads and the various apps, including education platforms, such as the Marefah System, and communications apps such as social media apps. Therefore, they believed that using the iPad apps enhanced communication and collaboration with their classmates regarding their studies as well as enabling them to become more interactive in learning mathematics. They also noted that the iPads supported them in achieving the goals of mathematics lessons. It is evident that the qualitative data from both sources agreed in several respects related to the research issues, such as the iPad and the various apps being beneficial for both teachers and students in facilitating the teaching and learning of mathematics. However, some students were unwilling to use the tablet devices and apps for learning purposes as they felt they did not have sufficient knowhow regarding its usage and they encountered other barriers such as interrupted or slow internet connection, low levels and difficulty recharging the device battery at school, the freezing of some apps during use and their work, forgetting the iPad at home, using non-instructional apps in the classroom, and fragile and easily broken screens.

In terms of pedagogical concerns in the teaching of mathematics, the findings reveal that mainly using the iPad and its apps helps to deliver the lessons in a faster and easier way. The findings also show that these tablet devices would support other pedagogical strategies in teaching and learning, such as a learner-centred strategy where these devices assist teachers in raising their students' self-reliance and constructing knowledge themselves. Furthermore, the findings show that the pedagogical concerns in the teaching and learning with the use of technology seemed to lead them to use the iPad and its apps in the classroom for saving time and organising lessons. Therefore, it is the stance of this paper that teachers and students, especially in SA, need to be prepared in the iPad use and its apps. This entails the necessity for the provision of training courses in iPad (and app) usage for both teachers and students, in the light of the pedagogical knowledge that enhance an interactive way of learning and teaching.

To conclude, the comparative results revealed that there are statistically significant differences in students' levels of achievement, with increases in mathematics performance for students using the iPads and its apps in learning mathematics against those using the conventional approach of book, paper, and pencil only. This current study may help the MoE and stakeholders in the education system of SA to resolve the issue of the low achievement of students in mathematics. In addition, the results indicated that there is high positive agreement toward engagement in using the iPad and its apps in learning and teaching mathematics. Teachers and students agreed with the benefits of the use of this device, and that students need support from the school management and teachers. Thus, the current study might help teachers in SA to motivate their students through different pedagogical strategies in teaching such as using the iPad and its different educational apps in the teaching process.

8.5 Study Implications and Recommendations

It is hoped that the findings of this study offer insights that can aid the successful integration of the iPad and its apps in the education process. Accordingly, several implications and recommendations are offered.

8.5.1 Training for Students and Teachers

The school management and teachers should consider providing students and teachers with courses on how to use tablet device and various apps in a suitable educational environment. One of the issues that was identified in this research was a lack of knowledge among students regarding the use of the iPad and apps. It was also found that teachers lacked the technological skills required to employ the iPad and apps, which caused them to be unwilling to incorporate the technology in class. School management should ensure the implementation of effective training courses for teachers, as this will give the integration of technology the best chance of success. Also, it is essential to provide sufficient time for the teachers to become familiar with using such devices and choosing appropriate apps for specific lessons in order for the integration to be successful. This is in line with the findings of Schembri (2015), who noted that enhanced learning through the use of technology would not happen without appropriately training teachers on how to use technology prior to implementing it in the learning process.

8.5.2 Maintaining and Updating Educational Technologies

In addition to training for students and teachers, maintaining and regularly updating educational technologies, such as tablet devices and apps, is essential. The findings of the students' focus groups identified some technical issues. For example, some apps froze during use, which negatively affected their learning. In this case, the school management should provide technical support for teachers and students to enable them to take full advantage of the benefits offered by integrating technology in teaching and learning. One of the significant themes in the interviews with teachers and students was the need to have a strong internet connection covering all areas of the school, thus eliminating issues with internet connectivity. The teachers suggested that the IT department at the school could solve the issues with the internet by fixing the modem or bringing an alternative internet router as a temporary solution. Currently, the majority of schools in SA have internet issues such as lack of high-speed internet or weak signal. Therefore, schools should work with the MoE to secure support and financing for rolling out strong internet connections that cover all classrooms in the school.

8.5.3 Rules and Regulations Guiding the Use of Tablet Device and Apps in Education

There is a need to establish clear rules and regulations guiding the use of tablet devices and apps for educational purposes. One of the concerns that the teachers raised in this research was the obstacle posed by some students' being distracted by the use of non-educational apps, such as social media apps, during study time in the classroom. It is suggested that it would be beneficial to give students extra activities using an app or allow them to search for new information related to the lesson to avoid them having the opportunity to chat or play games. In a related vein, the study recommends that the MoE and schools provide a Blackboard-type learning management system, such as Marefah, with guidelines on how use tablet devices and apps for learning purposes to encourage and support teachers and students in uploading files, lessons, videos, homework, tests, notifications, and communications, alongside different educational and social media apps.

8.5.4 Specific Educational Platform for Communication

Whilst social media apps were mentioned as beneficial for communication, this study recommends using a specific educational platform instead, both in the classroom and at home, to reduce the potential for distraction from social media. Moreover, there is a need for clearer guidelines specifying when students can communicate with their classmates.

8.5.5 Considerations for the Use of Tablet Devices

Schools should also ensure that their classrooms have enough electrical outlets for students to recharge their devices conveniently, thus addressing the obstacle of battery charging. The school management should also work with teachers to educate students concerning safety issues and protecting their devices. The devices should be fitted with screen protectors to avoid any damage, in particular broken screens.

8.5.6 Supporting Schools Financially

Ultimately, secondary schools should integrate technology (such as iPads and apps) in teaching and learning to improve and support education. This study has shown the value of tablet devices and apps in promoting students' learning and improving their performance in mathematics. It has also demonstrated that these tablet devices help teachers to increase their students' motivation, engagement, communication, and collaboration, and to ascertain their academic level. However, to address the lack of desire to use such technology in the learning process, the MoE should support schools financially to combat the obstacles that teachers and students encounter. In this regard, the MoE has already taken a step forward, entering into a contract with Tatweer to provide high-quality solutions and utilise technology, providing technology solutions and digital transformation for schools in SA, in accordance with the Saudi Vision 2030 (MoE, 2020). Therefore, it is essential for schools to leverage the opportunities offered by the MoE to integrate technology in all Saudi schools by encouraging their teachers and students to take advantage of the courses offered by the MoE.

8.6 Suggestions for Further Research

This study contributes to the existing literature by improving understanding of how iPads can contribute to teaching and learning at the secondary school level in SA, with a particular focus on mathematics education. This chapter has detailed the research findings in response to each of the research questions. However, the analysis also revealed other areas of significance and directions for future research that fell outside the scope of this study. In this study, the quantitative data employed to assess the effectiveness of the iPad intervention in improving students' achievement were obtained from pre- and post-tests administered to 10th grade students at a Saudi secondary school, finding a statistically significant difference in students' achievement when they used the iPad and different apps in mathematics learning. Future research could undertake fine-grained analysis of representative quantitative data from pre-tests and post-tests to examine specific domains of mathematics achievement, such as understanding, applying knowledge, and reasoning. Such analysis would enable future studies to verify the effectiveness of tablet integration in enhancing students' achievement. Furthermore, whilst the study showed statistically significant differences in students' achievement based on the intervention, it did not consider students' attitudes towards mathematics. Future research should measure the impact of technology use on various dimensions of their attitudes towards mathematics, such as liking learning mathematics, confidence in learning mathematics, and placing value on mathematics education, to establish whether using technology has any effect on their scores.

While quantitative research allows statistical exploration of research aims to determine an overall understanding of a situation, qualitative research provides contextually rich information. The qualitative data evaluating the influence of iPad use on the motivation of students and understanding the impact from teachers' perspectives came from in-depth interviews with teachers and focus groups with students at a secondary school in SA. The qualitative data showed that using iPads and different apps promoted students' motivation and indicated a positive change in the perceptions of teachers regarding the teaching of mathematical concepts based on using such technology. This study also highlights the substantial obstacles that students and teachers can encounter in using technology for teaching and learning and has offered possible solutions to overcome them to ensure full and successful intervention in the classroom. However, several other areas should be evaluated in future research endeavours in order to advance and complement the knowledge presented in this study.

