Exploring the use of mobile learning applications in the Physical Sciences classroom

by

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30 November 2022

DECLARATION

I Motlatsi Jacob Tsie, declare that this master's degree dissertation submitted to the Faculty of Education at the University of the Free State is my own independent work, except where stated otherwise by citations and sources acknowledged in-text and in the list of references. Further, this dissertation has not been submitted in whole or part for a degree at any other university or faculty of this university.

I also hereby agree that all copyrights of this work should be that of the University of the Free State.

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DEDICATION

I dedicate this research project to my lovely wife, Manaledi, who always believed in me whole-heartedly with love, understanding, support, and motivation that led to the successful completion of this academic journey.

Also, I dedicate this paper to my daughter, Naledi for her love and patience.

To my uncle Ben Mateka, for always pushing and critiquing everything I did. Your criticism made me sharper.

Lastly, I would like to dedicate this paper to the staff and Physical Science learners of Christiaan De Wet Combined School for inspiring me to conduct this research journey. Their inspiration to always improve made us resilient and persistent.

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ABSTRACT

Over the years, there has been a rapid increase in the development of technology. Most researchers have realised the importance of integrating technology in teaching and learning activities. This should also be included into curriculum planning as teaching with technology will assist in better lesson delivery. Since ICT tools are expensive to buy and maintain, smart phones through mobile apps provide alternatives that are readily available with most of them not requiring a subscription fee. Although e-Education policies that support the use of technology in the classroom are being implemented, schools in the Free State are still not exploiting this advantage. However, guidelines on how to use a smart phone in the classroom, is lacking. Additionally, because of the numerous apps advertised in stores, it is difficult to find a relevant app for use in the classroom. This study emanated out of concern that South African schools lack ICT and Physical Sciences resources and therefore learners will not grasp the importance of using smart phone technologies to enhance learning activities thus creating a digital gap in their knowledge and skills. In attempting to understand the role free mobile applications could play in a Physical sciences classroom, this study investigated if learners know how to install and use apps appropriately, and then assess them for suitability and applicability in the teaching-learning processes. The teaching and learning policies and the CAPS document were used to inform the study on what type of skills learners should acquire in Physical Sciences, especially by using smart phone apps. Additionally, TPACK informed on the different types of knowledge that an educator must possess in order to integrate technology in teaching and learning activities. This concurrent mixed method study selected 72 Grade 10 and 11 Physical Sciences learners from 2 schools in the Southern Free State by utilising observation sheets and questionnaires to elicit the impact of adopting mobile apps in teaching and learning activities. This was done through the testing of 4 applications; namely, the Physical Science mobile app, WhatsApp, the school planner app, and the Google classroom app. Key findings revealed that learners knew how to acquire mobile applications on their own. This can be acquired from an app store, or the internet through a browser and through sharing software which allows apps to be shared as an APK file. Additionally, learners knew how to evaluate content through the apps concerning its relevancy to the Physical Sciences. Learners experiences indicated that apps can be used to impact planning, provide sufficient practice, and improve communication between teachers and learners. Moreover, these apps prioritised learners to be in charge of their learning by allowing them to schedule events for later dates and to practise at any point without the supervision of an educator. However, app usage in the classroom provided loopholes that made it easier for learners to collude, proving that the usage of apps in the class must be supervised. These findings, therefore, call for a revision of policies that can guide smart phone usage in the classroom to avoid collusion. Additionally, app usage must be promoted in schools to provide learners with sufficient resources to access learning content with ease which will somewhat address the lack of resources in schools. Teacher-training must also include the use of ICT programmes to facilitate learning in schools. Teacher-trainees when on practice sessions at schools could monitor the progress of teaching-learning situations when using smart phones in classroom. Future studies must utilise eye-tracking software to determine the areas that learners generally hone into when using an app which can lead to better suitable apps being created for teaching and learning purposes.

Key words: curriculum, digital gap, ICT, integration of technology, mobile apps, TPACK

OPSOMMING VAN STUDIE

Oor die jare was daar 'n vinnige toename in die ontwikkeling van tegnologie. Die meeste navorsers het besef hoe belangrik dit is om tegnologie in onderrig- en leeraktiwiteite te integreer. Dit sluit kurrikulumbeplanning en onderrig met tegnologie in. IKT-toerusting is duur om te koop en in stand te hou. Slimfone deur middel van mobiele programme bied egter goedkoop alternatiewe en is geredelik beskikbaar. Die meeste van hierdie toepassings vereis nie 'n intekenfooi nie. Daar is beleide in plek soos die e-onderwysbeleid wat die gebruik van tegnologie in die klaskamer ondersteun, maar skole in die Vrystaat trek nie voordeel uit onlangse tegnologiese ontwikkelings nie. Hierdie beleide dui egter nie aan hoe 'n slimfoon in die klaskamer gebruik kan word en wanneer om dit te gebruik nie. As gevolg van die talle toeps wat in toepassingswinkels gepubliseer word, is dit ook moeilik om 'n relevante app te vind vir gebruik in die klaskamer. Hierdie studie is gebore uit kommer dat Suid-Afrikaanse skole nie oor IKT- en fisiese wetenskappe-hulpbronne beskik nie en dus nie die belangrikheid van die gebruik van slimfoontegnologieë sal besef om leeraktiwiteite in 'n fisiese wetenskappe-klaskamer te impakteer nie. Dit skep dus 'n digitale gaping tussen Suid-Afrika en die res van die wêreld. In 'n poging om die rol wat gratis mobiele toepassings in 'n fisiese wetenskappe-klaskamer kan speel, te verstaan, het hierdie studie ondersoek ingestel of leerders weet hoe om programme veilig te bekom en hulle te assesseer vir geskiktheid en toepaslikheid in die klaskamer. Daarbenewens is die leerders se vermoë om toepassings in die klaskamer te gebruik, ook ondersoek. Onderrig- en leerbeleide en KABV is gebruik om die studie in te lig oor watter tipe vaardighede leerders in fisiese wetenskappe moet aanleer. Daarbenewens het TPACK inligting verskaf oor die verskillende soorte kennis wat 'n opvoeder moet besit om tegnologie in onderrig- en leeraktiwiteite te integreer. Hierdie gelyktydige gemengde-metodestudie het 72 graad 10- en 11 fisiese wetenskappe-leerders van 2 skole in die Suid-Vrystaat met observasieblad en vraelyste gebruik om die impak van die gebruik van mobiele toepassings in onderrig- en leeraktiwiteite in 'n fisiese wetenskappe-klaskamer te ontdek. Dit is gedoen deur die toets van 4 toepassings, naamlik die fisiese wetenskap mobiele app, WhatsApp, die skoolbeplanner-app en Google klaskamer-app.

Sleutelbevindinge toon dat leerders weet hoe om mobiele toepassings op hul eie te bekom. Dit kan verkry word vanaf 'n app-winkel, of die internet deur middel van 'n blaaier en deur sagteware te deel waarmee programme as 'n APK-lêer gedeel kan word. Daarbenewens weet leerders hoe om inhoud te evalueer deur die toepassings relevant tot fisiese wetenskappe. Leerders se ervarings het aangedui dat programme gebruik kan word om beplanning te

beïnvloed, voldoende oefening te verskaf en kommunikasie tussen onderwysers en leerders te verbeter. Die gebruik van toepassings plaas die leerders in beheer van hul leer deur hulle toe te laat om gebeure vir ‘n later datum te skeduleer en om op enige stadium te kan oefen sonder die toesig van 'n opvoeder. Die gebruik van toeps/apps in die klaskamer het dit egter ook vir leerders makliker gemaak om mekaar se werk te kopieer – dus moet die gebruik van toeps in die klas onder toesig geskied.

Hierdie bevindings versoek dus ‘n aanbeveling oor die daarstel van beleide wat gebruik kan word om slimfoongebruik in die klaskamer sodanig te rig dat effektiewe leer sal plaasvind. Daarbenewens moet die gebruik van toepassings in skole bevorder word om leerders voldoende hulpbronne te bied sodat met gemak toegang tot leerinhoud verkry kan word om sodoende die gebrek aan hulpbronne in skole aan te spreek. Onderwysersopleiding moet ook die gebruik van IKT in skole insluit om leer te fasiliteer. Leerfasiliteerders kan gebruik word om die vordering van leer, deur middel van slimfone, in die klaskamer te monitor. Toekomstige studies moet gebruik maak van oogopsporingsagteware wat gebruik kan word om die areas te bepaal waarna leerders kyk wanneer hulle 'n toep gebruik, wat dus daartoe kan lei dat beter toepassings/toeps vir onderrig- en leerdoeleindes geskep word.

Sleutelwoorde: mobiele toepassings/toeps; IKT; TPACK; kurrikulum; integrasie van tegnologie; onderrig en leer; digitale gaping; Leer met tegnologie

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CLOSSARY OF TERMS

Android: operating system primarily used in mobile devices.

Denarian: A person who is between 10 and 19 years of age.

e-Education: The delivery of education or any type of training by electronic teaching methods.

Excel Data Analysis ToolPak: It is an Excel add-in program that provides data analysis tools for financial, statistical and engineering data analysis.

Google Play Store: The official distribution storefront for Android applications and other digital media such a music, movies and books, from Google. It is available on mobile devices and tablets that run the Android operating system (OS), supported Chrome OS devices, and on the web.

m-learning also known as **mobile learning**: accessing learning content through mobile devices.

Mobile application: a type of application software designed to run on a mobile device, such as a smartphone or tablet computer.

Mobile device: a small handheld computer that has a touch display or a small keyboard for text input.

Operating system: The programme that, after being initially downloaded into the computer by a boot programme, manages all the other application programmes in a computer.

Software: The programs and other operating information used by a computer.

Triangulation: Data gathering using more than one source at the same time.

ABBREVIATIONS AND ACRONYMS

ABBREVIATION	DEFINITION
APK	Android Application Package
Apps	Mobile applications
CAPS	Curriculum Assessment Policy Statement
CK	Content Knowledge
DBE	Department of Basic Education
DoE	Department of Education
HCI	Human Computer Interaction
ICT	Information Communication Technology
ITCs	Information Communication Technologies
NCS	National Curriculum Statement
OS	Operating System
PCK	Pedagogical Content Knowledge
PK	Pedagogical Knowledge
SAMR	Substitution, Augmentation, Modification and Redefinition
SMS	Short Message Service
SUS	System Usability Scale
TIPC	Technology Integration Planning Cycle
TK	Technological Knowledge
TPACK	Technological Pedagogical Content Knowledge
TPK	Technological Pedagogical Knowledge
UX	User Experience

CHAPTER ONE

ORIENTATION TO THE STUDY

1.1 INTRODUCTION

Over the years, there has been a rapid increase in the production and use of cell phone technology (Engel & Green, 2011:39) which is accessible through the use of mobile applications (apps) which can be installed in cell phone devices. These can be bought or downloaded for free from online stores such as the Google Play Store or Apple iStore, depending on the operating system of the mobile device. Their uses range from banking, home surveillance, communication, games, fashion, beauty, entertainment, and many more (Clement, 2019a: Online).

In 2015, over 80 000 applications available from the Google Play Store were classified as educational (Atkinson, 2015: Online). Clement (2019b: Online) added that this category (apps classified as educational) became the most popular in the Google Play Store, with 9.13% of all apps being in the first quarter of 2019. As of September 2019, the number of educational apps classified as free and educational, totaled over 232 000 (AppBrain, 2019a: Online). Further, a single APK (Android Application Package) download of one application could be shared by many users.

In education, these applications enable learning to occur everywhere (Steel, 2012:877). In addition, applications combine numerous features, making it easier for students to access several functions simultaneously. Some of the available apps have the potential to boost communication between teachers and learners (Thomas, O'Bannon & Bolton, 2013:297). Moreover, educators can send notes to a group of learners, while learners can text or share videos, thereby improving communication and collaboration (Mdlongwa, 2012:3) amongst themselves. Some apps have multimedia elements such as pictures and videos.; for example, videos have been documented as being effective for learning activities as learners can follow instructions on a video, and then perform required tasks such as practical experiments (DeWitt, Alias, Siraj, Yaakub, Ayob & Ishak, 2013:1119).

The benefit of technological adaptations in the classroom has been documented by different researchers. However, in the Free State which was the area of focus for the study, there's limited literature on how apps are used in schools. This implies that more exploration still needs to be in done by DBE (department of basic education) in order to help educators understand the roles apps can play in the Physical Sciences classroom which may inform all role-players of the benefits that might be gained from apps. The potential that applications could have in Free State high school classrooms needs to be explored more incisively to conscientise all stakeholders of its benefits. Research on how each province in South Africa integrated Apps in education was not readily available except for Gauteng province. Masango, Van Ryneveld and Graham (2022:337) stated that Gauteng Department of Education launched paperless classrooms which included supplying learners and educators with laptops, tablets and smartboard as well as providing educators with training. This project incurred billions of Rands. For this reason, literature from GDE may not apply due to the astronomical costs involved in launching the project. Moreover, there was limited literature on app usage for physical sciences in the classrooms across South Africa therefore indicating that more research is needed in order to assist educators in the integration of technology in pedagogical practices.

Kreutzer (2009:48) mentions that 97% of learners in low-income schools in South Africa have access to cell phones. Introducing educational applications to learners was easy as they already own the necessary devices where the applications can be installed. Furthermore, 80% of the learners are reported to be dependent on their cell phones (Pieterse, 2016: Online). As learners take their mobile devices (cell phones) everywhere they go, this means learning can potentially occur anywhere if the necessary applications have been installed. This makes applications ideal for learning. In this study, applications (Google Classroom, School Planner, WhatsApp and Physical Sciences mobile apps) were introduced to denarian and vicenarian learners who were motivated to explore how these apps impact on learning in the Physical Sciences.

This study sought to explore how easily accessible apps from the Google Play Store can influence learning in a Physical Sciences classroom in the Southern Free State in Grades 10 and 11. In this context ‘free’ refers to products that do not charge a subscription fee. This study is limited to applications that can be used to promote learning housed in Google Play Store.

1.2 STATEMENT OF THE PROBLEM

This research project explored how free mobile learning apps can affect learning in Physical Sciences education for Grades 10 and 11 in southern Free State schools. Such learning apps via the cell phone have not yet been fully exploited in the Free State schools especially in terms of enhancing the quality of learner-performance in the Physical Sciences. Accordingly, such a situation called for interventions which were recommended through the findings of this study.

1.3 THEORETICAL FRAMEWORK

Grant and Osanloo (2014:14) view a theoretical framework as a "blueprint to a house" in which the student and the researcher choose and what is to be build and how the process is carried out based on their imagination. Swanson (2013 as cited in Kivunja 2018: 46) added that a theoretical framework "is the structure that can hold or support a theory of a research study". It is evident that theoretical framework assists the study in researching and applying appropriate theories that guide the research process. The problem statement above (1.2) implies that the research had to use models that assist in the implementation of ICT studies in education. There are numerous models that can be used for this purpose such as the SAMR (Substitution, Augmentation, Modification and Redefinition) model, TIPC (Technology Integration Planning Cycle) model, and TPACK (Technological Pedagogical Content Knowledge) theoretical framework (see 3.2 for discussion of SAMR, TIPC and TPACK). The TPACK framework was best for this study because of the seven knowledge areas it possesses (Pedagogical Knowledge, Content Knowledge, Technological Knowledge, Pedagogical Content Knowledge, Technological Pedagogical Knowledge, Technological Content Knowledge and finally Technological pedagogical content knowledge). This is because Fu (2013:112) emphasised that education is an ongoing process, where the expectations of the learners to acquire information are changing away from traditional approaches. Learners must be engaged in the learning process to effectively gain from educative processes which may not be limited to classroom spaces. This, therefore, made ICT imperative for learning as it greatly influences how knowledge is acquired since ICTs provide educators and learners with the necessary tools and sources to actively access knowledge and skills (Paily, 2013:39; Mikre, 2011:116).