While the data provided comprehensive insights into the nature of tablet use in the educational environment and many of the findings align with wider research on using technology in the learning process in SA, questions remain regarding the generalisability of the research findings. It would be useful for future research to carry out similar studies in other secondary and elementary schools in SA to evaluate this area more comprehensively, including the impact on students' achievement and motivation and teachers' perceptions of the use of tablet devices and apps in teaching and learning.

Based on the findings of this study, it can be confirmed that further research is required to investigate several issues, whether in SA or other countries, particularly in relation to the following:

1. The findings of this study, undertaken with a sample at a secondary school over a two-month period, provide valuable information to help inform decision making by the MoE and stakeholders in the education system in SA concerning technology-enhanced learning. Extending the time of the experiment to a full semester (four months) or more and including two different grades with a larger sample size from both elementary and middle schools would provide additional benefits.

2. This study focused on the use of tablet devices and apps in general for educational purposes in GE in SA. The findings reveal wide acceptance of these tablets in the learning process. Further research should evaluate the impact of particular apps on students' achievement and motivation levels, covering all lessons during the experimental phase.

3. The study focused on mathematics and the findings showed that the tablet devices and apps supported students' achievement and motivation. Further research could focus on different subjects, such as English or Arabic, sciences, arts, or social science studies, differentiating the findings from those related to the specific mathematics content assessed in this study.

4. This study looked at teachers' perceptions on the use of tablet devices and apps in teaching and learning, but it did not cover the views of school management. Further studies could interview members of school management regarding the impact of using tablets and different apps on teaching and learning, as well as observing students during the experimental phase.
5. Further research needs to investigate teachers' professional and self-directed development related to technology use, with a particular focus on how successfully to integrate tablets and various apps in the classroom.

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Appendices

Appendix 1 Appendix 1A: Semi-Structured Interview Protocol - Teachers (English)

Teacher Interview

1- Do you use technology as teaching methods in your mathematics class? If yes. What type of technology do you prefer to use? Why do you use this technology in your mathematics class?
2- If you have a difficult to explain a mathematics lesson, do you prefer to use technology or other methods to make the mathematics' lesson easy for students? Why?
3- Do you think teachers need a training course about using technology/iPad in their mathematics class? What kind of training teachers need? Why did teachers do not use iPad as teaching methods?
4- Do you think that iPad usage contributes to increasing students' achievements in mathematics lessons? How? Did students' achievement differ when they used iPad?
5- Do you think that iPad affects students' grads? How?
6- Do iPad help students to achieve mathematics lessons goals?
7- Do you think the iPad motivate students to do more effort in the mathematics class? Why?
8- How the use of iPad contributes students' class participation?
9- Do you think that students become more engaged with the math lesson? Why?
10- How the use of iPad contributes students to collaborative learning and communicates with other students?
11- Do you think students become more creative and increase the students' thinking skills in a mathematics class by using iPad? Why?
12- Is the iPad contributing active engagement and interaction among students? Between students and teachers? How?
13- Do you think that students become more self-reliance because using the iPad? Why?
14- Who did the choice of iPad apps for each mathematics lessons? And why?
15- Did students submit their homework online? What do you think about their homework grades after iPad usage?
16- What are the most obstacles you have faced since you have been using iPad in your class? How did you exceed these obstacles in the class?

Appendix 2 Appendix 1B: Semi-Structured Interview – Teachers (Arabic)

مقابلة الشخصية للمعلم

1) هل تستخدم التكنولوجيا كأسلوب للتدريس في حصة الرياضيات او غيرها؟ اذا نعم. ما نوع التكنولوجيا التي تفضل استخدامها؟ لماذا تستخدم هذه التقنية في هذي الحصة؟

2) إذا كان لديك صعوبه في شرح درس معين في مادة الرياضيات ، فهل تفضل استخدام التكنولوجيا أو الطرق الأخرى التقليديه لجعل هذا الدرس في مادة الرياضيات سهلة للطلاب؟ لماذا ا؟

3) هل تعتقد أن المعلمين يحتاجون إلى دورة تدريبية حول استخدام التكنولوجيا(الايباد) لحصة الرياضيات الخاصة بهم؟ أي نوع من تدريب يحتاجه المعلمين؟ لماذا لم يستخدم معضم المعلمون الأيباد كوسائل تعليمية؟

4) هل تعتقد أن استخدام الايباد يساهم في زيادة الإنجازات الأكاديمية للطلاب في حصه الرياضيات؟لماذا؟ هل اختلف تحصيلهم الدراسي عندما استخدموا الايباد؟

5) هل نعنقد ان الأيباد يؤثر على درجات الطلاب؟

6) هل يساعد الايباد الطلاب في تحقيق اهداف الدرس؟

7) هل تعتقد ان الايباد يحفز الطلاب لعمل جهد اكثر في حصة الرياضيات؟ لماذا؟

8) كيف يساهم الايباد في مشاركة الطلاب داخل الفصل؟

9) هل تعتقد انه يصبح الطالب اكثر تفاعلا مع دروس الرياضيات اثناء استخدام الايباد؟

10) كيف يساهم استخدام الايباد في مساعدة الطلاب على التعلم التعاوني والتواصل مع الطلاب الآخرين (داخل او خارج المدرسة)؟

11) هل تعتقد أن الطلاب يصبحون أكثر إبداعًا وتزداد مهارات التفكير لديهم في مادة الرياضيات عن طريق استخدام الايباد؟ لماذا ا؟

12) هل يساهم جهاز الايباد في المشاركة النشطة والتفاعل بين الطلاب؟ بين الطلاب والمعلمين؟ ولماذا؟

13) هل تعتقد أن الطلاب يصبحون أكثر اعتمادا على أنفسهم بسبب استخدام جهاز الايباد؟ لماذا ا؟

14) من الذي اختار تطبيقات الايباد لكل درس من دروس الرياضيات؟ و لماذا؟

15) هل يرفع الطلاب واجباتهم المنزلية عبر الإنترنت؟ هل يتواصل الطالب مع الآخرين فيما يتعلق بدراستهم ومساعدة بعضهم البعض اذا واجهوا صعوبة رياضية؟

16) ما هي أكثر العقبات التي واجهتها منذ استخدم الايباد او التكنولوجيا في صفك؟ كيف تجاوزت هذه العقبات في الفصل؟

Appendix 3 Appendix 2A: Focus Group Interview – Students (English)

Student interview

1. Do you like mathematics class? Is math class challenging for you?
2. Have you used iPad in your mathematics class? What do you feel about using iPad in your mathematics class?
3. Do you think that mathematics became easier by using iPad?
4. Do you think iPad helped you to do mathematical problems? Why?
5. How is your mathematics' achievement after iPad usage? Is it increased or decreased?
6. Does your academic performance increase after iPad usage?
7. Does iPad encourage you to make more effort in math class? How?
8. Does the iPad help you to get feedback immediately?
9. What do you think about submitting your mathematics' homework through the iPad?
10. Have you contacted your classmates regarding mathematics' activities at class or home through the iPad? If yes. How do you feel about these communications at class or home?
11. Have you faced any technical problem on the iPad in your mathematics class? If yes. How did you exceed it?
12. Do you like to use iPad in future in your mathematics class? Why?

Do you have any question?

Appendix 4 Appendix 2B: Focus Group Interview – Students (Arabic)

مقابلات الطلاب

1 – هل تحب حصة الرياضيات؟ هل مادة الرياضيات تعبر تحديا بالنسبة لك ؟

2 – هل سبق واستخدمة الأيباد في حصة الرياضيات ؟ ما هو شعورك اتجاه استخدام الايباد في حصة الرياضيات؟

3 – هل تعتقد ان الرياضيات تصبح سهلة باستخدام الايباد؟

4 – هل تعتقد ان الايباد ساعدك على حل المسائل الرياضية؟ لماذا؟

5 – كيف اصبح انجازاتك في مادة الرياضيات بعد استخدام الايباد؟ هل زادة ام نقصت ؟

6 – هل ارتفع ادائك او تحصيلك الاكاديمي بعد استخدام الايباد؟

7 – هل يساعدك الايباد في بذل جهد اكبر في حصة الرياضيات؟ كيف؟

8 – هل يساعدك الايباد في الحصول حالا على التغية الرجعية ؟ كيف يتم ذلك؟

9 – ماذا تعتقد عن رفع او ارسال الواجبات المنزلية باسخدام الايباد؟

10 – هل سبق وتواصلت مع زملائك للاستفسار عن انشطة رياضيه داخل الفصل او في البيت عن طريق استخدام الايباد؟ اذا نعم. ماهو شعورك عن التواصل بين الزملاء عن طريق استخدام الايباد؟

11 – هل سبق وان واجهة مشاكل تقنية في الايباد داخل الفصل؟ اذا نعم. كيف تم اجتيازها ؟

12 – هل تحب ان تستخدم الايباد مستقبلا في حصص الرياضيات؟ لماذا؟

* هل لديك أي سؤال؟

Appendix 5 Appendix 3: Suggested List of Mathematics Apps

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The suggestion of Math Apps list for this research:

	App name	Description*	
1	Future Gate	Future gate is an environment of e-learning in Saudi Arabia as a new added system of education, and it depends on self-learning and participatory.	
2	PhotoMath	Simply point your camera toward a math problem and Photomath will magically show the result with a detailed step-by-step instructions. Photomath provides: • Camera calculator • Handwriting recognition • Step-by-step instructions	
3	MathWay	Mathway covers: - Basic Math - Pre-Algebra - Algebra - Trigonometry - Precalculus - Calculus - Statistics - Finite Math - Linear Algebra - Chemistry - Graphing	
4	cymath	Algebra: We support equation solving, factoring, logarithms, exponents, complex numbers, quadratic equations, trigonometry, partial fraction decomposition, polynomial division, etc. Calculus: We support product rule, quotient rule, chain rule, u-substitution, integration by parts, integration by partial fraction, trigonometric substitution, rationalizing substitution, and much more. Graphing: We support graph generation, intercepts, asymptotes, domains, ranges, and more!	
5	MathPaPa	• Solves linear equations and quadratic equations. • Solves linear and quadratic inequalities. • Graphs equations. • Factors quadratic expressions. • Order of operations step-by-step. • Evaluates expressions. • Solves systems of two equations.	

*The Description of each app is a copy-pasted from Apple store, 2018

Appendix 6 Appendix 4A: Semi-Structured Interview – Teachers: Pilot Study (English)

BADI ALDOSSRY

Teacher Interview

1- Do you use technology as teaching methods in your mathematics class? If yes. What type of technology do you prefer to use? Why do you use this technology in your mathematics class?

2- If you have a problematic mathematics lesson, do you prefer to use technology or other methods to make the mathematics' lesson easy for students? Why?
3- Do you think teachers need a training course about using technology/iPad in their mathematics class? What kind of training teachers need? Why did teachers do not use iPad as teaching methods?
4- Do you think that iPad usage contribute to academic achievements of students in a mathematics class? How? Does iPad help students to achieve their mathematics lessons goals?
5- Do you think the iPad motivate students to attend mathematics class? Why?
6- How the use of iPad contributes students to collaborative learning and communicates with other students?
7- Do you think students become more creative and increase the students' thinking skills in a mathematics class by using iPad? Why?
8- Is the iPad contributing active engagement and interaction among students? Between students and teachers? How?
9- Do you think that students become more self-reliance because using the iPad? Why?
10- Who did the choice of iPad apps for each mathematics lessons? And why?
11- Did students submit their homework online? Did they connect with others regarding their study and help each other's when they faced a mathematical difficulty?
12- What are the most obstacles you have faced since you have been using iPad in your class? How did you exceed these obstacles in the class?

Appendix 7 Appendix 4B: Semi-Structured Interview – Teachers: Pilot Study (Arabic)

BADI ALDOSSRY

مقابلة الشخصية للمعلم

1) هل تستخدم التكنولوجيا كأسلوب للتدريس في حصة الرياضيات او غيرها؟ اذا نعم. ما نوع التكنولوجيا التي تفضل استخدامها؟ لماذا تستخدم هذه التقنية في هذي الحصة؟

2) إذا كان لديك صعوبه في شرح درس معين في مادة الرياضيات ، فهل تفضل استخدام التكنولوجيا أو الطرق الأخرى التقليديه لجعل هذا الدرس في مادة الرياضيات سهلة للطلاب؟ لماذا ا؟

3) هل تعتقد أن المعلمين يحتاجون إلى دورة تدريبية حول استخدام التكنولوجيا(الايباد) لحصة الرياضيات الخاصة بهم؟ أي نوع من تدريب يحتاجه المعلمين؟ لماذا لم يستخدم معضم المعلمون الآيباد كوسائل تعليمية؟

4) هل تعتقد أن استخدام الايباد يساهم في الإنجازات الأكاديمية للطلاب في حصه الرياضيات؟ماهي طريقة الاستخدام؟ هل يساعد الايباد الطلاب على تحقيق أهداف دروس الرياضيات؟

5) هل تعتقد أن الايباد يحفز الطلاب على حضور دروس الرياضيات؟ ولماذا؟

6) كيف يساهم استخدام الايباد في مساعدة الطلاب على التعلم التعاوني والتواصل مع الطلاب الآخرين (داخل او خارج المدرسة)؟

7) هل تعتقد أن الطلاب يصبحون أكثر إبداعًا وتزداد مهارات التفكير لديهم في مادة الرياضيات عن طريق استخدام الايباد؟ لماذا ا؟

8) هل يساهم جهاز الايباد في المشاركة النشطة والتفاعل بين الطلاب؟ بين الطلاب والمعلمين؟ ولماذا؟

9) هل تعتقد أن الطلاب يصبحون أكثر اعتمادا على أنفسهم بسبب استخدام جهاز الايباد؟ لماذا ا؟

10) من الذي اختار تطبيقات الايباد لكل درس من دروس الرياضيات؟ و لماذا؟

11) هل يرفع الطلاب واجباتهم المنزلية عبر الإنترنت؟ هل يتواصل الطالب مع الآخرين فيما يتعلق بدراستهم ومساعدة بعضهم البعض اذا واجهوا صعوبة رياضية؟

12) ما هي أكثر العقبات التي واجهتها منذ استخدم الايباد او التكنولوجيا في صفك؟ كيف تجاوزت هذه العقبات في الفصل؟

Appendix 8 Appendix 5: Pre-Test and First Post-Test (Arabic)

الاسم ______________________________ التاريخ ____________

5 اختبار الفصل: النموذج (1)

اقرأ كلّ سؤال بعناية، ثم اكتب رمز الإجابة الصحيحة في المكان المخصص لذلك:

1) أوجد مجموع قياسات الزوايا الداخليّة لمضلع محدّب عدد أضلاعه 30. **1)** __________

A) $5400°$ **B)** $5040°$ **C)** $360°$ **D)** $168°$

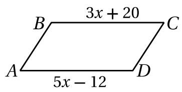
2) أوجد مجموع قياسات الزوايا الخارجيّة لمضلع محدّب عدد أضلاعه 21. **2)** __________

F) $21°$ **G)** $180°$ **H)** $360°$ **J)** $3420°$

3) إذا كان قياس كلّ زاوية داخليّة لمضلع منتظم °108، فأوجد قياس كلّ زاوية خارجيّة لهذا المضلع. **3)** __________

A) $18°$ **B)** $72°$ **C)** $90°$ **D)** $108°$

4) أوجد قيمة x في متوازي الأضلاع $ABCD$ المجاور. **4)** __________

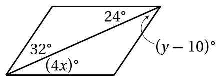


F) 4 **H)** 16
G) 10.25 **J)** 21.5

5) أيٌّ ممّا يأتي تُعدّ خاصيّةً لمتوازي الأضلاع؟ **5)** __________

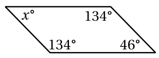
A) القطران متطابقان **C)** القطران متعامدان
B) القطران ينصّفان الزوايا **D)** القطران ينصّف كلٌّ منهما الآخر