The literature highlighted above indicated the expectations and the role ICTs can play in education. These expectations were best answered by TPACK. This is because TPACK is viewed as the centre as to how technology can be used to support content-specific pedagogical strategies (Graham, Burgoyne, Cantrell, Smith, St Clair, and Harris 2009: 71). For instance, due to the changing ways of learners to acquire knowledge, an educator must possess knowledge in Pedagogy, knowledge of the content and knowledge of how to use the content in pedagogy to assist in knowledge creation that accommodates the different ways knowledge is acquired. In addition, knowledge in suitable communication technologies promotes the engagement of learners in the learning process and how to use those technologies in pedagogical practices. TPACK can assist in selecting the technology which is to be used in a classroom such as the cell phone or laptops and how it is to be used. Tremblay (2010:217) added that that cell phones (technology) make the classroom more interactive, facilitates the learning process, and creates much interest in the lesson. Additionally, cell phones can be used in a learner-centred classroom creating much differentiation in instruction by promoting active participation and the construction of new knowledge (Thomas & O'Bannon, 2013:11). Furthermore, learning content is accessible in any space as cell phones are portable; hence, the use of ICTs in the classroom encourages learners to actively engage in new learning processes. The arguments raised by Tremblay (2010) and Thomas etal. (2013) as discussed above further emphasized the importance of technology in the education of learners in the classroom therefore placing the importance on the TPACK framework to the study as it enriches the learning experience. The TPACK knowledge areas therefore informs the research on the type of knowledge that an educator must possess in order to effectively guide the implementation of ICTs in education. This framework was also used in this study to guide the research process on the apps which were to be used in the study and the role they were to play in the study.

The benefits of ICT implementation have been thoroughly documented by different researchers as demonstrated above. However, due to poor infrastructure and the lack of resources in most schools, ICTs cannot be adequately utilised to benefit learners thus this creates a digital gap in the country (Sherman & Howard, 2012:2100). This calls for urgent interventions to be implemented to bridge this digital gap existing in most South African schools. Moreover, the notion of integrating free applications into classroom teaching-learning situations has not been sufficiently researched. As such, learners actively acquiring knowledge through technology had to be the focus area of this research. For this to occur, learners were guided to relevant resources (apps) which could be used to enhance their learning capabilities. This study sought to provide guidance for constructive learning in the Physical Sciences by exploring and unearthing the positive impact of free mobile applications. Accordingly, this study employs the pragmatism approach.

1.4 RESEARCH QUESTIONS

1.4.1 Primary Research Question

- What effect will the use of free mobile learning applications have on learning in Grade 10 and 11 Physical Sciences classrooms in the southern Free State?

1.4.2 Secondary Research Questions

- How does principles of teaching and learning influence learning in a physical sciences classroom?

- How does a teaching approach impact learning in a physical sciences classroom?
- What is the role of the CAPS document in classroom learning?
- What is the role of the TPACK framework in education?
- What is the role of digital technologies in learning?
- How has mobile technology been integrated in education?
- What are the abilities of the learners to select and acquire mobile applications for classroom usage?
- What are the abilities of the learners to test apps for suitability and applicability in the physical sciences classroom?
- What are the experiences of learners regarding the use of mobile learning applications?
- How does app usage in a classroom affect teaching and learning activities in a physical?

The primary research question combined education practices with app usage in that it aimed to understand how app usage affect learning. This implied that a theoretical basis for learning and for app usage had to be established therefore these secondary research questions (one to six) provided the necessary theory which was used to provide the basis for the study.

1.5 RESEARCH AIM AND OBJECTIVES

1.5.1 Aim

The aim of this study is to determine how free learning mobile applications can influence teaching-learning in the Physical Sciences in southern Free State schools.

1.5.2 Objectives

- Investigate how principles of teaching and learning influence a Physical Sciences classroom.
- Investigate how teaching approaches impact learning in a Physical Sciences classroom.
- Investigate how the policy stipulations of the CAPS document influence teaching and learning in a Physical Sciences classroom;
- Determine the role of the TPACK framework in science education;
- Assess the role of digital technologies in education;
- Investigate how mobile applications have been integrated in education;

- Observe the abilities of learners to select and access mobile applications for classroom usage;
- Evaluate procedures that can be used to assess app suitability and applicability for classroom usage;
- Investigate the experiences of learners regarding the use of mobile learning applications; and
- Determine how app usage in a classroom influences teaching and learning activities in a Physical Sciences classroom.

1.6 RESEARCH DESIGN

This study uses the mixed method research approach. Creswell (2013: 23 of 270) defines this approach as the “inquiry that combines or associates both qualitative and quantitative forms”. Additionally, Tashakkori and Creswell (2007:4) define mixed methods as the gathering and analysis of both qualitative and quantitative data in a single study. This approach allows for data triangulation to take place therefore increasing the credibility of the data (See 4.5.5). This study made use of the triangulation convergent design. Triangulation convergent design allows for collection of different but complementary data to be collected at the same time (Morse 1991: 122) thus making it easier to understand the research problem from both qualitative and quantitative views (See 4.4). This study uses both qualitative and quantitative methods in a single study. Specifically, the triangulation convergent design was applied where the qualitative data was collected using qualitative methods, and quantitative data was collected using quantitative methods. Both data types can be analysed using appropriate analysis techniques suitable for each method. After which, the data was mixed at the interpretation phase.

Qualitative methodology provides a researcher with a description of behaviours in the classroom as the learners interact with the apps. This is conducted through participant observations. Quantitative methodology provides the user rating of each software recommended which is then used to determine the value and usability of the software. The combination of both quantitative and qualitative data therefore informs the research on how the participants interacted with the apps, and how they view that particular app (see data collection 1.7 below). The data gathering process can therefore be divided into the qualitative and quantitative phases. Both phases were to be used regarding the following apps: Google

Classroom, School Planner, WhatsApp, and Grade 11 and 10 Physical Sciences applications in both phases. The criteria used to select these apps are outlined in chapter 3.

This study consists of 3 stages: app discovery, app testing, and app usage such that each stage has a different purpose. *App discovery* is aimed at discovering the different ways learners use to acquire apps. *App testing* is focused on learners interacting with the recommended apps for testing purposes. The last stage, *app usage*, aimed at learners using apps in classroom spaces. These 3 stages are used to inform the study if learners are able to find apps, test apps, and use apps; next they can then be used to suggest recommendations for further study. The 3 app stages are explained theoretically as follows:

Stage 1: App discovery

Participants are tasked to think of a topic they struggle with, and then find 3 apps that might be of help to them concerning the chosen topic. Participants must work independently by searching for the relevant apps, and then installing them. Then they would test the apps followed by reflecting on their interactions with the software using the aforementioned questionnaires.

Stage 2: App testing

The researcher then introduces a specific application to the participants, which they need to interact with. Participants test the apps for relevancy in the Physical Sciences classroom and its usability. The participants then reflect on their experiences of this interaction with the recommended application (post-test questionnaires). This is then analysed by applying the appropriate data analysis methods.

Stage 3: App usage

The researcher chose a relevant app suitable to a relevant topic of discussion. Then, through WhatsApp, participants are informed of this topic before the study commences. These apps were topic-specific aimed at fulfilling lesson objectives. Questionnaires were used to gather data from the participants, with a focus on investigating their competency levels in the use of mobile applications (pre-test questionnaire). As the learners interacted with the recommended application, the researcher simultaneously recorded the observations in a journal. These observations and answers to questionnaires are then critically analysed. Conclusions are drawn from the data and then all relevant information is communicated to the co-researchers.

The stages mentioned above were then used to evaluate the impact that applications have on learning in a Physical Sciences classroom. Stage 1 is used to answer research question 7 while stage 2 is used to answer research question 8 and stage 3 is used to answer research questions 9 and 10. The planned research sequence was:

Table 1: Sequence for the study for stage 2

Planned sequence	Planned activity and technique used
1st	Recommend an application based on the lesson plan and the desired aims of the learners
2nd	Observe participants' interaction with the applications
3rd	Provide participants with post-task questionnaires to facilitate reflection on the recommended software
4th	Record and analyse participants' responses
5th	Researcher reflects on the recorded observations

This study was underpinned by the pragmatism paradigm. Goldkuhl (2012:136) believes that pragmatism is "concerned with action, change and the interplay between knowledge and action". In this study learners were required to perform the following actions: discover apps, test apps, and use apps in a Physical Sciences classroom as indicated above. This paradigm is therefore ideal as it allows the researcher to observe learners' actions, and how those actions lead to the creation of knowledge. Furthermore, Johnson and Onwuegbuzie (2004:17) cited in Cameron (2011:101), regard pragmatism as being effective for mixed methodology as it advocates the "middle position philosophically and methodologically". This implies that researchers can use more than one method (both philosophically and methodologically) in a study to find answers to their research questions. The implication is that a researcher does not have to adopt constructive or positivistic ontological and epistemological assumptions, but rather assumptions that are necessary to provide answers to the research questions. Therefore, a research study may incorporate both quantitative and qualitative data in a single study as they are not restricted by either qualitative or quantitative approaches. Pragmatism is therefore the most appropriate approach to provide answers to the main research question.

1.7 DATA COLLECTION

Axinn and Pearce (2006:1) stated that data collection strategies for mixed methods "combine elements of one method such as structured interviews with elements of other methods such as observations". This implies that more than one method can be used to gather qualitative data and quantitative data. For instance, a study can use interviews and observations to inform the qualitative data. In this study, data was collected through document analysis, observations, tasks, and questionnaires. Document analysis was necessary as it helped review the existing literature which provided orientation to the study, select appropriate theoretical framework and methodology for the study. The first six objectives were realized through document analysis whereas observations were used to answer research question seven. Task sheets helped in realising research questions eight to nine while questionnaires were used to answer research question 6 to 10 (See table 27).

The observations proceeded via video recordings and entries in a research journal. Video recordings were used to study learner-interactions by utilising relevant software which afforded the researcher the ability to review the data as many times as possibly necessary (Pirie, 1996:3). Furthermore, they promote data integrity, as the methods used by the researcher were all recorded such that any malpractice could be easily identified. Journal entries was used together with video data to very observations made by the researcher. Also, questionnaires provided feedback on the specific app being used, and they fostered anonymity of identities and information which was captured expeditiously (Debois, 2019: Online). Additionally, questionnaires are easier to distribute to reach a wider audience, are affordable, and provide an immediate response (Mathers, Fox & Hunn, 2007:9). Participants were handed questionnaires to gather demographic data and to investigate their competency levels in using mobile applications (pre-test questionnaire). Demographics data helps The study followed the *3 app stages* as explained above.

The data gathering process employed app discovery, app testing, and the app usage stages (See research plan chapter 4). Participants were provided with internet connectivity, and their ability to find apps for classroom usage were tested. Participants tested WhatsApp, Google Classroom, Physical Science mobile apps, and the school planner apps. Participants were required to reflect on their use of the recommended apps through an app review questionnaire and a SUS questionnaire. Each questionnaire was tailored for a specific purpose in the study (this is discussed later in chapter 4). In addition to the tools mentioned above, the study utilised task sheets for app testing. Because the 4 apps are different, each task was specific to a certain app. These tools, together with observations, aided in collecting suitable data for the study. This therefore allowed the researcher to collect both qualitative and quantitative data.

1.8 SAMPLING

Bhardwaj (2019:58) defined sampling as "a procedure to select a sample from individual or from a large group of population for certain kind of research purpose". The study sampled learners in Grades 10 and 11 from three different schools in the southern Free State Province of Republic of South Africa. Teddlie and Yu (2007:85) indicated that mixed methods designs can combine both probability and purposive sampling techniques to provide answers to the research questions. This study made use of random purposive sampling method when selecting participants. Only learners enrolled for the Physical Sciences as a subject participated in this study as they met the inclusion criteria (Acharya, Prakash, Saxena & Nigam, 2013:332). It was also of benefit to the researcher to choose participants who were easily accessible (Etikan, Musa & Alkassim, 2016:2) and in close proximity to the research sites. This allowed the researcher who resided in the area to save on travel costs and to have sufficient contact time with the learners. This ensured that data captured was of rich quality for the study.

1.9 DATA ANALYSIS AND QUALITY ASSURANCE

Ibrahim (2015:99) defines data analysis as "the process of performing certain calculations and evaluation in order to extract relevant information from data is called data analysis." The pre- and post-test questionnaires were analysed through the SPSS and the Excel Data Analysis ToolPak. The Data Analysis ToolPak is an Excel add-in program that provides data analysis tools for financial, statistical and engineering data analysis. This includes descriptive statistics, ANOVA test, correlation, histogram, t-test and any other inferential statistics that that can be performed in SPSS. This tool was used because it is readily available and the researcher is familiar with the ToolPak. In this study both qualitative and quantitative data were collected. Each type of data was analysed using relevant data analysis methods specific for each type of data.

Statistical analysis was applied to test the correlation between the learners' performance and behaviour. The data from observations and learners' responses were compared to test the correlation of the two types of data. Hypothesis testing was conducted on quantitative data and qualitative data after which all data was coded to categorise themes and patterns in the data (thematic analysis). This study utilised both descriptive and inferential statistics. To ensure data validity and integrity, triangulation processes were used (Bryman, 2004:1).

The results were presented with the aid of tables and graphs to provide an in-depth analysis. Conclusions were drawn from the results, and recommendations were suggested based on the findings.

The results and the evidence from literature determined the impact that free mobile applications have on learning in the Physical Sciences.

1.10 VALUE OF THIS RESEARCH

This study sought to add to the body of knowledge in various ways. It aimed to provide learners with the necessary tools to guide knowledge-creation through the use of mobile applications. Noor-Ul-Amin (2013:2) emphasises the potential of ICT to greatly accelerate and enrich learning. It is cheaper to use the resources that the learners already (cell phones) possess than buying new equipment. Further, the study could assist in recommending the review of policies on education to aid in the successful implementation of ICTs through mobile learning applications, especially in times of crises like the Covid-19 pandemic. Moreover, this study promotes ways in which educators and learners can communicate effectively. Also, it will aid educators in their pedagogical development in the Physical Sciences through the use of cell phones. In addition, Wang and Woo (2007:70) believe that ICT integration can lead to new educational practices. The study introduces new developments in education which expand the existing body of knowledge, thus eventually decreasing the gap in the usage of learning applications in Free State classrooms.

1.11 ETHICAL CONSIDERATIONS

The researcher sought and received permission from the Free State Department of Education, the learning facilitators of the subject in the Motheo District, the principals of the selected schools, and the parents/guardians of the learner-participants. The relevant documents (attached as appendices) provide evidence that the researcher received full permission to conduct the study at the selected schools. Each participant was required to sign a (voluntary) consent form before the commencement of the study. The participants were informed on all details of the research processes as required when complying with ethical practices (Jones, 2012:151). In addition, the researcher reported the correct findings of this study to ensure and preserve data quality. Additionally, the researcher was working under a supervisor. The use of video recordings (with permission) demonstrated the authenticity of the data gathering processes, which fostered validation to the data. The researcher, in addition to member checks, reported the findings to the participants as co-researchers in this study.

1.12 CHAPTER LAYOUT

The *first chapter* informed the reader of the purpose of the study and how the study was conducted. The reader was first provided with the background of the study, and then an overview of the literature. The purpose of the study was communicated through the research aim and research objectives. Chapter one also informed the reader on the relevant research design and how the study contributed to the body of knowledge. Lastly, the ethical considerations were outlined.

In *chapter two* studies from published literature were discussed to identify principles associated with teaching and learning in a Physical Sciences classroom.