6) أوجد قيمة كلٍّ من x و y، حتى يكون $ABCD$ المجاور متوازي أضلاع. **6)** __________



F) $x = 6, y = 42$ **H)** $x = 20, y = 42$
G) $x = 6, y = 22$ **J)** $x = 20\ , y = 22$

7) أوجد قيمة x، حتى يكون الشكل الرباعي المجاور متوازي أضلاع. **7)** __________



A) 44 **C)** 90
B) 46 **D)** 134

8) إذا كانت إحداثيات ثلاثة رؤوس لمتوازي الأضلاع $ABCD$ هي: $A(0,0)\ ,\ B(2,4)\ ,\ C(10,4)$، فأوجد إحداثيات الرأس D. **8)** __________

F) $D(8,0)$ **G)** $D(10,0)$ **H)** $D(0,4)$ **J)** $D(10,8)$

9) أيٌّ ممّا يأتي تُعدّ خاصيّةً للمستطيل؟ **9)** __________

A) الأضلاع الأربعة متطابقة. **C)** القطران متعامدان.
B) القطران ينصّفان الزوايا. **D)** الزوايا الأربع قوائم.

10) الشكل $ABCD$ مستطيل قطراه $\overline{AC}$ و $\overline{BD}$، إذا كان $AC = 2x + 10$ وَ $BD = 56$، فأوجد قيمة x. **10)** __________

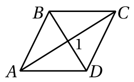
F) 23 **G)** 33 **H)** 78 **J)** 122

11) إذا كانت إحداثيات ثلاثة رؤوس للمستطيل $ABCD$ هي: $B(-5, 0), C(7, 0), D(7, 3)$، فأوجد إحداثيات الرأس A. **11)** __________

A) $A(-5, 7)$ **B)** $A(3, 5)$ **C)** $A(-5, 3)$ **D)** $A(7, -3)$

5 اختبار الفصل: النموذج (1) (تتمّة)

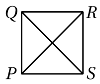
12) أوجد $m\angle 1$ في المعيّن $ABCD$ المجاور. ______



F) $45°$ **H)** $90°$

G) $60°$ **J)** $120°$

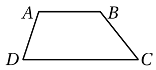
13) أوجد $m\angle PRS$ في المربع $PQRS$ المجاور. ______



A) $30°$ **C)** $60°$

B) $45°$ **D)** $90°$

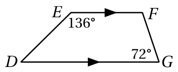
14) أي زاويتين ممّا يأتي تُعدّان زاويتي قاعدة لشبه المنحرف $ABCD$؟ ______



F) $\angle A, \angle C$ **H)** $\angle A, \angle D$

G) $\angle B, \angle D$ **J)** $\angle D, \angle C$

15) أوجد $m\angle D$ في شبه المنحرف $DEFG$ المجاور. ______



A) $44°$ **C)** $108°$

B) $72°$ **D)** $136°$

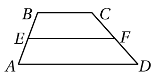
16) غطاء محرك سيارة عُمر على شكل شبه منحرف، طول قاعدته الخلفيّة 30 in، وطول قاعدته الأمامية عند مقدّمة السيارة 24 in، فما طول القطعة المتوسطة لهذا الغطاء؟ ______

F) 25 in **G)** 27 in **H)** 28 in **J)** 29 in

17) إذا كان طول إحدى قاعدتَي شبه منحرف 44، وطول قطعته المتوسطة 36، وطول القاعدة الأخرى $2x + 10$، فأوجد قيمة x. ______

A) 9 **B)** 17 **C)** 21 **D)** 40

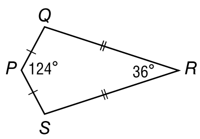
18) إذا كان الشكل $ABCD$ المجاور شبه منحرف، و$\overline{EF}$ القطعة المتوسطة، فأيُّ عبارة ممّا يأتي صحيحة؟ ______



F) $EF = \frac{1}{2}AD$ **H)** $EF = AB$

G) $AE = FD$ **J)** $EF = \frac{BC+AD}{2}$

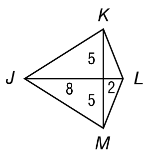
19) أوجد $m\angle S$ في شكل الطائرة الورقية المجاور. ______



A) $100°$ **C)** $200°$

B) $160°$ **D)** $360°$

20) أوجد طول $\overline{JM}$ في شكل الطائرة الورقية المجاور. ______



F) $\sqrt{29}$ **H)** $\sqrt{13}$

G) $\sqrt{89}$ **J)** 11

Appendix 9 Appendix 6: Second Post-Test (Arabic)

الاسم ______________________________ التاريخ ____________

6 اختبار الفصل: النموذج (1)

اقرأ كلّ سؤال بعناية، ثم اكتب رمز الإجابة الصحيحة في المكان المخصص لذلك:

1) إذا كان $\triangle ABC \sim \triangle JKL$ ، وكان $AB = 8, BC = 6, JK = 10$, $JL = 4.8$ ، فما معامل التشابه من $\triangle ABC$ إلى $\triangle JKL$.

A) $\frac{4}{5}$ **B)** $\frac{5}{4}$ **C)** $\frac{5}{3}$ **D)** $\frac{3}{5}$ **(1**__________

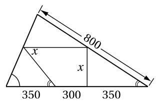
2) رُسم مخطط لمنزل طول شرفة فيه 12in وعرضها 8in ، إذا كان عرض الشرفة الحقيقي 12ft ، فما طولها الحقيقي؟ **(2**__________

F) 8 ft **G)** 10 ft **H)** 16 ft **J)** 18 ft

3) معامل تشابه مربعين 2:3، إذا كان محيط أصغرهما 150 cm، فما محيط الآخر؟ **(3**__________

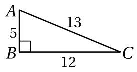
A) 450 cm **B)** 300 cm **C)** 200 cm **D)** 225 cm

4) أوجد قيمة x في الشكل المجاور. **(4**__________

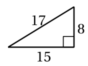


F) 400 **H)** 300
G) 280 **J)** 180

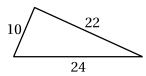
5) أيُّ المثلثات الآتية يشابه $\triangle ABC$ المجاور؟ **(5**__________



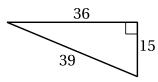
A)



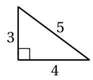
C)



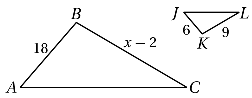
B)



D)



6) إذا كان $\triangle ABC \sim \triangle JKL$ في الشكل المجاور، فأوجد قيمة x. **(6**__________

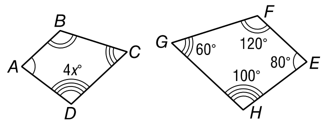


F) 10 **H)** 25
G) 14 **J)** 29

7) إذا كان $ABCD \sim PQRS$ ، وكان: $PS = 12$ ، $QR = 4$ ، $BC = 6$ ، $AB = 10$، فأوجد معامل تشابه $ABCD$ إلى $PQRS$. **(7**__________

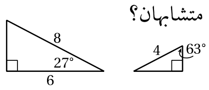
A) $\frac{1}{2}$ **B)** $\frac{3}{2}$ **C)** $\frac{5}{3}$ **D)** $\frac{5}{6}$

8) إذا كان $ABCD \sim EFGH$ ، فأوجد قيمة x . **(8**__________



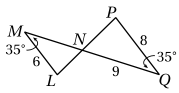
F) 15 **H)** 25
G) 20 **J)** 3

9) أيُّ نظرية أو مسلّمة يمكنك استعمالها لإثبات أن المثلثين المجاورين متشابهان؟ **(9**__________