In *chapter three*, digital technologies as a method of enhancing learning, was explained.

Chapter four discussed the research design in detail. It fully described the methodology, timeline, and how the data was captured and analysed. Furthermore, the sampling techniques employed by the researcher and the population size were provided.

In *chapter five*, the results were analysed. This analysis was used to present the findings on how learners viewed the software which they utilised.

Chapter six outlined the conclusions based on the results presented in chapter four. This was used to evaluate and suggest recommendations concerning the impact of free mobile applications in Physical Sciences classrooms.

1.13 LIMITATIONS

This study was limited to learners enrolled in the Physical Sciences in Grades 10 and 11. Each participant was required to possess a smart phone in order to participate in the study. In addition, this study is limited to schools only in the southern Free State as data gathering is expensive and time-consuming if one has to travel distances to access research sites. The two schools were approximately 40 kilometres away from each other thus making them accessible to the researcher. Moreover, Grade 12 learners were excluded in this study due to them being involved in studying for the National Examinations. A further limitation included not using Apple operating system phones which are very costly and not within reach of the majority of the participants who were from underprivileged families. Additionally, only applications classified as educational in Google Play Store were used in this study, hence the researcher only made use of 4 apps, after a thorough literature study was conducted to decide on which relevant apps to access. Also, limited data budgeted for the study made it difficult for selected learners to download the required apps for the study.

1.14 CONCLUSION

The purpose of this chapter was to provide an introduction into the study. This was accomplished by first covering the study's background and describing the problem statement. Secondly, the chapter also presented an overview of literature related to the study. Further, the research questions, the aim, objectives, the overview of the methodology, the research design, and the research paradigm that was used to guide the study, were articulated. lastly, the contribution of this study to the research community, ethical considerations, and the chapter layout were provided. The next chapter provided a more detailed review of the literature related to this study.

CHAPTER TWO

TEACHING AND LEARNING IN A PHYSICAL SCIENCES CLASSROOM

2.1 INTRODUCTION

Chapter one provided the orientation to the study which pertained to investigating the impact of mobile applications in a Physical Sciences classroom. This chapter (2) focused on the principles of teaching and learning, teaching approaches, teaching techniques that guide teaching-learning processes in a Physical Sciences classroom. This chapter commenced with the discussion of teaching principles adhered to in the classroom. This is then followed by the description and impact of teaching approaches commonly used in the classroom. Lastly, the focus shifted to pedagogical content knowledge (PCK) as guided by CAPS. The role of this chapter was to provide an understanding of how learning occurred without the intervention of mobile applications as well as provide theory into the rules that must be adopted for teaching and learning.

2.2 TEACHING AND LEARNING PRINCIPLES

2.2.1 Teaching Principles

Teaching is regarded as an "intimate contact between a more mature personality and a less mature one which is designed to further the education of the latter" (Rajagopalan, 2019: 5). This indicates that an engagement has to take place between an educator and a learner to help learners gain knowledge; therefore, in teaching, both the educator and the learner can play various roles. This type of engagement is facilitated by teaching approaches which are discussed in 2.3. Teaching is guided by principles. A teaching principle is defined as "a rule for guiding the ship of education so that it will reach the port designated by the philosophy of education; it is a compass by which the path of education is directed" (Srivastava, 2019:20). The implication is that teaching is governed by a set of rules which must be adopted by both the educator and learners in order for effective teaching-learning to occur. These principles then influence approaches which are used in pedagogical strategies, methods and techniques.

In this regard, Barrick and Thoron (2020: 1-2) propose 4 principles which must be adopted in teaching: organisation and structure of the subject matter, providing motivation, reward and reinforcement, and techniques used in instruction.

These principles are discussed below:

2.2.1.1 Organisation and structure of the subject matter

When subject matter to be learned is organised and structured and clear to the learner, it becomes easier for learning to take place in a classroom. This is because content becomes clear to the learners and learning happens rapidly. In order to enable the rapid learning of the subject matter, the amount of experience learners possess concerning the subject matter must be considered. The implication is that teachers must know the type of learners in front of them, and how much experience they possess in the subject matter. Learners' prior knowledge influences the rate at which they can effectively learn new content, and how it is imbibed (Walberg 2010: 8). Teachers must therefore have a clear understanding of what knowledge learners possess in order to build on this previous knowledge thus making it easier for learners to learn new knowledge (National Research Council of United States, 2002: 140). Teachers must then be prepared to devise ways of organising and structuring a lesson to promote learning based on the learners' prior knowledge. Also, the presentation of the content must be organised astutely to suit the learner and must be appropriate to suit the cognitive levels of the learners. In physical sciences, the assessment guidelines help in organising the content (see appendix Q). This guidelines details how long a subject matter to be taught should last, the resources to be used as well as the knowledge to be build from. For instance, chemical reactions in grade 10 builds on the introduction of chemical reactions covered in grades 8 and 9. Learners need this prior knowledge in order to handle the demands of the same topic in grade 10 and above.

Also, the organisation of the content must be logically structured. Research indicates that there are several ways content can be arranged for classroom teaching. Content organisation must commence from the curriculum design stage. Curriculum goals must be made clear (American Association for the Advancement of Science 2001: 45) in order to decide on how the subject matter is to be designed. Curriculum goals are used to assist educators to plan different ways subject matter can be structured, in addition to selecting the type of techniques which will be appropriate for the acquisition of new knowledge and skills. To understand the curriculum requirements and organisation of the Physical Sciences subject in South Africa, the CAPS document, together with the assessment guidelines used in the Free State province were analysed in section 2.4.

In sum, subject matter organisation depends on curriculum goals. These goals assist in choosing the relevant teaching techniques which can be applied to assist learners in gaining new knowledge. New knowledge is based on prior knowledge, hence the need for educators to understand the learners' prior knowledge. It is therefore integral that teaching must be meaningful to the learner and should be organised at a level understood by learners to make it more meaningful to real-life situations. Understanding the subject matter, coupled with learner motivation, influences how successful learning occurs in classroom.

2.2.1.2 Providing motivation.

Motivation plays a significant role in a classroom. As stated in the organising and structuring of the subject matter above, teaching must be facilitated by considering the competency level of the learner. As such, teaching-learning processes should consider the interests, aspirations and needs of the learners. Hammer (2001:53-54) suggests that learners should be motivated to learn which occurs if they are involved in the setting of goals, setting of the classroom environment, and engaged in interesting topics. Ur (1996: 280) adds that interest in the subject can be increased by the personalisation of tasks and activities, setting clear task goals, using varied topics, and providing entertainment. Barrick and Thoron (2020:2) claim that "learners are motivated when they attempt tasks that are challenging to the extent that success is perceived to be possible but not certain". It is evident that motivation plays a critical role in teaching-learning situations. As such, there are different strategies that have been documented to increase learner motivation to excel in the classroom. Learners must be included in planning learning activities that challenge and stimulate their interest in the subject; hence, making learning easier and enjoyable. In addition, "the motivational level of the learner is increased by the contact between the learner and environment, and teachers and fellow learners" (Urdan & Schoenfelder, 2006: 333). Therefore, the responsibility rests on the shoulders of both the teacher and learners to keep the class motivated. Motivation alone is not enough to encourage learning, reward and reinforcement also play a vital role.

2.2.1.3 Reward and reinforcement

Reinforcement can be regarded as being either positive or negative. Positive reinforcement is defined as "encouragement that follows good behaviour" (Eremie & Doueyi-Fiderikumo 2019: 25). Both positive and negative behaviour must be reinforced in the classroom. Teacher-behaviour influences how a learner engages in a classroom (Skinner & Belmont 1993: 578). Therefore, the engagement of a learner in lessons can be seen as positive or negative depending on how a learner interprets the actions of a teacher. A positive attitude towards a learner can therefore positively influence the behaviour of a learner in a Physical Sciences classroom as learners perform better when they feel that their actions are valued. Cosgrove (1982), cited in Baranek (1996:11) believes that if immediate praise is given to positive learner behaviour, this increases chances of this behaviour being reinforced. For example, praise from a teacher on a well-researched class assignment motivates the learner to increase efforts to better the previous score (Fitriati, Fatmala & Anjaniputra 2020: 600). Conversely, acknowledging the efforts of learners if they did not perform well, also provides encouragement to perform better. Furthermore, timeous feedback, a clear explanation as to where a learner went wrong when answering a question, and the use of positive language makes learners feel valued; therefore, this enhances the learning process. This acknowledgement can be made via body language, verbally by using positive language, and by the displaying positive attitudes to uplift the struggling learner. A teacher appending a star on a learner's paper after an assessment, is a sign of acknowledging high performance, and is regarded as a positive reinforcement.

Negative reinforcement is defined as an approach that may give unfavourable experiences to learners who tend to be disruptive to prevent re-occurrences of negative behaviours in the classroom. Tauber (1982: 64) asserts that negative reinforcement is actually a positive strategy for managing a classroom since it discourages bad behaviour thus granting both teachers and learners ample time for a smooth lesson-delivery. Furthermore, it reduces class disruptions and increases learner attention (Kelly & Pohl 2018: 27). A teacher can reduce the number of assignments given to the learners depending on how well they perform in class, both academically and in terms of discipline. Negative reinforcement is not punishment as it focuses on removing negative conditions to promote good behaviour, while punishment focuses on the negative behaviour. For instance, a learner who is late for class can be punished by sitting for detention after school hours, whereas in negative reinforcement you explain to the learner to be punctual as to not miss out on the interesting content to be covered in class.

Studies indicated above revealed that when behaviours are being reinforced, learners become more motivated to learn such sound behaviours. However, to be more effective, the response must follow immediately after the learner's behaviour. In a classroom both positive and negative reinforcements can be applied to manage discipline and increase learner engagement. Reward and reinforcement apply to all subjects. In a Physical Sciences classroom, it is equally important to reward and reinforce behaviours that encourage learning to take place. For instance, timeous feedback on completed assessment tasks must indicate the steps taken in to order to arrive at the correct answer, therefore allowing learners to recognise their mistakes, and then perform corrective work.

2.2.1.4 Techniques used in instruction.

Content must be presented in a variety of ways to inspire learners to gain a deeper understanding of it (Barrick et al., 2020: 2). The implication is that the same concept can be taught using different tools and techniques. For instance, in a Physical Sciences classroom, using computer simulations assists as a visual aid for learners to understand the flow of current in any electrical circuit, therefore fast-tracking the process for them to answer questions correctly relating to the topic. The same strategy can be applied when using a physical electric circuit to conduct experiments in the laboratories or classroom settings. Additionally, using iron filings to indicate the magnetic field lines facilitates or quickens learners' understanding of the concept of magnetism. Drawing a bar magnet and placing magnetic field lines around it, also depicts how electric field lines are arranged around a bar magnet. Gilbert (1978: 46) indicates that determining the lesson objectives is an effective way to assist an educator in selecting the relevant teaching techniques. Depending on the objectives, a teaching technique that best attains the chosen objective must be applied. Walberg (2010: 27) states that "teachers who provide good instruction also make use of several chief factors that affect learning: prior learning, coordinating content across grade levels, time spent on learning, motivation, and classroom morale".

Walberg (2010) and Barrick (2020) as cited above recognised that effective teaching is based on sound didactic principles. The type of instruction method must have the desired impact of learning on the learner. Therefore, adhering to principles mentioned above implies that effective teaching requires that the content to be taught must be organised, clear, and simple to understand. Moreover, learners must be rewarded for their quality efforts in class which may emanate from a lesson that motivates them to enhance their performance where the teacher uses a variety of teaching techniques in a classroom in order to accommodate diverse groups of learners and their needs. The next section discusses principles of learning.

2.2.2 Learning Principles

Effective learning is guided by both teaching principles and learning principles. As stated above, learners become highly motivated to learn when they are interactively involved in classroom activities. Furthermore, a learner-centred classroom (see 2.3.1) engenders critical-thinking, collaboration, communication, and creativity. Abbott (1994), as cited in Watkins, Lodge, Whalley, Wagner and Carnell (2002:1-8), defines learning as "that reflective activity which enables the learner to draw upon previous experience to understand and evaluate the present, so as to shape future action and formulate new knowledge". The implication is that effective learning is an active process that connects learners' prior knowledge to new knowledge, such that learning becomes enjoyable and relevant to real-life experiences hence, teaching-learning principles paves the way for learners and teachers to make learning effective.

The principles of learning have been extensively discussed by several researchers such as Brody, Brown, Clinkenbeard, Cross, Cross and Fülöp (2017:1) who proposed twenty principles (see table below). The first eight principles focus on how learners think and learn, principles nine to twelve focus on how to motivate learners, while principles thirteen to twenty focus on the learner's wellbeing, interpersonal relationships, and social context.

Table 2: Top 20 principles of teaching and learning (Brody et al., 2017:1)

Principle	**Description of the principle**
1	Students' beliefs or perceptions about intelligence and ability affect their cognitive functioning and learning.
2	What students already know affects their learning.
3	Students' cognitive development and learning are not limited by general stages of development.
4	Learning is based on context, so generalising learning to new contexts is not spontaneous, but instead it needs to be facilitated.
5	Acquiring long-term knowledge and skills is largely dependent on practice.
6	Clear, explanatory, and timeous feedback to students is important for learning.
7	Students' self-regulation assists learning, and self-regulatory skills can be taught.
8	Student creativity can be fostered.
9	Students tend to enjoy learning and perform better when they are more intrinsically than extrinsically motivated to achieve.
10	Students persist in the face of challenging tasks and process information more deeply when they adopt mastery goals rather than performance goals.
11	Teachers' expectations about their students affect students' opportunities to learn, their motivation, and their learning outcomes.
12	Setting goals that are short term (proximal), specific, and moderately challenging enhances motivation more than establishing goals that are long term (distal), general, and overly challenging.
13	Learning is situated within multiple social contexts.
14	Interpersonal relationships and communication are critical to both the teaching-learning process and the social-emotional development of students.
15	Emotional wellbeing influences educational performance, learning and development.
16	Expectations for classroom conduct and social interaction are learned and can be taught using proven principles of behaviour and effective classroom instruction.

Principle	Description of the principle
17	Effective classroom management is based on (a) setting and communicating high expectations, (b) consistently nurturing positive relationships, and (c) providing a high level of student support.
18	Formative and summative assessments are both important and useful but require a variety of approaches and interpretations.
19	Students' skills, knowledge, and abilities are best measured by assessment processes grounded in psychological science with well-defined standards for quality and fairness.
20	Making-sense of assessment data depends on clear, appropriate, and fair interpretation.

In line with teaching-learning strategies, Moss (2006: 5) grouped his principles into 5 areas, which assist in implementing quality education:

- Teaching and learning must be based on the understanding of the learner
- Learners must be actively engaged to derive meaning from instruction
- Classroom environment must be supportive and challenging
- Classroom partnerships enhance learning
- Teaching and learning must shape social and cultural contexts

Understanding the learner (Moss principle 1) means being able to understand how learners acquire new knowledge, what knowledge they already possess, what motivates them, and facts about their wellbeing. This is because learners' wellbeing (Brody et al. 2017 - principle fifteen) influences how they learn. Additionally, principles one to nine (table 2 above) help the teacher to understand how knowledge is formed, and ways in which learners can be motivated to learn; therefore, when a teacher understands these principles, then learning can occur with ease. Brody et al. (2017) suggest that long-term knowledge is attained through practice (principle five), and that when learners are actively engaged then learning occurs freely (principle nine). This is supported by theories pertaining to a learner-centred classroom, and by the second principle advocated above by Moss (2006). The paragraph above implied that practice is regarded as the best pedagogy technique as it fosters long term knowledge. Learners practicing questions pertaining to Newton's laws regularly means they can be able to answer questions that deal with Newton's laws as the content is already imprinted on to their brains.

The classroom atmosphere (Moss principle 3) plays a critical part in the learning process; hence it must be both supportive and challenging such that effective collaboration occurs within the classroom context. The classroom space becomes supportive when learners' cultural beliefs are considered since a classroom consists of learners from different socio-economic backgrounds and diverse cultures. Additionally, a classroom must be free of discrimination of any kind such that it can lead to a learner being comfortable to learn. Furthermore, principles of teaching espousing the role of motivation in learning is supported by Brody et al. (2017: 21), with reference to principles nine to twelve. Furthermore, to maximise the engagement of the learners, a teacher must help them master goals that can help them gain new skills and new knowledge. This may include short-term goals which are slightly challenging. Also, effective communication improves the classroom culture of learning and reinforces positive behaviour in learners. A teacher as an expert, must support learners by answering questions effectively while using appropriate language. Furthermore, learners must feel valued which can in turn motivate them to engage cordially with other learners. Active participation in learning activities must be encouraged as it enhances learning which is critical for the holistic social development of the learners (principle fourteen).

It is clear from the discussions above that effective learning is guided by prescribed principles. However, learners learn in unique ways, and these principles do not guide a teacher on how to accommodate different learning styles, nor on how to deal with learners who are struggling. These problems do not diminish the importance of the learning principles which indicate the basic roles learners and educators play in a classroom. These principles assist the teacher to understand a learner so that adequate pedagogical techniques can be adopted to enhance learning. Moreover, effective learning occurs when learners are engaged in a supportive classroom which provides the learners with a rich social and cultural context that facilitates meaningful relationships.

In sum, the learning principles therefore complement teaching principles in a sense that they recognise adequate teaching techniques must be adopted for effective learning to proceed. Lastly, even though motivation assists the learners in acquiring quality learning, a classroom still needs to be a supportive environment to encourage a learner to flourish.

2.3 TEACHING APPROACHES USED IN A PHYSICAL SCIENCES CLASSROOM

The Cambridge Dictionary (2022) defines an approach as "a way of considering or doing something". Richards and Rodgers (2014: 21) state that an approach describes the nature of the subject matter to be taught. Teaching approaches can then be defined in varied ways of delivering content while teaching in a classroom. These also influences the pedagogical strategies. Over the years, studies have identified and discussed numerous approaches that can be used in teaching and learning; however, some of these approaches can be classified as either teacher-centred or learner-centred (Al-Zu'be, 2013: 24-25). Other examples of approaches in teaching include the research-based approach (Schreiner, Louis & Nelson 2020:118), whole-child approach, problem-based approach, and the metacognitive approach. For the purpose of this study, discussions were based on teacher-centred and learner-centred approaches. Examples of these teaching approaches are listed in table 3 below.

Table 3: Examples of teacher-centred and learner-centred approaches

Teacher-centred approaches	Learner-centred approaches
Subject-matter centred approach	Interactive approach
"Banking" approach	Constructivist approach
Disciplinal approach	Integrated approach
Individualistic approach	Collaborative approach
Indirect, guided approach	Direct approach

The purpose of Table 3 was to illustrate different approaches that can be used to facilitate teaching and learning within each approach. Moreover, the purpose of the study is not on different teaching approaches but instead how app usage could potentially impact teaching and learning and therefore discussing each approach in detail does not aid in answering the proposed research questions. However, in order to understand how apps impact learning, it is important to understand how learning is carried out in a physical sciences classroom without the intervention of the apps hence the need to list the above-mentioned examples. Therefore, a generic discussion on both teacher and learner centred learning is sufficient for this study.

2.3.1 Teacher-centred Approach

The teacher-centred approach or traditional teaching refers to the "communication of knowledge to learners in a learning environment in which the teacher has the primary responsibility" (Serin 2018:164). Dambudzo (2015: 21) confirms that knowledge is transferred from an educator to a learner verbally while the learners listen. This information is based on the teacher's expert knowledge in the subject, and it is textbook-driven making it easier for learners to locate what they were taught from the textbooks. For example, in a Physical Sciences classroom, a teacher stands in front of class and teaches learners by writing on a chalkboard while explaining electrical circuits. The learners have to visualise the different types of circuits being explained by the teacher. Hence, learners are seen as “receptacles” or “raw material” (Kaymakamoğlu 2018:30) implying that the teacher takes sole responsibility in helping them gain knowledge through recitation. Garrett (2008:35) agrees that in a teacher-centred environment:

- The teacher is the only leader
- Responsible for organisation of the classroom and all the paperwork
- Responsible for administering discipline
- Makes and distribution of rules
- Learners are given limited responsibilities

Emaliana (2017: 60) confirms that teachers control all aspects of learning and that learners are expected to benefit from a teacher answering all their questions. Additionally, this approach is suitable for large classes as class activities can be carried out in a brief period of time. Further, class presentations proceed much smoother as learning materials have been thoroughly prepared by a teacher. Moreover, classrooms are easier to organise when only one person has to take responsibility for the organisation of the subject matter and classroom layout.

However, theories of learning view this strategy as problematic because it leads to boredom as learners’ interest in the subject is reduced. In addition, learners tend to retain less information as compared to a learner-centred environment. Since learning is not an active process for learners, they are viewed as passive listeners (Fahraeus, 2013: 1-6) and thus become less engaged in class discussions.

2.3.2 Learner-centred Approach

Learner-centred teaching “is an approach in which learners have control over the learning process” (Darsih, 2018:34). Serin (2018:164) contends that this environment must provide a suitable setting in which learners can hone their skills. Emaliana (2017:59) believes that learner-centred approaches promote self-directed learning, reflective learning, deep learning and provides learners with the necessary motivation. A learner-centred environment must therefore equip learners with the necessary skills that can aid in reflective and deep learning.

The educator enacts the role of a facilitator of knowledge (Mascolo 2009:4). The implication is that an educator is not regarded as the sole transmitter of knowledge but as someone who facilitates learning. Teachers must possess the ability to therefore interact and communicate with the learners effectively. These skills are key to guide learners on what they must do.

Learning is conducted collaboratively, but learners may learn both as individuals and in groups. Classrooms are organised in small groups to assist learners to effectively engage in small-group discussions. This is executed to promote better communication among learners. As such, the educator must walk around and supervise different groups, encourage participation, and help teach assessment skills.

Studies by Flom (2013) and Azadovna (2020:1) reveal 5 key characteristics of learner-centred instruction:

- engages learners in the hard, messy work of learning.
- includes explicit skill instruction.
- encourages learners to reflect on what they are learning and how they are learning it.
- motivates learners by giving them some control over learning processes.
- encourages collaboration.

These characteristics are discussed below:

2.3.2.1 Learner-centred teaching engages learners in the hard, messy work of learning

In a teacher-centred classroom, teachers do everything. However, as explained by Darsih (2018:34) in her definition of a learner-centred environment, learners take responsibility of their learning. The implication is that learners engage in curriculum planning, construction of knowledge, formative assessment, self-assessment, and selection of materials used in the learning processes. This means more responsibility is placed on the learners as compared to teacher-centred learning. However, Landry, Saulnier, Longenecker Jr & Wagner (2008:177) suggest that teachers must assist learners in designing the learning tasks. Therefore, teachers and learners work collaboratively to achieve the outcomes of daily routines and requirements as per the curriculum's guidelines.

2.3.2.2 Learner-centred teaching includes explicit skills instruction

"Learner-centred teachers facilitate learners how to think, solve problems, evaluate evidence, analyse arguments, and generate hypotheses - all learning skills essential to mastering materials in the discipline" Weimer (2012a:132). Although the role of the teacher has evolved to a facilitator of knowledge, the expectation is that the learners must still be taught different ways of actively gaining knowledge. For example, the demonstration of ohmic conductors by an educator through experimentation in class to show learners how they can investigate Ohms

Law and the construction of graphs that depicts the relationship between current and voltage, assists the learners to master the section on electric current. In line with this, the teacher can teach learners about what a hypothesis is, and how to evaluate to authenticate the hypothesis. Learners must be taught the necessary skills which can be used to guide the learning process.

2.3.2.3 Learner-centred teaching encourages learners to reflect on what they are learning, and how they are learning it

Learners must know what to learn, how to learn, and ways to reflect on what they have learned. The skills of instruction mentioned above must include different ways learners can be assessed. Landry, Saulnier, Longenecker Jr & Wagner (2008:176) believe that focusing on the learners' learning processes, enables the learners to attain the desired outcome from each activity. Additionally, assessment becomes authentic which then allows the learners to reflect on their learning processes and their understanding of the subject matter. The goal is to create an awareness among learners of their learning processes.

2.3.2.4 Learner-centred teaching empowers learners over learning processes

As stated above, studies reveal that the responsibility of the learning processes falls on both the teacher and learners (Wagner et al., 2008; Darsih, 2018; Flom, 2013). When learners are involved in the planning of the lesson's activities, this provides them with the necessary motivation to own the learning process in class. Darsih (2018:40) believes that learners can be motivated into taking responsibility for their learning by teachers delegating certain aspects of the curriculum to the learners to empower them with some type of control. For instance, learners can help to set tasks on relevant topics to be tackled in class, thus they will feel motivated to complete such activities successfully.

2.3.2.5 Learner-centred teaching encourages collaboration

"Learner-centred teachers work to develop structures that promote shared commitments to learning. They see learning individually and collectively as the most important goal of any educational experience (Weimer, 2012:81). The promotion of shared commitments implies that learners must team together and collaborate. Learners must therefore have the same commitment to learning activities. A teacher can also learn from learners. Learners can collaborate on a practical assessment by setting up the apparatus and performing the experiment together. According to Otukile-Mongwaketse (2018: 13), learning activities are more interesting to learners when they interact with their fellow classmates and tend to participate actively in their learning. Nagaraju (2013:) adds that learners tend to talk more in a learner-centred environment and this provides a sense of security for them while reducing their anxiety levels.

These 5 characteristics observed above can aid a teacher in creating a learner-centred classroom. A learner-centred classroom encourages critical-thinking, creativity, collaboration, and communication, and these can be achieved as discussed above. This is also supported by the learning principles discussed in 2.2.2, specifically principle 5. Additionally, principles of teaching (2.2.1.4) suits learner-centred environments as it believed that quality outcomes are achieved when learners work collaboratively by applying appropriate techniques to ensure maximum retention of knowledge and skills. However, implementing this strategy may prove to be challenging as it requires a thorough understanding of the approach which includes making-sense of different roles played by learners and educators, the skills which must be learned, and the curriculum.

2.3.2.6 Challenges of learner-centred teaching

All learners do not learn at the same pace, and therefore placing the responsibility of learning on the learners themselves, puts the educator at risk of not completing curriculum. Tadesse (2020:75) adds that there is in most cases time to implement active learning. Teachers have a prescribed curriculum which must be covered in a stipulated time. Additionally, this pressurises the educators to learn more about this approach, how it can be implemented, and how to successfully assess learners. Mascolo (2009: 8) believes that learning occurs better when a “more expert partner in a learning activity directs the learner, breaks down a task to make it more manageable, supports the deployment of a learner’s attention, helps to manage frustration and so forth”. This therefore implies that learning occurs better when a teacher (more-able partner) guides the learner (novice partner) in knowledge creation. It is therefore difficult to expect learners in the same classroom to be able to guide each other without the teacher’s intervention. Therefore, the teacher is still in charge of learning activities, therefore no burden is placed on the learner. Furthermore, Du Plessis (2020:4) adds that classrooms also become noisy as learners are constantly talking, and learners may miss some content knowledge as instruction is not delivered to all the learners at once. It is evident that a learner-centred approach may not hold all the answers when it comes to selecting an appropriate teaching approach; however, learning becomes active when learners are engaged throughout the lesson. Additionally, learners learn to communicate effectively since they learn from each other, which increases the retention of content for longer periods thus promoting to the mastery of the subject content as the learning process is designed to be collaborative in order to instil communication and teamworking skills (Darsih 2018:38). This method gives learners a voice thus increasing their motivation which is one of the key principles of teaching (see 2.2.1.2).

It is my belief as a researcher that in a Physical Sciences classroom, learners perform better through being actively engaged in the learning activities. This belief is based on 5 years of teaching the subject. A learner who is able to construct practical activities tends to understand the subject matter better since the learner has first-hand knowledge thus promoting retention. However, it becomes difficult to supply all learners with modern gas law apparatus in a large classroom as many schools may not afford such equipment; hence, making it difficult to provide learners with relevant experience. Large classroom sizes and lack of resources can lead to schools adopting a teacher-centred approach as compared to a learner-centred approach. Another issue is that teacher-training centres still operate on the premise that the teacher is the ‘knowledgeable other’ rather than as a facilitator of knowledge.

The choice of the teaching-learning approach therefore determines how learners were to be assessed, the responsibilities of teacher and learners, and methods of instructions used. In order to select best-practice techniques, it is best to understand the principles of teaching and learning which guide pedagogical practices.

Research indicates that there are numerous techniques which can be used in pedagogy. These techniques can either be used in combination or individually. However, teaching techniques must be relevant to the type of skills and knowledge learners must obtain, therefore the CAPS (DoE, 2006) document must be referred to constantly as a guide to foster quality teaching and learning.

2.4 PEDAGOGY OF CONTENT KNOWLEDGE

Shulman (1987:7) indicates that educators must possess a thorough knowledge on how to effectively integrate subject content knowledge into their teaching approaches so as to foster effective learning. This section outlines how the CAPS influences PCK in a Physical Sciences classroom.

In South African schools, CAPS plays a vital role in informing the educator on the necessary skills learners must acquire. According to the DBE (2011: 3), the CAPS document informs

South African curricula from Grades R to 12. As this study is based in a Physical Sciences classroom setting, this section reviews the CAPS document related to this subject. The CAPS document guides educators to understand time-allocation for each topic, which topics must be taught per grade, and methods of assessment on each unit of the subject.

By following the CAPS document, curriculum delivery becomes continuous. Subject matter covered in Grade 11 must flow cohesively to gel with the content to be taught in Grade 10. For instance, in the Table 4 below the section on electricity and magnetism is taught across Grades 10 to 12. The unit on electrical circuits in Grade 10 informs the learners in terms of measuring current, voltage, and resistance in both a series and parallel circuit; whereas in Grade 11 learners still use the same circuit but must be able to measure energy and power across each circuit component. In Grades 10 and 11 internal resistance is ignored when calculations are done in class activities, but in Grade 12, the same circuits learned in Grades 10 and 11 now include calculations involving internal resistance.

Table 4: Topics covered per grade in the same knowledge areas (DBE, 2011: 10)

Knowledge Area	Grade	Topic content
Electricity and magnetism	Grade 10	**Magnetism** (magnetic field of permanent magnets, poles of permanent magnets, attraction and repulsion, magnetic field lines, earth's magnetic field, compass), **Electrostatics** (two kinds of charge, force exerted by charges on each other [descriptive], attraction between charged and uncharged objects [polarisation], charge conservation, charge quantization), **Electric circuits** ([emf], potential difference [pd], current, measurement of voltage [pd] and current, resistance, resistors in parallel) 14 hours
	Grade 11	**Electrostatics** (Coulomb's Law, Electric field), **Electromagnetism** (Magnetic field associated with current-carrying wires, Faraday's Law), **Electric circuits** (Energy, Power) 20 hours
	Grade 12	**Electric circuits** (internal resistance and series-parallel networks), **Electrodynamics** (electrical machines [generators, motors], alternating current) 12 hours

Table 4 above shows what a learner is expected to learn in the Electricity and Magnetism knowledge area as described by CAPS in the Physical Sciences discipline. It is evident from the Table 4 that the CAPS aids teachers in understanding the quality of content knowledge they must possess to teach successfully in each grade, and how this knowledge serves as prior knowledge for the next grade. Teaching and learning are based on learners' prior knowledge which indicates that the CAPS is also based on pedagogic principles (2.2.1.1). Furthermore, the CAPS document includes assessment guidelines which explain exactly what must be taught within a knowledge area, and the period of time that must be allocated in each knowledge area. These guidelines are updated every year to keep up with the demands of the subject.