A) AA **C)** SSA
B) SAS **D)** SSS

10) أوجد طول $\overline{MN}$ في الشكل المجاور. **(10**__________

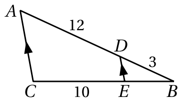


F) $5\frac{1}{3}$ **H)** 7
G) $6\frac{3}{4}$ **J)** 12

11) يقف طالب طوله $5\,ft$ بجوار شجرة، وعندما كان طول ظلّه $4\,ft$ ، كان طول ظل الشجرة $44\,ft$ قدمًا، فما ارتفاع الشجرة؟ **11)**__________

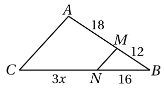
A) $35\frac{1}{2}$ ft **B)** 45 ft **C)** $51\frac{1}{2}$ ft **D)** 55 ft

12) إذا كان $\overline{DE} \parallel \overline{AC}$ في $\triangle ABC$ المجاور ، وكان $BD = 3$ ، $AD = 12$، و$CE = 10$ ، فأوجد BE. **12)**__________



F) 1 **H)** 2
G) $1\frac{1}{2}$ **J)** $2\frac{1}{2}$

13) إذا كان $\overline{MN} \parallel \overline{AC}$ في $\triangle ABC$ المجاور، فما قيمةx؟ **13)**__________

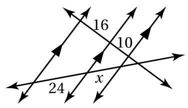


A) 8 **C)** 25
B) 10 **D)** 29

14) إذا كان $\triangle FGH \sim \triangle PQR$ ، وكان $PQ = 10$ ، $FG = 6$، ومحيط $\triangle PQR$ يساوي 35، فما محيط $\triangle FGH$؟ **14)**__________

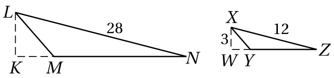
F) 21 **G)** 27 **H)** 31 **J)** $58\frac{1}{3}$

15) أوجد قيمة x في الشكل المجاور. **15)**__________



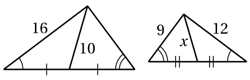
A) 14 **C)** 16
B) 15 **D)** 18

16) إذا كان $\triangle LMN \sim \triangle XYZ$، وكان $\overline{KL}$, $\overline{WX}$ ارتفاعين لهما، فأوجد KL. **16)**__________



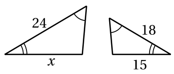
F) 6 **G)** 7 **H)** 9 **J)** 19

17) أوجد قيمة x في الشكل المجاور. **17)**__________



A) 5 **C)** $6\frac{1}{2}$
B) 6 **D)** $7\frac{1}{2}$

18) أوجد قيمة x في الشكل المجاور. **18)**__________

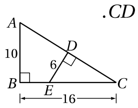


F) 16 **H)** 20
G) 18 **J)** 21

19) معامل التشابه بين مثلثين قائمَي الزاوية $\frac{1}{32}$ ، إذا كان طول أحد ساقَي المثلث الكبير 8m وطول وتره 16m، فما طول وتر المثلث الصغير؟ **19)**__________

A) 0.25 m **B)** 0.75 m **C)** 0.50 m **D)** 2 m

20) في $\triangle ABC$ المجاور، إذا كان: $\overline{DE} \perp \overline{AC}$ ، $AB = 10, BC = 16$, $DE = 6$، فأوجد CD. **20)**__________



F) 10 **H)** 14.83
G) 9.6 **J)** 8

Appendix 10 Appendix 7A: Student Consent Form (English)

University of Glasgow | School of Education

Student Consent Form

Title of Project
The effectiveness of iPad in enhancing instruction in Mathematics Teaching and Learning for Secondary Schools in Saudi Arabia
Name of Researcher: Badi Aldossry

1. I confirm that I have read and understand the Plain Language Statement for the above study and have had the opportunity to ask questions.
2. I understand that my son's participation is voluntary and that he is free to withdraw at any time, without giving any reason.
3. I hereby consent to the interview being audio-taped.
4. I agree / do not agree (delete as applicable) for my son to take part in the above study.

Confidentiality/anonymity

I acknowledge that all participants will be referred to by pseudonym.

Dependent relationships

I acknowledge that there will be no effect on my son's grades/employment arising from his participation or non-participation in this research.

Data usage and storage

- The material will be treated as confidential and kept in secure storage at all times.
- The material will be destroyed once the project is complete.
- I agree to waive my copyright to any data collected as part of this project.

CONSENT

I agree for my son to take part in this research study ☐

I do not agree for my son to take part in this research study ☐

Name of Participant

Name of Person giving consent (if different from participant, eg Parent) Date Signature

Researcher Date Signature

Version 2 - Dec 2014

Appendix 11 Appendix 7B: Student Consent Form (Arabic)

University of Glasgow | School of Education

نموذج موافقة الطالب

عنوان البحث
تأثير الأيباد في تعزيزالتعليم في تدريس وتعليم الرياضيات للمدارس الثانوية بالمملكة العربية السعودية
اسم الباحث: بادي الدوسري

1. أؤكد أنني قد قرأت وفهمت "بيان اللغة السهلة" للدراسة المذكورة أعلاه وأتيحت لي الفرصة لطرح الأسئلة

2. أدرك أن مشاركتي تطوعية وأنني حر في الانسحاب في أي وقت دون إبداء أي سبب

3. أنا أوافق على إجراء المقابلة الصوتية

4. أوافق / لا أتفق (احذف حسب الاقتضاء) للمشاركة في الدراسة المذكورة أعلاه

السرية / عدم الكشف عن هويته

أقر بأن جميع المشاركين سيشار إليهم باسم مستعار

علاقات تابعة

. أقر بأنه لن يكون هناك تأثير على درجاتي / وظيفتي الناشئة عن مشاركتي أو عدم مشاركتي في هذا البحث

استخدام البيانات والتخزين

. سيتم التعامل مع المعلومات على أنها سرية ويتم الاحتفاظ بها في مخزن آمن في جميع الأوقات
. سيتم تدمير المعلومات بمجرد اكتمال المشروع
. أوافق على التنازل عن حقوق الطبع والنشر لأي بيانات تم جمعها كجزء من هذا المشروع

موافقة

( ) أوافق على المشاركة في هذه الدراسة البحثية

( ) أنا لا أوافق على المشاركة في هذه الدراسة البحثية

اسم المشارك

التوقيع   تاريخ   اسم الشخص المسئول عن المشارك
(اذا كان مختلف عن المشارك على سبيل المثال الوالد)

التوقيع   تاريخ   الباحث

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Appendix 12 Appendix 8: Research Ethics Approval

University of Glasgow

College of Social Sciences

Date 30th July 2018

Dear Badi Shara F Aldossry

College of Social Sciences Research Ethics Committee

Project Title: The effectiveness of iPad in enhancing instruction in Mathematics Teaching and Learning for Secondary Schools in Saudi Arabia

Application No: 4001700186

The College Research Ethics Committee has reviewed your application and has agreed that there is no objection on ethical grounds to the proposed study. It is happy therefore to approve the project, subject to the following conditions:

- Start date of ethical approval: _30th July 2018
- Project end date: 30th June 2021
- Any outstanding permissions needed from third parties in order to recruit research participants or to access facilities or venues for research purposes must be obtained in writing and submitted to the CoSS Research Ethics Administrator before research commences. **Permissions you must provide are shown in the *College Ethics Review Feedback* document that has been sent to you.**
- The data should be held securely for a period of ten years after the completion of the research project, or for longer if specified by the research funder or sponsor, in accordance with the University's Code of Good Practice in Research: (https://www.gla.ac.uk/media/media_490311_en.pdf) (Unless there is an agreed exemption to this, noted here).
- The research should be carried out only on the sites, and/or with the groups and using the methods defined in the application.
- Any proposed changes in the protocol should be submitted for reassessment as an amendment to the original application. The *Request for Amendments to an Approved Application* form should be used:
  https://www.gla.ac.uk/colleges/socialsciences/students/ethics/forms/staffandpostgraduateresearchstudents/