Table 5: Assessment guidelines for Grade 10, term 1 (DBE, 2021:3)

2021 Grade 10 Physical Sciences Recovery ATP

TERM 1 (45 days)	Week 1 ~~27 – 29 Jan~~ (3 days)	Week 2 ~~1 – 5 Feb~~ (5 days)	Week 3 ~~8 – 12 Feb~~ (5 days)
CAPS Topics	**MATTER AND MATERIAL: Revise matter and classification (2 hrs)**	**MATTER AND MATERIAL: Revise matter and classification (4 hrs)**	**MATTER AND MATERIAL: States of matter and the kinetic molecular theory (4 hrs)**
Requisite pre-knowledge	• Classification of matter	• Classification of matter	• Phases of matter
Resources (other than textbook) to enhance learning	• Study guides • Previous question papers • Mindset & You tube videos	• Study guides • Previous question papers • Mindset & You tube videos	• Apparatus to determine heating/cooling curve • Study guides • Previous question papers • Mindset & YouTube videos • Simulations
Assessment – Informal Assessment: Remediation	• Homework (n=3)	• Homework (n=3) • Informal test 1	• Homework (n=2) • Informal test 2
Assessment – SBA (Formal)	None	None	Formal experiment: Heating/cooling curve of water

The assessment guidelines indicate which topic is to be taught, what resources are to be used, and how assessments should be planned and executed. From the Table 5 above, a minimum of 3 weeks should be allocated to cover teaching aspects of matter and material. Learners must know the classification of matter and phases of matter. In order to assess the learners, a total of 7 homework activities, 2 informal tests, and a formal experiment involving the heating and cooling curve of water must be conducted. Additionally, the list of resources which aid teachers in their pedagogy is indicated.

The CAPS document is therefore integral to the teaching and learning of the Physical Sciences. It guides both the educator and learners on the knowledge areas they must focus on, and which skills learners must acquire from each activity. Furthermore, it provides them with relevant resources which can be used in both teaching and learning. Moreover, education becomes a continuous process where learners acquire new skills based on their prior knowledge. The teacher must demonstrate a variety of skills during lessons that assists learners to acquire the necessary skills. Therefore, teaching approaches (2.3) must address the needs of the learners as directed by CAPS.

Wahid, Hamzah and Zakaria (2020:1572) claim that when a teacher conducts teaching based on a certain approach, the implication is that the teacher has already chosen an appropriate method. This method must then be accompanied by a complementary technique. The relationship between the teaching approach, methods, and techniques is summarised in Figure 1 below.

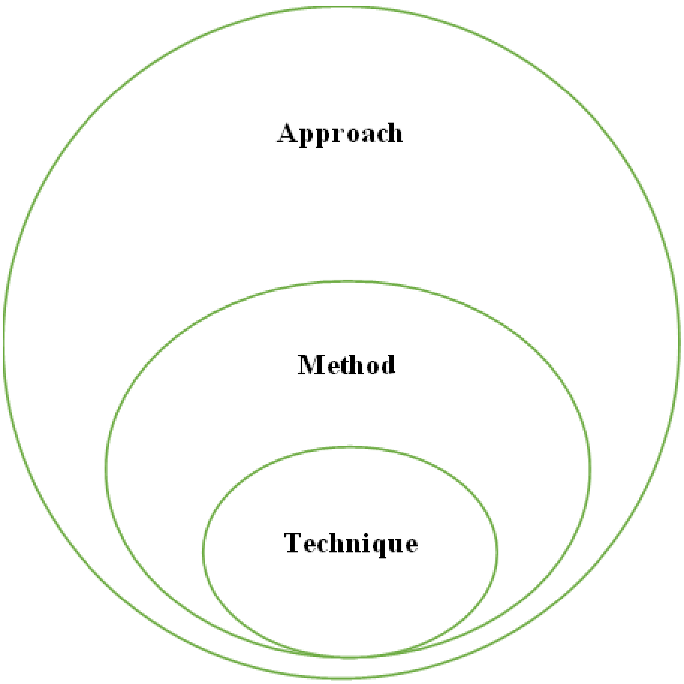

Figure 1: The dimension of teaching (Garcia, 1989, cited in Yusnita, 2014)

Figure 1 above indicates that an approach has several methods that can be used in teaching and learning. Additionally, methods have techniques that can be adopted within each method. Therefore, when an educator selects an approach to be used for instruction, the methods and techniques of instructions must already be visualised. A teaching method is therefore regarded as “a systematic series of teacher actions aimed at a teaching objective that has been set” (Wahid et al., 2020:1572). These methods include inductive and deductive teaching methods. Moreover, teaching techniques are important because they display the skills that educators must possess and apply in pedagogy.

Learning and teaching principles discussed above (2.2) play an important role in guiding the pedagogical practices of educators including classroom management. Techniques of instruction should foster learners to successfully acquire relevant knowledge (behaviours and thoughts) which includes understanding different methods learners apply to acquire content knowledge as well as knowing the different learning styles of learners.

Learners come from different socio-economic backgrounds and have cultural and religious differences. Additionally, learning occurs differently for learners and therefore teaching techniques employed must be for the benefit of the learner to assimilate and recreate knowledge. Principles of learning (2.2.2) indicate that a teacher must understand a learner in terms of understanding how they imbibe knowledge. Pashler, McDaniel, Rohrer and Bjork (2008:105) add that people differ in what mode of instruction works best for them. According to Gholami and Bagheri (2013:700), learners learning styles can be classified as visual, auditory, read/write, and kinaesthetic. The diverse way in which people learn implies that pedagogical techniques adopted must cater for all of these learning styles. However, curriculum in a physical sciences classroom is guided by the CAPS document so having a thorough understanding of this document helps a teacher understand the necessary skills which must be employed in a classroom while teaching the subject. As indicated above (2.2.1.4), a variety of techniques can be used in one lesson delivery where learners can be beneficially engaged in lesson activities.

Below are examples of techniques that can be used in a Physical Sciences classroom:

- Practice and repetition
- Discussions
- Scientific Method
- Direct instruction

These techniques are discussed below:

2.4.1 Practice and Repetition

With this technique, learners learn through repetition of learning activities. Bruner (2001: 1) states that "repetition matters because it can hasten and deepen the engagement process". Repetition used as a teaching technique helps learners increase their assimilation of the subject matter, and therefore information can actually be retained for a longer time. Through repetition, learners learn vital skills easily such as being able to recall, calculate, and apply skills they have been taught. Learners constantly practising answering questions that involve calculations pertaining to electrical circuits tend to master those skills with ease due to the fact that their learning was deepened by the repetition process. Therefore, the information was stored for recall in order to analyse for testing purposes, as well as in everyday routines. However, repetition can be boring and thus reduces motivation in learners. This can be corrected by providing learners with constant and timeous feedback (2.2.1.3). This technique falls under teacher-centred approaches and therefore has the same drawbacks mentioned in 2.3.1.

2.4.2 Discussions

Wilkinson (2009:330) regards discussions as the "collaborative exchange of ideas among a teacher and learners or among learners for the purpose of furthering learners' thinking". Discussions are regarded as examples of teaching techniques which can be used in a Physical Sciences classroom. They promote communication in the classroom while also giving learners a voice such that learners and educators collaborate to construct classroom activities. Additionally, discussions aid learners in the development of critical-thinking skills. Schwab (1954), cited in Larson (2000: 661), believes that discussions improve learners' communication and cognitive skills. As indicated in the teaching principles, learners must feel appreciated and motivated to participate in classroom discussions (see 2.2.1.2). A teacher expressing appreciation towards learners' contribution in classroom discussions encourages them towards greater participation which challenges them to think critically about topics in learning environments. The role of the teacher is to function as a facilitator in the classroom while allowing in-class collaboration. Discussions can be between learners (peer to peer) or between a learner and a teacher.

For the discussion method of instruction to be effectively applied, learners must astutely demonstrate their ability to display sound communication skills which include to be able to make claims and supporting such claims with evidence, being able to critique ideas and not to just agree with their fellow classmates, and how to circumvent obstacles and find solutions (Larson 2000: 663). Additionally, discussions must adhere to the learners' different learning styles. For instance, in an investigation to find ohmic and non-ohmic substances, ideas can be written on the board (teacher-learner discussions) or on a page (learner-to-learner discussions) which helps learners to visualise and identify ideas which already had been discussed.

Discussions as a means of instruction has been described to possess the following advantages (Weimer, 2011: online):

- Participation makes learners interested in the learning process
- Learners are engaged
- The teacher is provided with immediate feedback
- Learners get instant feedback
- Preparation is encouraged through participation
- Participation can be used to control what is happening in class
- The manner in which learners participate is controlled
- Communication between learners is encouraged
- Participation is used to develop speaking skills
- Learners participate using the language of the course

It is evident that class discussions promote effective learning as learners learn in an active environment (learner-centred approach). Furthermore, teachers measure learners' progress in the subject by observing how they collaborate with each other or when attempting to explain a concept to their peers. Learners benefit from sharing ideas which in turn motivates them to learn (Abdullah, Bakar & Mahbob, 2012: 516).

However, adopting discussion as a method of instruction requires the teacher and learners to collaborate. Any unwillingness on the part of participants may hinder knowledge-creation in the classroom. In addition, this method cannot be used solely in the classroom as the learners must first understand what the discussions are based on; other appropriate instruction methods may be combined with the discussion method to engender lively interactive teaching-learning. However, the CAPS document does not guide educators on how learners can be assessed through the discussion method, therefore the assessment process regarding the discussion method needs clarification. This is because assessment guidelines are restrictive and can only be done through informal and formal activities. Additionally, the CAPS document for Physical Sciences does not indicate whether practical investigation skills should be discussed thoroughly in the classroom; only learners knowing how to proceed with discussions are able to perform practical investigations effectively. However, large group discussions tend to be disruptive and learners tend to do less; therefore, little to no learning takes place.

The benefits of the discussions (as discussed above) method of instruction indicate that learners can acquire knowledge easier and rapidly. This method is preferably combined with other methods of instruction where even mobile applications promote discussion processes.

2.4.3 Problem-solving

Kuzle (2015: 69) believes that problem-solving as an instructional method helps learners develop knowledge in the subject area through application of problem-solving strategies. Lopez-Jimenez, Gil-Duque and Garces-Gómez (2021: 17) indicate that problem-solving techniques follow a 4-step process (Definition, planning, execution, and analysis). When problem-solving is used, learners must use preliminary information to assist them in defining the type of problem they experience. This is then followed by a plan of action which must be adopted to solve the problem. An execution of the plan is then required. Learners must then analyse and evaluate the plan to determine if it solved the problem.

2.4.4 Direct Instruction

This technique employs using any teacher-centred style. Kim and Axelrod (2005:114) state that "direct instruction begins with a clear and systematic presentation of knowledge". It involves a teacher going to the chalkboard, writing and explain during instruction, while the learners are actively listening.

In this technique a teacher makes the decision on how learners must be taught and the goals learners must achieve. The teacher can emphasise important concepts that learners must know from the curriculum, and lessons can be generated in order to accommodate learning styles. Additionally, this technique is more useful in introducing new content in class, as well conducting practical demonstrations (Renard, 2019).

However, the prolonged use of this method leaves learners passive, therefore hindering learning. To prevent learners from being bored, this method can be used in conjunction with other relevant teaching techniques which increase the engagement of the learners in lessons.

2.4.5 Scientific Method

The scientific method is regarded as "a process for asking and answering questions using a specific set of procedures" (Gerde, Schachter & Wasik, 2013:6) consisting of 6 steps as depicted in the Figure 2 below.

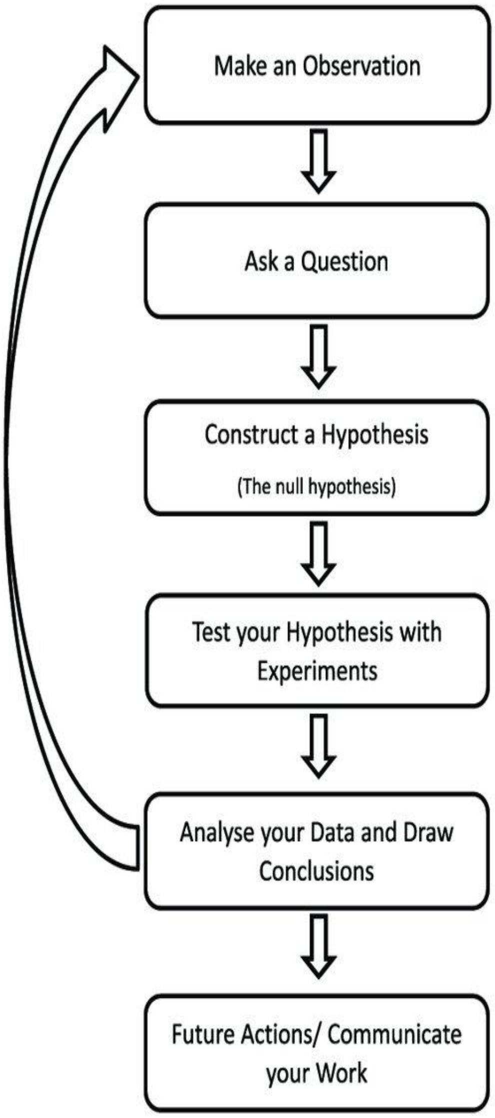

Figure 2: The scientific method steps (Yeoman, Bowater and Nardi, 2015:3)

The scientific method therefore offers a solution to a problem using the steps mentioned above.

Haig (2018: 12) believes that the scientific method is important because:

- It offers a codified way of learning
- It allows for justification of claims to be made
- It is a central feature of science

Since the scientific method follows a systematic approach, it is easy to discover how the findings of a research were realised, therefore the justification of claims is understood. Learning therefore becomes a systematic approach that begins with the learners' observation of the problems provided in class. The CAPS guidelines require learners to use the scientific method to conduct practical investigations (DBE, 2011: 145). This implies that research projects and practical activities in a Physical Sciences classroom must follow the scientific method. Teachers must therefore be familiar with this method in order to incorporate it as a useful and relevant teaching technique. However, there are several scientific methods proposed by different researchers which make it difficult to select an appropriate one. Additionally, scientists follow different methods depending on the nature of investigation which makes it difficult to apply this method (Moeed, 2013:542).

In sum, the scientific method can be utilised in a Physical Sciences classroom as it is recommended by CAPS and allows for claims to be justified as stated above. It is evident that multiple techniques can be employed to interest learners to achieve better outcomes, but each technique applied must suit the learners' learning styles. In this regard, the CAPS is crucial in guiding educators to understand the type of knowledge they must possess, in addition to using suitable techniques to transmit content knowledge effectively to learners.

2.5 CONCLUSION

Teaching and learning when guided by pedagogical principles make it easier for learners to learn effectively. These principles inform the educator about the needs of the learners such that guiding learners in the classroom becomes smoother. The principles of teaching state that in a classroom, subject matter should be organised logically, and therefore lessons must build from new knowledge based on learners' prior knowledge. Additionally, appropriate teaching techniques must be applied to facilitate the acquisition of necessary knowledge and skills in the subject. As such, a learner needs both motivation and reinforcement of behaviour in order to perform in the classroom. Learning in a classroom can be driven by either teacher-centred or learner-centred approaches. Moreover, learning principles emphasise that in order for a learner to learn effectively, active learning must be practised as learners learn effectively when they are engaged. Additionally, the diversity of the learners must be considered, such that a positive classroom atmosphere is created to maximise learners' performance. The CAPS document plays a vital role in the teaching and learning of the curriculum as it guides the education process in a logical manner. The next chapter (3) discussed literature pertaining to mobile application usage in the classroom.