Yours sincerely,

Dr Muir Houston
College Ethics Officer

Muir Houston, Senior Lecturer
College of Social Sciences Ethics Officer
Social Justice, Place and Lifelong Education Research
University of Glasgow
School of Education, St Andrew's Building, 11 Eldon Street
Glasgow G3 6NH
0044+141-330-4699 Muir.Houston@glasgow.ac.uk

Appendix 13 Appendix 9: Approval Letter for the Implementation of the Study at Alrowad Secondary School, SA (Arabic)

Royal Commission For Jubail & Yanbu
Royal Commission in Jubail

الهيئة الملكية للجبيل وينبع
الهيئة الملكية بالجبيل

Inter Office Memorandum

مذكرة داخلية

الرقم: ٦١٧/٢٠/٦

التاريخ: ١٥ رمضان ١٤٣٩ هـ

الموضوع: الموافقة على تطبيق البحث العلمي للباحث/ بادي شارع الدوسري

المكرم/ مدير إدارة الخدمات التعليمية **المحترم**

السلام عليكم ورحمة الله وبركاته،،،

إشارة الى خطابكم رقم (٥/٢٠/١٢١٦/٤٣٩) بتاريخ ١٤٣٩/٠٨/٢٨هـ، المبني على طلب الباحث/ بادي شارع فهد الدوسري أحد المعلمين المبتعثين لإكمال مرحلة الدكتوراه في بريطانيا من قبل وزارة التعليم، لتطبيق بحث علمي في مدارس الهيئة الملكية بالجبيل وتحديداً على عينة من الطلاب بمدرسة الرواد الثانوية بعنوان (تأثير الآيباد في تعزيز التعليم في تدريس وتعليم الرياضيات للمدارس الثانوية بالمملكة العربية السعودية).

نفيدكم بموافقة صاحب الصلاحية على تطبيق البحث العلمي على أن يتم تزويد إدارة تطوير القوى العاملة بنتائج البحث العلمي.

وتقبلوا خالص تحياتي وتقديري ،،،

مدير إدارة تطوير القوى العاملة

معتمد إلكترونياً

ذعار بن شجاع المطيري

عدد المرفقات: ١

التوزيع:

ص/ قسم تطوير القوى العاملة

الهيئة الملكية للجبيل وينبع
الهيئة الملكية بالجبيل
مذكـــرة داخـلـيـــة

Royal Commission For Jubail & Yanbu
Royal Commission in Jubail
Inter Office Memorandum

الرقـم : ٥ / ٢٠ / ١٣٠٤ / ٤٣٩
التاريخ : ٢٤ / ١٠ / ١٤٣٩هـ

الموضوع : تسهيل مهمة باحث

المكرم / مدير مدرسة الروّاد الثانوية المحترم

السلام عليكم ورحمة الله وبركاته:

إشارةً إلى خطاب مدير إدارة تطوير القوى العاملة رقم (٦/٢٠/٦١٧) بتاريخ ١٤٣٩/٠٩/١٥هـ بشأن طلب الباحث / بادي شارع فهد الدوسري أحد المعلمين المبتعثين لإكمال مرحلة الدكتوراه في بريطانيا من قبل وزارة التعليم لتطبيق بحث علمي في مدارس الهيئة الملكية بالجبيل على عينة من الطلاب بمدرسة الرواد الثانوية بعنوان (تأثير الآيباد في تعزيز التعليم في تدريس وتعليم الرياضيات للمدارس الثانوية بالمملكة العربية السعودية).

نأمل منكم تسهيل مهمته لإتمام بحثه وتوزيع الاستبانة على عينة من الطلاب.

شاكرين لكم تعاونكم .

وتقبلوا تحياتي ،،،

مدير إدارة الخدمات التعليمية

د. محمد بن سعيد الهاجري

التوزيع :
ص / قسم التخطيط والتطوير .

التعليم بمعايير عالمية
NCA CASI • NWAC • SACS CASI
ACCREDITED
AdvancED

Appendix 14 Appendix 10A: Teacher Consent Form (English)

University of Glasgow | School of Education

Teacher Consent Form

Title of Project
The effectiveness of iPad in enhancing instruction in Mathematics Teaching and Learning for Secondary Schools in Saudi Arabia
Name of Researcher: Badi Aldossry

1. I confirm that I have read and understand the Plain Language Statement for the above study and have had the opportunity to ask questions.
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.
3. I hereby consent to the interview being audio-taped.
4. I agree / do not agree (delete as applicable) to take part in the above study.

Confidentiality/anonymity

I acknowledge that all participants will be referred to by pseudonym.

Dependent relationships

I acknowledge that there will be no effect on my grades/employment arising from my participation or non-participation in this research.

Data usage and storage

- The material will be treated as confidential and kept in secure storage at all times.
- The material will be destroyed once the project is complete.
- I agree to waive my copyright to any data collected as part of this project.

CONSENT

I agree to take part in this research study ☐

I do not agree to take part in this research study ☐

Name of Participant	Date	Signature

Researcher	Date	Signature

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Appendix 15 Appendix 10B: Teacher Consent Form (Arabic)

University of Glasgow | School of Education

نموذج موافقة المعلم

عنوان البحث
تأثير الآيباد في تعزيزالتعليم في تدريس وتعليم الرياضيات للمدارس الثانوية بالمملكة العربية السعودية
اسم الباحث: بادي الدوسري

1.أؤكد أنني قد قرأت وفهمت "بيان اللغة السهلة" للدراسة المذكورة أعلاه وأتيحت لي الفرصة لطرح الأسئلة

2.أدرك أن مشاركتي تطوعية وأنني حر في الانسحاب في أي وقت دون إبداء أي سبب

3.أنا أوافق على إجراء المقابلة الصوتية

4.أوافق / لا أتفق (احذف حسب الاقتضاء) للمشاركة في الدراسة المذكورة أعلاه

السرية / عدم الكشف عن هويته

أقر بأن جميع المشاركين سيشار إليهم باسم مستعار

علاقات تابعة

.أقر بأنه لن يكون هناك تأثير على درجاتي / وظيفتي الناشئة عن مشاركتي أو عدم مشاركتي في هذا البحث

استخدام البيانات والتخزين

.سيتم التعامل مع المعلومات على أنها سرية ويتم الاحتفاظ بها في مخزن آمن في جميع الأوقات
.سيتم تدمير المعلومات بمجرد اكتمال المشروع
.أوافق على التنازل عن حقوق الطبع والنشر لأي بيانات تم جمعها كجزء من هذا المشروع

موافقة

( ) أوافق على المشاركة في هذه الدراسة البحثية

( ) أنا لا أوافق على المشاركة في هذه الدراسة البحثية

التوقيع   تاريخ   اسم المشارك

التوقيع   تاريخ   الباحث

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Appendix 16 Appendix 11A: Plain Language Statement – Teacher Interview (English)

College of Social Sciences Research Ethics Committee

University of Glasgow

College of Social Sciences

Plain Language Statement

(Main Study - Teacher)

1. Study title and Researcher Details

My name is Badi Shara F Aldossry. I am a student at the University of Glasgow. For my doctoral studies I am carrying out a research project. The title of the project is:

The effectiveness of iPad in enhancing instruction in Mathematics Teaching and Learning for Secondary Schools in Saudi Arabia

This research is supervised by Prof Victor Lally at the University of Glasgow (victor.lally@Glasgow.ac.uk, telephone: 01413303424) and Dr David Morrison-Love of the University of Glasgow (email: David.Morrison-Love@glasgow.ac.uk, telephone: 01413303096).
Thank you for taking the time to read this.

2. Invitation

I would like to invite you to take part in this research study. Before you decide whether you would like to take a part it is important for you to understand why the research is being done and what it will involve. Please take the time to read the following information carefully and discuss it with me if you wish. Please feel free to ask questions about anything about which you are unclear. If you would like to have more information, please contact me. Please take your time to consider whether you wish to take part.

3. What is the purpose of the study?

The main purpose of the study is to understand the use of iPad in teaching and learning through examining the effectiveness of using this technology (iPad) for educational purposes and highlight the obstacles involved of iPad usage in the implementation in Saudi Arabia Schools. In addition, this research aims to help in developing better use of iPad in secondary schools and to investigate instructors and student's uses and experiences with iPad in education.