CHAPTER THREE

MOBILE APPLICATIONS IN TEACHING AND LEARNING

3.1 INTRODUCTION

In chapter 2, principles of teaching and learning, effective teaching strategies in the Physical Sciences, as well as the role of the CAPS (Physical Sciences) document were discussed. In this chapter (3), I focused on the role apps play in learning in a Physical Sciences classroom. This was achieved by expanding the literature discussed in 1.3, as well as the literature discussed in chapter 2. Firstly, it commenced with the explanation of different models of technology integration in education. Then, the unpacking of the TPACK framework followed. Focus was then shifted to the role digital technologies play in education. The literature study then elaborated on the implementation of technology for classroom use by comparing developed countries to developing countries. This was followed by a discussion on apps which was used in this study. The chapter concluded with a summery on the literature discussed in this chapter.

The previous chapter stated that teaching techniques adopted in a Physical Sciences classroom must promote learner-participation in classroom activities as learners learn best when they are gainfully engaged. Additionally, more than one teaching technique can be employed to facilitate learning due to the different learning styles that learners exhibit. As stated in chapter one, apps can play a variety of roles in teaching and learning; hence, understanding how applications function, and how they can be utilised effectively in different classroom situations can empower teachers to assist in skilfully facilitating teaching-learning activities to enhance academic performance. Since mobile apps fall under digital technologies, in the next section, digital technologies are discussed extensively in terms of how they can enhance learning.

3.2 HOW CAN DIGITAL TECHNOLOGY ENHANCE LEARNING?

3.2.1 Digital technologies

Digital technology is defined as any electronic tool, device and resource which can be used to process, store, and generate data (Victoria State Government, 2019). These can be divided into two categories: mobile and fixed devices. A laptop and a mobile phone are examples of mobile devices, while a television and a desktop computer are examples of fixed technological devices. Each technology tool can be activated to function for more than one purpose. For example, a mobile phone incorporates texting and calling facilities, internet access, and saving of information, thus enabling the user to access to multiple functions. Technology can be used to perform a variety of tasks which include banking, gaming, teaching and learning, emailing, group discussions, and many more.

There are technologies that can only be accessed when connected to the internet and those that do not require internet connectivity. These are referred to as online and offline technologies respectively. To gain access to these technologies, one can activate them through application stores including Google play store (for phones running an android operating system), Microsoft store, and Apple store. An account is required to download these resources. Furthermore, websites also grant access to some of these technologies. Additionally, these resources can also be shared among users with special applications such as Google files, Bluetooth, near field communication devices (NFC) and any other technological method that allows sharing of resources.

3.2.2 Models of Integrating Technology in the Classroom

There are several models which can be used to guide the effective integration of technology into education which include: SAMR, TIPC, and TPACK models. Hamilton, Rosenberg and Akcaoglu (2016: 434) view the SAMR model as "a four-level approach to selecting, using, and evaluating technology in K-12 education". These levels are substitution, augmentation, modification, and redefinition. Romrell, Kidder and Wood (2014:4) and Aldosemani (2019:47) add that the SAMR model allows educators to integrate technology using these four steps by starting at the lowest level as illustrated in Figure 3 below.

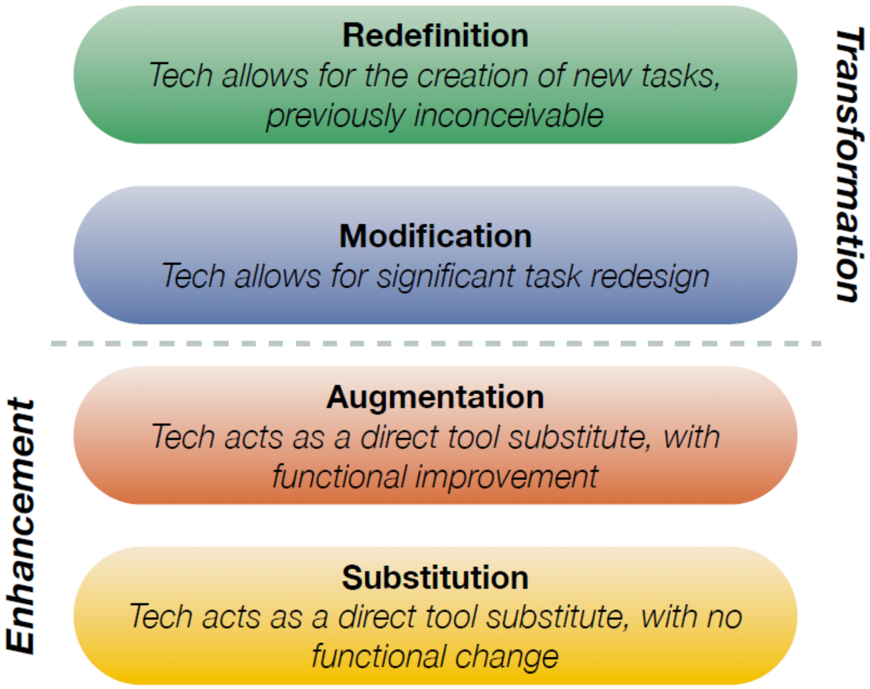

Figure 3: The SAMR model (Puentedura 2012: 6)

Figure 3 above shows that according to the first two stages, technology is used to enhance the learning process, while the last two stages refer to technology being used to transform learning. At *substitution level*, technology acts a direct replacement of a learning activity without additional functions to that learning activity (Romrell et al., 2014:4). The implication is that, instead of learners penning notes on paper, they can substitute this by typing the notes on a word-processing function on their smart phones in the classroom. At the *augmentation level*, technology is still used as a substitute to a learning activity, but functionality is added. Using the same note-taking example above, the processing technology has spelling and grammar checks to edit notes (Warsen & Vandermolen 2020:168). This means that the added function to assist in note-taking activities is the augmentation process.

As outlined above, the first two levels demonstrated how technology can be used to enhance the quality of note-taking in class. The *modification step* implies that technology is used to alter a learning activity (Smith, 2019). The lesson and learning outcomes are designed to help students increase their knowledge by learning with technology. To increase a learner's mastery of content, mobile apps are invaluable as they provide learners with numerous topical questions and answers which can be used for increasing one's proficiency in a specific content area. As such, the learner is exposed to a variety of questions, in addition to being guided on how to get to the correct answer by using different methods which increases knowledge in the subject area. Accordingly, learners practice methods are altered as they can now activate their mobile devices at any place as they are not limited to a specific place which also enhances learning how to use modern technologies. At the *redefinition stage,* Jude, Kajura and Birevu (2014:106) add that technology “allows for creation of new tasks previously inconceivable (visualizations tools, simulations)”. Notes can include clear pictures and video links which are accessible on a learner’s smart phone. Moreover, simulations in a classroom can improve learners’ understanding of a topic. For instance, it is easier for learners to understand electromagnetic induction through a simulator than pictures in a textbook - simulations provide an effective demonstration of the electromagnetic induction process in a Physical Sciences classroom.

Additionally, the SAMR model encourages teachers and learners to move from lower levels to higher levels by using technology. It can be seen that technology is integrated directly from the substitution level (lowest level) to the redefinition level (highest level). With each level, the understanding of technology increases the level of understanding regarding use of devices, in addition to improving the success rate in learning activities. This means that learners and educators can become accustomed to using technology in a classroom with ease to enhance teaching-learning situations.

However, there are numerous challenges in adopting the SAMR model. Hamilton et al. (2016: 435) maintain that there is no theoretical explanation from peer-reviewed literature (and there is limited literature on both quantitative and qualitative levels) to simplify the interpretation of this model; therefore, it becomes difficult to use it for integrating technology into education.

The next model is the TIPC model which is defined as the technology integration cycle which Hutchison and Woodward (2018:4) believe “was developed based on the types of knowledge that teachers need to employ in order to successfully integrate digital technology”. These knowledge areas are discussed broadly in the TPACK framework below, and therefore it would be beneficial to use the TPACK model as the TIPC model is discussed within TPACK model.

The Technological Pedagogical Content Knowledge (TPACK) framework as described by Koehler and Mishra (2009:60) has become integral regarding how researchers understand integration of technology in a classroom (Baran, Chuang & Thompson, 2011:370). Further, Koehler and Mishra (2009:60) contend that this framework proves to be fundamental to educators to teach effectively with technology. This model can be described as a useful framework on the type of knowledge educators must possess in order to effectively integrate technology in their pedagogical practices, and how this can expand their knowledge (Baran et al., 2011:371). In addition, the application of this framework requires that attention must be equally focused on technology, content, and pedagogy in the attainment of learning objectives (Wetzel & Marshall 2011:73). As such, TPACK is viewed as central to how technology can be exploited to support content-specific pedagogical strategies (Graham, Burgoyne, Cantrell, Smith, St Clair & Harris 2009: 71). The TPACK model is further divided into seven knowledge areas as depicted in Figure 4 below.

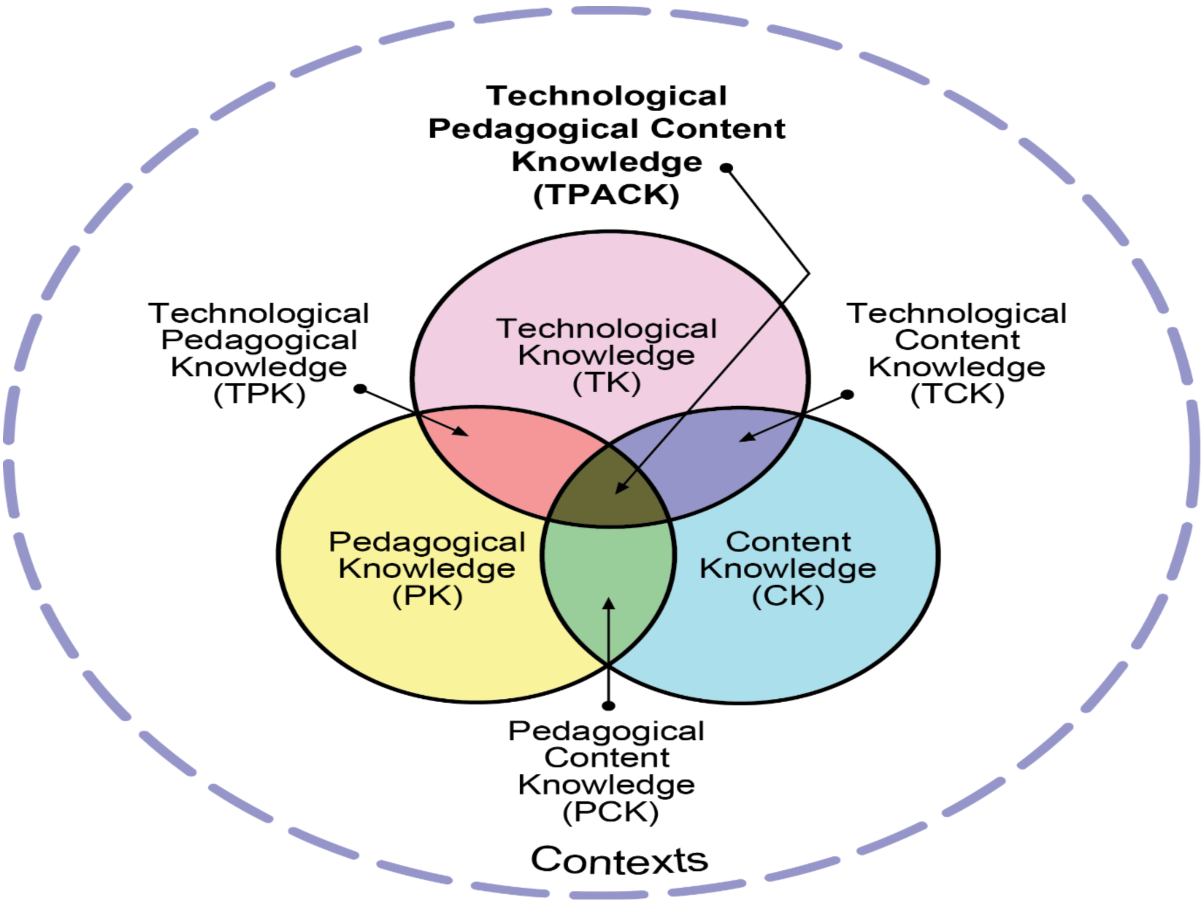

Figure 4: The TPACK framework (Koehler & Mishra, 2009:63)

They are listed as:

1. Pedagogical Knowledge (PK)
2. Content Knowledge (CK)
3. Pedagogical Content Knowledge (PCK)
4. Technological Knowledge (TK)
5. Technological Pedagogical Knowledge (TPK)
6. Technological Content Knowledge (TCK)
7. Technological Pedagogical Content Knowledge (TPACK)

Pedagogical Knowledge refers to the ability to teach in a classroom. An educator must be able to manage a class of learners effectively, deliver meaningful content to learners, and knowing how to grade content generated by learners. This also includes the ability to plan lessons effectively, and strategies to adopt to arouse learners' curiosity. Educators are expected to thoroughly know the specific content (CK) about each subject that they teach. The PCK is the midpoint between CK and PK. As explained in 2.4, PCK in a Physical Sciences classroom is influenced and guided by the CAPS document which spells out the type of knowledge educators should possess (and for learners to imbibe) in a Physical Sciences classroom, and how such knowledge is to be obtained. Teachers must also possess unique knowledge on how to integrate content knowledge and pedagogical knowledge to best assist a learner in gaining new knowledge. Educators must use appropriate teaching strategies to best present the subject content to the learners to assist learners to easily understand the topic. Additionally, an educator must possess knowledge in technology (TK) which ranges from handling simple technological tools (pen and paper) to modern digital devices. An educator must then use an appropriate technology to best present the subject content and skills to the learner (TPK). This may include interactive boards, projectors, mobile apps, or any technology that may prove effective in teaching learners. Moreover, the selected technology must present in an effective manner the subject content so that the learners easily grasp all concepts that are being taught (TCK).

The TPACK was born from the previously discussed knowledge areas. According to Brantley-Dias and Ertmer (2013:113), TPACK uses the knowledge that a teacher possesses on how to integrate pedagogical practices with content knowledge and emerging technologies. This is aimed at helping the learner master the subject at hand. This model is the basis of technology adaptation in a classroom. For TPACK to be effective, the content, technology and pedagogy are not viewed as three different entities, but instead as one.

3.2.3 The Impact of TPACK on Learning

TPACK has been documented to have impacted learning in numerous ways as studies reveal that technologies have proven to be useful due to having the potential to enhance, extend and enable student learning (Henderson, Selwyn & Aston 2015:1). It is believed that with the prolonged use of technology, students showed an improvement in test performances (Higgins, Xiao & Katsipataki, 2012:6). Njiku, Mutarutinya and Maniraho (2021:3) add that TPACK can be used for curriculum planning, assessment, and lesson preparations.

3.2.3.1 Planning

The lesson plans serve as the foundation for effective learning. Barrick (2020) emphasises that when subject matter is organised, learning becomes easier. A lesson plan is therefore regarded as "a written description for this process; where the materials, the method, the time and the place of education as well as methods for evaluating the students are described in detail" (Nesari & Heidari 2014:27).

This process can be guided by asking: *what*, *how*, and *which*? For instance:

- What do I expect learners to understand from this topic?
- What are the lesson objectives?
- What strategies will be best to relay content to the learners?
- How will learners realise the lesson objectives?
- How will learners be assessed?
- Which tool is best for relaying the content?