4. Why have I been chosen?

You have been chosen because you are a mathematics teacher at this secondary school, and there is another mathematics teacher is involved in this research as you.

5. Do I have to take part?

It is up to you to decide whether or not to take part. If you decide to take part you are still free to withdraw at any time and without giving a reason.

1/2

6. What will happen to me if I take part?

I would like to interview you for approximately 40 minutes, and make a recording of the interview. This will take place by arrangement with you. The interview will be conducted by face to face at a mutually convenient time during the experimental period. The data from this interview may be used in my doctoral thesis, and also any publications arising from it. You may request a copy of these documents from me when the research is completed.

7. Will my taking part in this study be kept confidential?

The data will be gathered and coded by numbers or letters rather than the names of participants, and once the data has achieved its purpose, it will be destroyed. Access to computer files to be available by password only and, after analysis, the data will be destroyed in the presence of the researcher and the supervisors.

Please note that assurances on confidentiality will be strictly adhered to unless evidence of wrongdoing or potential harm is uncovered. In such cases the University may be obliged to contact relevant statutory bodies/agencies.

8. What will happen to the results of the research study?

After analysis, the data will be destroyed in the presence of the researcher and the supervisors. The data from this interview may be used in my doctoral thesis, and also any publications arising from it. You may request a copy of these documents from me when the research is completed.

9. Who is organising and funding the research?

Saudi Arabian Embassy

10. Who has reviewed the study?

This project has been considered and approved by the Social Sciences/School of Education Research Ethics Committee at the University of Glasgow, UK.

11. Contact for Further Information

For further information, please contact Prof Victor Lally at the University of Glasgow (victor.lally@Glasgow.ac.uk, telephone: 0141 330 3036) and Dr David Morrison-Love of the University of Glasgow (email: David.Morrison-Love@glasgow.ac.uk, telephone: 01413303096).

If you have any concerns regarding the conduct of this research project you can contact the College of Social Sciences Ethics Officer, Dr Muir Houston, email: Muir.Houston@glasgow.ac.uk

Appendix 17 Appendix 11B: Plain Language Statement – Teacher Interview (Arabic)

College of Social Sciences Research Ethics Committee

College of Social Sciences

بيان توضيحي

(دراسة رئيسية - مدرس)

1)**عنوان الدراسة وتفاصيل الباحث**

اسمي بادي شارع الدوسري أنا طالب في جامعة غلاسكو لدراسة الدكتوراه أقوم بتنفيذ مشروع بحثي عنوان المشروع هو

تأثير الأيباد في تعزيز التعليم في تدريس وتعليم الرياضيات للمدارس الثانوية بالمملكة العربية السعودية

يشرف على هذا البحث بروفيسور فيكتور لالي في جامعة غلاسكو

(، هاتف: 01413303424 **victor.lally@Glasgow.ac.uk)**

ود. ديفيد موريسون-لوف من جامعة غلاسكو

(، هاتف: 01413303096 **David.Morrison-Love@glasgow.ac.uk :**البريد الإلكتروني**)**

شكرا لأخذ الوقت الكافي لقراءة هذا

2)دعوة

أود أن أدعوكم للمشاركة في هذه الدراسة البحثية. قبل أن تقرر ما إذا كنت ترغب في المشاركة ، من المهم أن تفهم سبب إجراء البحث وما تشمله. يرجى أخذ الوقت الكافي لقراءة المعلومات التالية بعناية ومناقشتها معي إذا كنت ترغب في ذلك. لا تتردد في طرح أسئلة حول أي شيء أنت غير واضح. إذا كنت ترغب في الحصول على مزيد من المعلومات ، يرجى الاتصال بي. يرجى أن تأخذ وقتك للنظر في ما إذا كنت ترغب في المشاركة

3) ما هو الغرض من الدراسة؟

الهدف الرئيسي من الدراسة هو فهم استخدام الايباد في التدريس والتعلم من خلال دراسة مدى فعالية استخدام هذه التقنية (الايباد) للأغراض التعليمية وإبراز العقبات التي ينطوي عليها استخدام الايباد في التطبيق في مدارس المملكة العربية السعودية. بالإضافة إلى ذلك ، يهدف هذا البحث إلى المساعدة في تطوير الاستخدام الأفضل لجهاز الايباد في المدارس الثانوية والتحقيق في استخدامات الطلاب وتجاربهم مع الايباد في التعليم

4)لماذا تم اختياري؟

.لقد تم اختيارك لأنك معلم رياضيات في هذه المدرسة الثانوية ، وهناك معلم رياضيات آخر يشارك في هذا البحث مثلك

5)هل يجب علي المشاركة؟

الأمر متروك لك لتقرر ما إذا كنت ستشارك أم لا. إذا قررت المشاركة ، فلا يزال لديك الحرية في الانسحاب في أي وقت ودون إبداء سبب

6)ماذا سيحدث لي إذا شاركت؟

أود إجراء مقابلة معك لمدة 40 دقيقة تقريبًا ، وإجراء تسجيل للمقابلة. هذا سيحدث بالترتيب معك. سيتم إجراء المقابلة عن طريق سكايب أو الهاتف في وقت مناسب للطرفين خلال الفترة التجريبية. يمكن استخدام البيانات من هذه المقابلة في أطروحة الدكتوراه ، وأي منشورات ناشئة عنها. يمكنك طلب نسخة من هذه المستندات مني عند اكتمال البحث

7)هل سيظل مشاركتي في هذه الدراسة سرية؟

3/2

سيتم جمع البيانات وترميزها بالأرقام أو الحروف بدلاً من أسماء المشاركين ، وبمجرد أن تحقق البيانات غرضها ، سيتم تدميرها. الوصول إلى ملفات الكمبيوتر لتكون متاحة عن طريق كلمة المرور فقط ، وبعد التحليل ، سيتم تدمير البيانات في وجود الباحث والمشرفين.

يرجى ملاحظة أن الضمانات المتعلقة بالسرية سيتم الالتزام بها بدقة ما لم يتم الكشف عن أدلة على ارتكاب مخالفات أو ضرر محتمل. في مثل هذه الحالات ، قد تكون الجامعة ملزمة بالاتصال بالهيئات / الهيئات القانونية ذات الصله

9)ماذا سيحدث لنتائج الدراسة البحثية؟

بعد التحليل ، سيتم تدمير البيانات في وجود الباحث والمشرفين. يمكن استخدام البيانات من هذه المقابلة في أطروحة الدكتوراه ، وأي منشورات ناشئة عنها. يمكنك طلب نسخة من هذه المستندات مني عند اكتمال البحث

10)من قيم هذه الدراسة؟

تم دراسة هذا المشروع والموافقة عليه من قبل لجنة أخلاقيات البحوث في العلوم الاجتماعية / كلية التربية في جامعة جلاسجو بالمملكة المتحدة

11)الاتصال للحصول على مزيد من المعلومات

لمعلومات أكثر، يرجى الاتصال

بروفيسور فيكتور لالي في جامعة غلاسكو

(، هاتف: 0141 330 3036 **victor.lally@Glasgow.ac.uk)**

والدكتور ديفيد موريسون-لوف من جامعة غلاسكو

.(، هاتف: 01413303096 **David.Morrison-Love@glasgow.ac.uk :**البريد الإلكتروني**)**

إذا كان لديك أي مخاوف بشأن إجراء هذا المشروع البحثي ، يمكنك الاتصال بمسؤول أخلاقيات كلية العلوم الاجتماعية ،

الدكتور موير هيوستن ،

Appendix 18 Appendix 12A: Plain Language Statement – Quasi-Experiment and Student Focus Group (English)

University of Glasgow | School of Education

Participant Information Sheet - pupils

Title of project and researcher details

The effectiveness of iPad in enhancing instruction in Mathematics Teaching and Learning for Secondary Schools in Saudi Arabia

Researcher: Mr. Badi Aldossry

Supervisors: Prof Victor Lally and Dr David Morrison-Love

Course: PhD of Education.