From the lesson plan, an educator can choose a relevant teaching strategy which can be used to help learners acquire content and skills much easier as guided by the Physical Sciences guidelines in the CAPS (RSA, 2017) document. Furthermore, a lesson plan must also indicate diverse ways an educator will implement strategies in a classroom to ensure active participation in the learning activities. The TPACK framework also suggests that proper planning includes relevant technology which must be used in teaching and learning. The technology used must enable effective learning to occur with minimal distractions. It should "enable and empower students to understand ideas" (Hooper & Rieber, 1995:159).

However, with a wide range of technologies available, it becomes a chore to decide which technology can be used to best guide the acquisition of content? Graham et al. (2009:71) advises that the TPACK framework serves as a guide to how educators can choose relevant technologies to assist learners. Understanding the TPACK model assists an educator in designing creative lesson plans for effective teaching and learning in a classroom. Additionally, the teaching strategies and content should be used as a guide to help select a relevant technology to support content acquisition. The role of technology must be clearly defined during the planning process. For instance, will technology be used to enhance or a present content? There are numerous technologies that can be used in class which includes whiteboards, Smart televisions, tablets, smart phones, interactive boards. These technologies can be used to either present or enhance the pedagogical practices in a classroom – the astute teacher chooses the best strategy to advance innovative and creative teaching in all his/her lessons.

3.2.3.2 Pedagogy

Schmidt et al. (2009:134) indicate that the TPK knowledge domain in the TPACK framework "refers to teachers' knowledge of how various technologies can be used in teaching and understanding that using technology may change the way an individual teaches". The understanding of different technologies provides an educator with a clear plan on how each technology can be used to enhance learning. In this regard, TPACK enables an educator to incorporate the use of more than one technological device to enhance content quality to offer effective support to learners. An educator can use an interactive digital whiteboard to present a class lesson. From the board visuals (Charts, tables, and simulators) can be used together with text to give the content more credibility thus making it easier for learners to understand and become actively engaged in the lesson while considering the different learning styles in the learning process. Furthermore, important concepts can be easily highlighted thus making it easier for learners to identify and interact with such that classrooms become lively spaces that engender quality teaching and learning.

Personal computers and laptops with a projector can also stimulate teaching and learning. Reich and Daccord (2015:4) believe that presentation software like PowerPoint impacts learning by incorporating videos, audios and images. Alkash and Al-Dersi (2017: 6) add that presentation software helps to "attract and sustain the much-required learners' attention" which increases the motivation to learn. Visual presentation such as videos, pictures, charts, tables enhance content delivery by helping a learner build a mental picture of the subject matter; hence, the occurrence of deep-learning within the learner. Furthermore, the use of different themes and charts makes it easier to offer differentiation regarding content and different concepts. Knowledge gained through the implementation of TPACK can lead to effective technology utilisation thus enhancing the quality of lesson-delivery. Furthermore, educators can now be capacitated to gauge which technological instrument (or a combination of technological devices) best favours the enhancement of content delivery and practical pedagogy for effective learning to occur. In addition, technology offers educators with an opportunity to collaborate and extend learning beyond classroom (U.S. Department of Education, 2017:28). Roschelle (2003:8) believes that technology can improve students' performance if they are allowed to use their hand-held devices to submit their assignments online, retrieve homework, review their grades, and participate in group discussions.

It is evident from the reviewed literature that the adequate implementation of TPACK increases in its effectiveness when aligned to quality instruction and astute planning until the evaluation stage. Further, technology transforms and enhances methods of how a learner can be assessed. According to the U.S. Department of Education (2017:58), technology assessment tools advantages an educator to include a better quality of question types:

- Graphic response: includes any item to which students respond by drawing, moving, arranging, or selecting graphic regions;
- Simulations: students immerse themselves in roleplaying to test their knowledge in contexts that facilitate situations similar to real-world scenarios;
- Equation response: students respond by entering an equation;
- Performance-based assessments: students perform a series of complex tasks; and
- Technology-enhanced questions: students demonstrate more complex thinking and share their understanding of materials in a way that was previously difficult to assess using traditional means.

Therefore, technology can be used to assist in the teaching processes as well as assessment techniques in educational contexts. Additionally, learners can use their own devices; hence, making it easier and cheaper to implement and integrate technology for schools from low socio-economic ecologies. However, smartphones vary in sizes, and therefore a small screen can affect the display of content, thus compromising the benefits of such devices.

3.2.4 Shortcomings of the TPACK Model

Technology changes rapidly, thus educator skills in technology must be upskilled to meet the intricacies of managing technological inventions (Kompa, 2018).

Bull and Bell (2009:1) state that TPACK cannot be regarded as being beneficial to educators as some educators doubt its existence or are not *au fait* with its processes. In other words, it is believed that this model is not well understood (Brantley-Dias & Ertmer, 2013:108), therefore it is difficult educators to buy-in to use this model. Additionally, there are numerous variations of TPACK as a concept as Hofer and Swan (2008:196) describe TPACK as a "moving target … vary[ing] with among teachers in different situations". These variations arise from the fact that this model is not clearly defined because different researchers attempt to create their own meaning of this model.

Although this model is not well defined, it still serves as a valuable guide in assisting educators on how technology can be integrated in the classroom. The seven learning areas indicate a clear connection between the different types of knowledge that is gained when using this framework. Thus, TPACK can be applied to provide a frame of reference as it examines many of the issues that arise when learning combines with technology, content, and pedagogy in the teaching of the Physical Sciences (Jita, 2016:19). Since TPACK is fundamental to technological implementation in learning, this study therefore applies the TPACK framework to assess the impact apps were to have in a Physical Sciences classroom.

3.3 ROLE OF DIGITAL TECHNOLOGY IN EDUCATION

As demonstrated throughout the study, technology in education which has evolved all through the decades has been studied by several researchers who demonstrated the crucial role that it plays in education. The TPACK framework discussed in 2.2.2 above indicated that for this model to work, technology, pedagogy and content must be combined as one entity. Although technologies are used at all school levels, from pre-primary to tertiary education, for the purpose of this study the role that technology plays is limited to curriculum development and learning.

3.3.1 Curriculum Development

"Curriculum development focuses on determining what knowledge, skills, and values students learn in schools, what experiences should be provided to bring about intended learning outcomes, and how teaching and learning in schools or educational systems can be planned, measured, and evaluated" (Richards, 2001a:2). Using digital technology for curriculum development means migrating from traditional teaching and learning practices but focusing on how to effectively integrate digital technology into teaching and learning, thus adopting a new modern approach. Digital technology is readily available and easily accessible which can be used to provide information and easy communication in schools. The integration of ICTs has the potential to impact positively on schools in terms of the transformation of teaching and learning processes and its outcomes. This occurs at various levels including rich instructional environments, meeting students' individual needs, and delivery of educational content to stimulate and motivate students (Nachmias, Mioduser, & Forkosh-Baruch, 2008:165). In this process, technology support through collaborative learning and help define teacher-student roles (Means, 1993:5). Kozma (2000:5) adds that ICT-based innovations help to foster better student practice, quality pedagogy, and creative ICT techniques to plan lessons in schools.

Technology can play a critical role in helping learners to acquire skills such as study skills, working in teams, and effectively communicating. It can also lead to a revision of a new curriculum to support learning that incorporates the seven learning areas demonstrated by the TPACK model. This implies that technology guides role-players to make astute decisions on what content the curriculum should cover, which tools are needed to provide support to educators and learners and assist educators in adopting relevant teaching methods and techniques that will be suitable to achieve lesson objectives.

The role of digital technology in education revealed that in curriculum development, technology can be used to help learners gain necessary skills and knowledge for learning as guided by the CAPS document, in addition to promoting collaborative learning. Moreover, it helps to improve educators' teaching practices, designing quality curricula, improving communication between educator and learners, and promoting collaboration between educators. This also increases collegiality in terms of knowledge-sharing to enrich the quality and width of subject content which is required to expand and sharpen specialist educators' expertise in their field. Also, in this regard, it is critical for educators to discuss how technology can be effectively integrated in teaching-learning activities since there are dissimilar roles technology that can affect curriculum development.

3.3.2 Learning

Prensky (2010:23) cited in Cimermanová (2018:220), believes that "Today's students will not live in a world where things change relatively slowly, but rather in a future where things change extremely rapidly - daily and exponentially". Importantly, the future involves the integration of digital technology in learning processes. Also, computers and associated technologies have demonstrated potentially transformative properties (Tamim, Bernard, Borokhovski, Abrami & Schmidt, 2011:5). Higgins et al. (2012:4) believe that digital technology plays the following roles in learning:

- Promotes collaboration between students;
- Supplements traditional teaching techniques; and
- Assists learners with disabilities, and those from disadvantaged backgrounds, by implementing remedial and extra tutorial programmes as catch-up interventions.

To enhance to quality technology integration in lessons, collaboration should be promoted among learner-groups. This is increased by utilising communication apps such as WhatsApp, Facebook, Twitter, Snapchat and Zoom which allow communication to take place at a low cost; hence, learners can communicate in groups more frequently.

Higgins et al. (2012:4) states that digital technology can be used as a supplement to traditional teaching techniques. Digital technology supports traditional teaching techniques via Video technologies which help learners visualise content to get a better understanding of concepts. For instance, learners understand the topic better when a teacher utilises YouTube clips, thus enabling learners to grasp what is meant by momentum. Moreover, Matrix and Hodson (2014:19) suggest that infographics is an “important step towards developing a pedagogical approach that draws on visuals” as it accommodates different learning styles that enable students to visualise information by using photos, slides or any other graphical format. Additionally, the use of simulation software, coupled with traditional teaching techniques, can increase students’ performance in the Physical Sciences (Rutten, Van Joolingen & Van der Veen, 2012:138). Valdez et al. (1999:5) add that “Technology offers opportunities for learner-control, increased motivation, connections to the real-world, and data driven assessments tied to content standards that when implemented systemically, enhance student achievement as measured in a variety of ways, including, but not exclusively limited to, standardized achievement tests”.

Currently, there are simulation technology tools available which can be used in schools. Furthermore, learning content becomes accessible in any place as technologies such as laptops and smart phones are portable. However, as better modern technologies emerge every day, the challenge is finding the right technology which is accessible with a free subscription from an app store. In order to supplement traditional teaching practices, technology can extend or expand a classroom activity by offering more information through tools such as the World Wide Web YouTube or providing them with practice apps which help them master content through practice, thus enabling them to be better equipped for assessment purposes.

3.3.3 Challenges of Adopting Digital Technology

It is evident that digital technologies have clear and defined roles in education, but its use presents challenges. Although the World Wide Web is an information source, it sometimes provides confusing, untested, and unreliable content which can mislead (Buckingham, 2007:113). Additionally, curriculum change is challenging for educators as technology adoption and integration is carried out on a national scale (Vivian, Falkner & Falkner, 2014:1). This necessitates that relevant and sufficient resources must be developed nationally to ensure that educators create interesting learning strategies and adopt innovative pedagogy that uplifts education in general. Furthermore, the cost and maintenance of digital technologies can be astronomical. However, although there are policies stipulated to adopt technology usage, Laurillard (2008: 21) believes that they are not working as well as they should. This makes it challenging for educators to effectively create and expand learning areas and offer support to students.

As discussed above, digital technologies play a significant role in education because it has a positive influence on learning that guides curriculum creation. The challenge is how technology can be successfully implemented and integrated into teaching-learning contexts. Also, solutions to mitigate challenges emanating from such a move, must be seriously considered. To address the cost impact, among other possible challenges associated with digital technologies, this study proposed the use of mobile digital technologies as there are tools that are readily available to the majority of learners who possess digital devices. The next section reviews the implementation of mobile technologies in schools.

3.4 INTEGRATION OF MOBILE APPLICATIONS: A GLOBAL VIEW

Personal Digital Assistants (PDAs), iPod, tablets, mobile phones, smart phones, and laptops are examples of mobile devices which have been available for many years (Table 6 below).

Table 6: Historical timeline of mobile devices (Abugohar, Yunus, Rabab'ah & Ahmed 2019:153)

Device	Year	Comments
Newton Message Pad	1993	First PDA on the market
Palm Computing	1996	First commercially successful PDA
Microsoft Tablet PC	2001	First tablet on the market
Apple iPod	2001	First commercially successful MP3 Player
Apple iPhone	2007	First smartphone from Apple - iOS released
Apple iPod Touch	2007	First non-phone PDA from Apple
Amazon Kindle	2007	First commercially successful eBook reader
Google Android OS	2008	First serious competitor to Apple iOS
Apple iPad	2010	First commercially successful tablet computer
Apple iPad Mini	2012	First small tablet computer from Apple

As depicted in Table 6 above, mobile devices have been present since 1993. Today (2022), there is a proliferation of mobile devices compared to 2012. As the years progress, the mobile devices gain more popularity. Each mobile device carries its own advantages over devices of the same nature. For instance, *iPod touch* released in 2007, was built to accomplish a multitude of educational objectives (Banister, 2010:121). It had programmes like YouTube, iTunes, and Safari for internet. Although this may seem ancient compared to today's technology, it represented a new experience for educators and students (Chartrand, 2016:4). Additionally, tablets, like all mobile devices, possess several advantages including drawing of diagrams, viewing lectures, and recording notes (Fojtik, 2015:743).

For the purpose of this study, the focus was on the smartphone, which like other mobile devices, possesses some advantages and disadvantages when used in a classroom. Baker, Lusk and Neuhauser (2012:1) state that smartphones offer many features in one device. This includes audio, texting facilities, photography, emails, and more. Additionally, cell phones cameras can be used to collect scientific data, capturing and storing of visual data, and documenting information (Cui & Wang 2008:72). However, cell phone usage poses several disadvantages: teachers claim that they serve as a distraction, used as a device to cheat in a test or exam, promotes bullying, and in some cases, learners take sensitive or embarrassing pictures of other learners which may be used to shame or belittle others.

Smartphones run on downloaded apps where each app has a specific purpose; it can incorporate all different apps allowing the user to use several apps in one device. Additionally, each cell phone has hardware that is necessary to enable proper functioning of an app. For instance, the size of a RAM can determine how fast an app is going to perform. Additionally, the camera quality can enhance the photo quality for scientific data capturing. In short, there can never be a discussion of apps without the devices that enable them. Installed apps on a smartphone can be used in both a classroom environment and at home, thus allowing for learning to take place anywhere.

It is evident that there are numerous ways of integrating technology in the classroom. To best guide the proper integration of technology into the classroom, this research looked at technology implementation worldwide in the education sector. Although there are separate roles technology can play in research, as demonstrated throughout this study, the focus was on the role of technology through mobile applications to achieve better learning outcomes. Apps can also be classified as part of ICT as they are technologies that provide valuable information, in addition to facilitating communication in a classroom.

This study first explored a global perspective on the implementation of apps, followed by a regional perspective, and lastly the local perspective.

3.4.1 Integration of Mobile Technology: A Global Overview

This section focused on previous literature from different regions of the world which provided a global perspective of the integration of mobile applications in education. In some regions, the literature was not readily available, therefore discovering how m-learning (mobile learning) is integrated proved to be difficult. This section highlighted important mobile learning apps and how they have been integrated in different regional high schools.

North American region

Clayton and Murphy (2016:101) worked collaboratively with students in K-12 (schools in the United States) schools to produce short "instructional videos concerning the appropriate use of specific digital tools and apps". These videos could then be accessed through YouTube or the school website. Clayton et al. (2016) discovered that through this exercise, student ownership, peer-to-peer feedback, and use of literacy applications increased. In addition, Thomas and

Muñoz (2016:26) surveyed 628 high school students from ten schools which had integrated mobile learning. They found that 90.7 % of the students use their devices for schoolwork. Further, students tend to use their devices that include the calculator (91.4 %), and accessing the internet, calendar, and educational (74 %) apps. Thomas and Muñoz (2016) observe that although students are utilising mobile phones, training is still required to discover the right technology which has the relevant and precise features to assist optimally with science matters.