You are being invited to take part in a research project into using iPad in mathematics class in school, along with your classmates from your class. A research project is a way to learn more about something. You are being asked to take part because your class is an involvement in this research.

Before you decide if you want to take part, it is important for you to understand why the research is being done and what it will involve. Please take time to read the information on this page carefully and discuss it with others in the class and your parent/carer if you wish. Ask me if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

What will happen if you take part

The purpose of this study is to find out whether or not pupils enjoy in their learning by using iPad, what they like or don't like about it, and whether they feel that it helps them to learn better.

If you decide to take part, you will take a pre-test before we start and post-test at the end. Do not worry; these tests are not affecting your grades. You do not have to answer any questions that you don't want to.

Also, I will ask you some questions about what you think about using iPad in your learning. You will be in a group with other students from our class. You do not have to answer any questions that you don't want to. This will take about 30 minutes and we will do this during class time. I will record your answers on a voice recorder so that afterwards I can listen carefully to what you said.

I will be finished gathering information after two months from the start day.

You do not have to take part in this study, and if you decide not to, or your parent/carer does not wish you to take part, you will still be part of the class exactly the same as you are now. If, after you have started to take part, you change your mind, just let me know and I will not use any information you have given me.

Keeping information confidential (private)

I will keep the information from the group discussion, tests and my notes about your learning in a locked cabinet or in a locked file on my computer. When I have finished writing my study I will destroy all the information.

When I write about what I have found out, your name will not be mentioned. If you like you can choose another name for me to use when I am writing about what you said. No-one else will know which name you have chosen. Only the others in the focus group will know what you said.

However, if during our conversation I hear anything which makes me worried that you might be in danger of harm, I might have to tell other people who need to know about this.

The results of this study

When I have gathered all of the information from everyone who is taking part I will write about what I have learned in a thesis, which is a long essay, which I have to complete for the course I am studying on. This will be read and marked by my teachers at university. I will tell you and the other students who have taken part what I have found out about what you think about using iPad in your learning. I will also tell other teachers in the school. I will destroy all of my notes and recordings when the project is finished.

Review of the study

This study has been reviewed and agreed by the School of Education Ethics Forum, University of Glasgow

Contact for further Information

If you have any questions about this study, you can ask me, Mr. Badi
() or my supervisors, Prof Victor Lally (victor.lally@Glasgow.ac.uk)
and Dr David Morrison-Love (David.Morrison-Love@glasgow.ac.uk)or the Ethics officer for the School of Education: Dr. Muir Houston: Muir.Houston@glasgow.ac.uk

Appendix 19 Appendix 12B: Plain Language Statement – Quasi-Experiment and Student Focus Group (Arabic)

University of Glasgow | School of Education

ورقة معلومات المشارك – التلاميذ

عنوان المشروع وتفاصيل الباحث

تأثير الآيباد في تعزيزالتعليم في تدريس وتعليم الرياضيات للمدارس الثانوية بالمملكة العربية السعودية

الباحث المشارك: الاستاذ بادي الدوسري

المشرفون: بروفيسور فيكتور لالي ودكتور ديفيد موريسون-لوف

المرحلة : دكنوراه في التربية

أنت مدعو للمشاركة في مشروع بحثي لاستخدام الايباد في فصل الرياضيات في المدرسة ، بالإضافة إلى زملائك في الفصل الدراسي. مشروع البحث هو وسيلة لمعرفة المزيد عن شيء ما. تتم مطالبتك بالمشاركة لأن صفك يشارك في هذا البحث.

قبل أن تقرر ما إذا كنت ترغب في المشاركة ، من المهم أن تفهم سبب إجراء البحث وما ستشمله. يرجى أخذ الوقت الكافي لقراءة المعلومات الموجودة على هذه الصفحة بعناية ومناقشتها مع الآخرين في الصف وأولياء الأمور / مقدمي الرعاية إذا كنت ترغب في ذلك. اسألني إذا كان هناك أي شيء غير واضح أو إذا كنت ترغب في مزيد من المعلومات. خذ وقتك لتقرير ما إذا كنت ترغب في المشاركة أم لا.

ماذا سيحدث إذا شاركت

الغرض من هذه الدراسة هو معرفة ما إذا كان التلاميذ يستمتعون في تعلمهم أم لا باستخدام الايباد، وما يحبونه أو لا يعجبهم ، وما إذا كانوا يشعرون أنه يساعدهم على التعلم بشكل أفضل

إذا قررت المشاركة ، فستتلقى اختبارًا مسبقًا قبل البدء والاختبار لاحقًا. لا تقلق؛ هذه الاختبارات لا تؤثر على درجاتك. لا يتعين عليك الإجابة عن أي أسئلة لا تريده.

أيضا ، سوف أسألك بعض الأسئلة حول ما تفكر فيه باستخدام الايباد في التعلم الخاص بك. سوف تكون في مجموعة مع طلاب آخرين من فصلنا. لا يتعين عليك الإجابة عن أي أسئلة لا تريدها. سيستغرق هذا حوالي 30 دقيقة وسنفعل ذلك خلال وقت الصف. سوف أسجل إجاباتك على مسجل صوت حتى يتسنى لي بعد ذلك الاستماع بعناية إلى ما قلته

سوف يتم الانتهاء من جمع المعلومات بعد شهرين من يوم البدء.

لا يتعين عليك المشاركة في هذه الدراسة ، وإذا قررت عدم القيام بذلك ، أو إذا كان والدك / مقدم الرعاية لديك لا يرغب في المشاركة ، فستظل جزءًا من الفصل تمامًا كما أنت الآن. إذا كنت قد غيرت رأيك بعد أن بدأت في المشاركة ، فقط أخبرني ولن أستخدم أي معلومات قد أعطيتها لي.

الحفاظ على سرية المعلومات (خاصة)

سأحتفظ بالمعلومات من المناقشة الجماعية والاختبارات وملاحظاتي حول تعلّمك في خزانة مقفلة أو في ملف مغلق على الكمبيوتر. عندما انتهيت من كتابة دراستي سوف أدمر كل المعلومات.

عندما أكتب عن ما اكتشفته ، لن يتم ذكر اسمك. إذا كنت تحب يمكنك اختيار اسم آخر لي لاستخدامه عندما أكتب عن ما قلته. لن يعرف أي شخص آخر الاسم الذي اخترته. فقط الآخرين في المجموعة سيعرفون ما قلته.

ومع ذلك ، إذا سمعت خلال حديثنا أي شيء يجعلني قلقًا من احتمال تعرضك لخطر الأذى ، فقد أحتاج إلى إخبار الآخرين الذين يحتاجون إلى معرفة ذلك.

نتائج هذه الدراسة

عندما أجمع كل المعلومات من كل شخص يشارك ، سأكتب عن ما تعلمته في أطروحة ، وهي مقالة طويلة ، والتي يجب أن أكملها في الدورة التي أدرس فيها. سيتم قراءة هذا وتعليمه من قبل المعلمين في الجامعة. سأخبركم والطلاب الآخرين الذين شاركوا في ما اكتشفته حول ما تفكرون به في استخدام جهاز الايباد في تعلمك. سأخبر المدرسين الآخرين في المدرسة أيضًا. سوف أدمر كل ملاحظاتي وتسجيلاتي عندما ينتهي المشروع.

مراجعة الدراسة

تمت مراجعة هذه الدراسة والموافقة عليها من قبل نموذج الأخلاقيات بقسم التربية ، جامعة جلاسجو.

إذا كان لديك أي أسئلة حول هذه الدراسة ، يمكنك أن تسألني ،

الاستاذ بادي (
أو المشرفين لدي ، البروفيسور فيكتور
لالي)*victor.lally@Glasgow.ac.uk*(
والدكتور ديفيد موريسون-لوف *(David.Morrison-Love@glasgow.ac.uk)*

أو مسؤول الأخلاقيات في كلية التربية: د. موير هيوستن *Muir.Houston@glasgow.ac.uk*

شكرا لقراءتك هذا!