However, "Cell phones in the classroom may help students take more responsibility for their own learning" (Clayton & Murphy, 2016:108). Diliberto-Macaluso and Hughes (2016:50) surveyed the impact that technology had on student performance with fifty-four psychology undergraduate students, and concluded that the usage of apps led to an improvement in students' test scores, especially in the multiple-choice questions.

Consequently, there is tremendous support for the integration of mobile applications in education, but they tend to cause distractions. Pulliam (2017:20) conducted a study on how the use of cell phones affects teachers. This study sampled 289 teachers and 159 students, and it was found that 87% of the teachers believed that students lacked concentration in the classroom and recommended that the use of cell phones in schools should be discouraged or controlled. Further, and alarmingly, teachers found that students took 'inappropriate' pictures of their body parts and sent it to peers during classroom instruction or took pictures of other students in compromising positions which led to cyberbullying (Thomas, O'Bannon & Bolton, 2013: 300).

However, Kim and Faith (2020:1) believe that cyberbullying occurs whenever youth use digital technology for leisure, but this decreases when it is used to access information. Therefore, to mitigate the effects of cyberbullying on the youth more efforts must be made into promoting technology for information purposes. American schools have realised the benefits of mobile applications; however, the successful integration of these applications depends on how educators view these technologies. Currently, there are conflicting views concerning educators' views on technology as tools that can be used to enhance learning, as some view mobile applications in the classroom as being distractive.

Asian region

Hans and Sidana (2018:995) surveyed 217 students to investigate the Enterprise Resource Planning (ERP) software usage in a school. Their findings revealed that the use of ERP software was very satisfactory since it provided students with "immediate feedback, simulations, records, study materials, and captured all the data in the system only". Farrah and Abu-Dawood (2018:50) conclude that using mobile phone applications helps students to understand and remedy their weaknesses, reduce their misconceptions, and reinforce learning. The use of SMS software makes learners aware of everything in class while promoting classroom interactivity (Farrah et al., 2018:50-51). Etcuban and Pantinople (2018:255) conducted a study on the impact of mobile applications in Philippines with a sample of 40 Grade 8 learners, and their findings revealed that the effective use of mobile applications can improve learner-performance in Mathematics, and they therefore recommended the use of applications as they allow learning to be enhanced maximally.

Lestari, Agung and Musadad (2019:4) observed fifty Grade 11 students in Indonesia, focusing on how technology can be used to enhance critical-thinking skills. They concluded that android-based puzzles can be used to improve critical-thinking in the following ways:

- Students solve puzzles, therefore solving problems becomes easier.
- Learning activities move from passive listening to becoming more interactive.
- Learning becomes more interesting and more engaging.

Learner-interest in the subject is fostered as the software is created and focused in an environment that learners are familiar with; hence, making it easier for them to learn. Additionally, Chou and Feng (2019: 12) state that when using tablets, learners in Grade 9 performed better than those using laptop devices; therefore, they believed that tablets are better suited for instruction as compared to laptops. However, Wu (2019: 354) believes that the rise in technologies threatens educators' authority as they are no longer the only source of knowledge in the classroom, and a learner may challenge an educator as being wrong during a class instruction as the he/she believes that the content they read in (unreliable) websites might be correct.

European region

Ceci (2020a) conducted a study on the most popular apps used in UK schools where participants included 60 000 children between the ages of 4 and 15., and it was found that the most popular apps used in this age group included the Homework app, Google Classroom, Khan Academy, Edmondo, and Quizlet. Additionally, Ferreira, Moreira, Santos-Pereira and Durão (2015:4608) sampled 151 students in 2009 and 273 students in 2015 in their quest to discover the extent of the role of technology in teaching and learning, and concluded that technology is mainly used as a tool rather than a teaching methodology. Further, BOYD (Bring your own device) devices evoked active participation from the students. However, they warned that technology usage does not guarantee success in learning, but should be used as an "effort" to support involvement of learners in education.

Although integration of mobile technologies appears to possess limitless potential, some countries are calling for their ban in schools. In France, the use of cell phones in schools (up to Grade 9) was banned totally in 2018 (Hess, 2019).

Although research shows that mobile app learning has been integrated in different regions of the world, there is limited literature to support how technology integration affects both the rural and urban areas of the same country as the bulk of the reviewed literature emanated from developed nations. In sum, the different researchers mentioned above state that there are numerous advantages and disadvantages of integrating technology in learning activities all around the world.

3.4.2 Mobile Technology Integration: African Continent

Rabiu, Muhammed, Umaru and Ahmed (2016:477) state that mobile phones greatly influence academic performance at school level; and therefore parents, educators and psychologists should be educated to the idea of using them in a classroom as well as at home. To investigate this impact, different researchers explored the impact of mobile apps in schools on the African continent.

Jayaprakash and Chandar (2015:1) reviewed apps that can be used in teaching by focusing on Blackboard collaborate, Blackboard mobile learning, Doceri, Google Classroom, Dropbox, and Class Dojo which revealed that these apps grant access to education material for both the educators and students. Further, all the apps used could be used in both e-learning and m-learning. Atteh, Assan-Donkoh, Mensah, Boadi, Badzi and Lawer. (2020:36) who investigated the impact of social media websites such as Twitter and Facebook in schools in Ghana which elicits concerns such as bullying and lack of privacy, believe that "social media networking permits free sharing of thoughts, access to pictures, videos, news, business, brands and other updates" - and therefore they should be recommended for use in education because of their many benefits such as the enhancement of communication.

The above articles indicate that some African countries have also investigated what roles mobile apps play in education. However, literature on how these technologies are applied in schools is very limited, but there is an abundance of information on the integration of technology at university level from different regions. More studies should be conducted to address the gap between technological integrations in African schools, and the rest of the world. This may in turn make it easier for educators to adopt app usage for instruction. Although research has demonstrated how apps can impact education on the African continent, Famuyiwa (2009:175) believes that the benefits can be better achieved by developed nations. A view of how much technology has developed in Africa implies that, although more work still needs to be done in order to fully reap benefits from of these technological advancements, mobile technologies give the African continent the opportunity to bridge the technological gap between African countries and the developed nations. However, this does create room for further research on what the state of mobile technology on the African continent is.

3.4.3 Mobile Technology Integration: South Africa

Maphalala and Nzama (2014:464) investigated how learners use cell phones in schools by sampling over one hundred students in KwaZulu-Natal schools, and discovered that learners who use cell phones to search for content, do not understand apps such as access calculator, spell check, and social networking. In addition, in a study by Ngesi et al. (2018:1) involving forty-four learners in Grade 9 from the Eastern Cape, mobile technologies were used to increase the learner-educator contact time which was achieved through the use of “Mxit app”.

O’Hagan (2013:57) adds that the Siyavula apps advances a real solution to the textbook crisis in South African schools as books are available for both Mathematics and Physical Sciences from Grades 10 to 12. Jantjies and Joy (2015:317) add that “M-thuto was used to support learning during lessons and thus compensating for the resources such as textbooks which were needed by each learner as the system was able to provide notes and exercises which could also be accessible through their books”. Such invaluable resources are therefore available to assist the integration of mobile applications in the classrooms for better learner-performance. Additionally, the e-Education policy serves as guide to provide adequate implementation of teaching via technology as they are aimed at connecting learners and teachers to “better information, ideas and one another via effective combinations of pedagogy and technology” (RSA, 2004:14). This indicates that these policymakers and the Government view teaching with technology as integral to providing learners and educators with valuable information.

In addition, learners also support the use of apps in schools. A survey comprising of ninety-three matriculants indicated that 55.9% of the learners would like smartphones to be used in schools, but there should be conditions to limit their ‘disruptive’ nature in schools (Mavhunga, Kibirige, Chigonga & Ramaboka, 2016:72). This indicates that learners see both the positive and negative effects of using cell phones, hence they are asking for controlled use.

However, the ‘M-thuto’ app is online-based and therefore not accessible to all learners. This indicates that there is a lack of resources in implementing ICTs in schools, especially those in disadvantaged communities (Munje & Jita, 2020:264-5; Chisango & Marongwe, 2021:149). Moila and Makgato (2014:1017) add that “teachers and learners lack the necessary knowledge and skills to use educational technologies effectively for teaching and learning purposes”. The lack of resources, technical support, and limited skills slows down the integration of ICT in schools. Also, the e-Education policies do not provide guidance as to how mobile applications should be used in a classroom. This is exacerbated by the limited literature on how technology can be integrated in Physical Sciences lessons, hence the potential use of mobile apps in Physical Sciences has not been explored fully.

In South Africa, it was found that most learners have access to mobile devices, as indicated in Foko’s (2009:6) study that surveyed of 399 students from South African Schools, and it was revealed that over 97% of learners from disadvantaged schools possess a smartphone. Although most of the learners have resources necessary to access apps in the classroom, the lack of skills and limited literature presents a challenge in understanding how digital technologies can been used to best effect in a Physical Sciences classroom. Therefore, future research is required to assist educators to better implement relevant technologies in their classrooms, in addition to the understanding of policies. Moreover, teacher-training is of paramount importance in order to equip staff with ICT skills for them to take advantage of the technological developments in mobile applications.

The next section reviews different methods which can be used to evaluate the relevancy and usability of the app for specific purposes.

3.5 ASSESSING SOFTWARE QUALITY AND USER-SATISFACTION

User experience studies determine how people interact with a type of software, and what are their assessment of the product. Usability tests the performance of a software on any digital device: web-based or non-web-based. Tullis and Albert (2013:5) define usability as the ability of the user to perform a task successfully with a product (software). There are several tests that can be used to determine the usability and value of a software.

According to Kluth, Krempels and Samsel (2014:149), the following methods can be used to assess usability: cognitive walk-through, heuristic evaluation, user-observation, think aloud, and automated usability testing. Although different methods can be used to assess the usability of a software, Dicks (2002:27) claims that most experts use four criteria when testing: easy to learn, useful, easy to use, and pleasant to use; but these do not measure the efficiency of the software. Software can be simple to use but it may not be performing a task efficiently, and therefore when a usability study is conducted, it should focus on user-experience (UX) goals. Tullis and Albert (2013b:44) introduce two goals for UX testing: performance and satisfaction. Performance is achieved if the user can perform a task successfully, but in order for satisfaction to be achieved, a software must be able to perform a desired task, be easy to use, pleasant to use, and easy to learn how to use. Tullis and Albert (2013b) claim that satisfaction is all about the feelings and thoughts of a person interacting with the software.

Rauschenberger, Schrepp, Pérez Cota, Olschner and Thomaschewski (2013:40) recommend a 6-scale questionnaire with twenty-six items. The scale should be set to measure: attractiveness, efficiency, perspicuity, dependability, stimulation and novelty named User Experience Questionnaire (UEQ). Tullis and albert (2013b: 137) recommend using user-reported metrics to measure usability. These include post-task and post-session ratings. Post session ratings include:

- Aggregating Individual Task Ratings
- System Usability Scale (SUS)
- Computer System Usability Questionnaire
- Questionnaire for User Interface Satisfaction
- Usefulness, Satisfaction, and Ease-of-Use Questionnaire
- Product Reaction Cards
- A Comparison of Post-session Self-Reported Metrics
- Net Promoter Score

Each of the above as listed by Tullis and Albert (2013) is influenced by what the user is testing concerning the product; it can be navigation, user satisfaction, likeability, and user interface. The UEQ could not be used in this study as there was a minimum of four apps to be evaluated, and that would require participants to answer a 26-item test at least four times. Additionally, the focus was not on attractiveness, nor was it on novelty. The UX testing does not reveal what each system does, but shows how an app performs, and how users view the system.

Ma et al. (2011:1) claim that “the usability of mobile applications is critical for their adoption, particularly because of the relatively small screen and awkward (sometimes virtual) keyboard” of smartphones. It therefore became necessary for this study to test the usability of the four recommended apps. Usability studies reveal how functional the app may be, and the feelings of the users on a system. Software that is easy to use, useful, and pleasurable to use, is the ideal. Usability tests reveal that any user behaviour with an app is measurable. There was limited literature on usability of educational apps. A large number of these apps, marked as educational, needs to be regulated and validated. This may assist educators and learners in choosing the right software.

For this study, software was evaluated for satisfaction and functionality in a Physical Sciences classroom to determine how it can impact learning. If learners are satisfied with the functionality of the app, this can increase their motivation in learning the subject, therefore making the learning process interesting. Additionally, evaluating an app on functionality may reveal how an app can be used to impact pedagogical approaches in the classroom (see 2.3 for teaching approaches). To determine whether a software is usable, a SUS questionnaire is used together with an app review question and task sheets (see 4.6.3). The UX tests are used by experts to determine the usability of computer systems. Since apps were tested for usability in this study, the same tests were used to determine if an app was applicable for use in a Physical Sciences classroom as they reveal user emotions when interacting with apps.

3.6 SELECTION CRITERIA FOR APPS IN A PHYSICAL SCIENCES CLASSROOM

As stated in chapter 1, there are more than 2300000 apps housed in the Google Play Store which are identified as educational or having an educational benefit; therefore, selecting an app to use can become a daunting task especially for people who rarely use computer devices, whether portable or desktops. Apps fall under various categories including games, fashion, banking, communication, and educational. Ceci (2022) states that knowing the type of app needed for educational tasks helps to narrow the search as there are more than 2.6 million apps housed in Google Play Store (as of 31 March 2022).

Although several types of users can acquire apps in diverse ways, knowing the type of app needed for a task is still a necessity. An app can be recommended to another person, but if no one is using the type of app one needs, then apps can be found by searching apps that fall under a certain category. For the purpose of this study, the following criteria were used to select apps which were to be evaluated. Different databases were consulted but not a single criterion was identified which could guide an educator into choosing the appropriate app for use in a classroom. However, from the reviewed literature, the following may guide a user in selecting a relevant app. In order to choose an app for use, a user must ask the following questions:

- Why do I need this app?
- Is it readily available?
- What do I need to access it?
- Is the app usable?
- Do I prefer app A over app B?

Since apps are used for different purposes, a Physical Sciences educator must know why the app is required in class as this can make it easier to navigate through the app stores or surf the internet using search engines.

3.6.1 Purpose of an App

As indicated throughout this study, different researchers have discussed roles that mobile applications can play in education. When selecting an app for classroom lessons, it is important that the selected app meets the goals of the lesson. Powell (2014:21) advises that the learning objectives can assist in choosing an app. The teacher must first clarify the role an app is to play in a classroom, as this establishes a purpose for using any app selected for use. This is influenced by the objectives an educator would like the learners to achieve regarding a given topic. This is coupled with the scientific skills that a learner must acquire as guided by the CAPS (RSA, 2013) document, and principles of teaching and learning discussed in chapter 2.

For instance, an educator may want to use an app to communicate classroom content to learners after school hours, and therefore this can help an educator in selecting the most relevant app for communication. Learners learn diverse ways of communicating through the use of video-conferencing software. The search on the internet can then provide a list of relevant applications that can suit the purpose described by the user. However, relevancy is determined by the availability and accessibility of the app as an app may seem relevant but the availability of the app for classroom use helps determine if the app will be relevant for use in the classroom.

3.6.2 Availability of Apps

Jayaprakash and Chandar (2015:3) indicate that mobile applications are available to play a variety of roles in teaching and learning such that classrooms today are filled with electronic devices that can be used to enhance knowledge. The availability of mobile apps was therefore never in question, rather the purpose. Suppose a teacher would like learners to perform an experiment on ideal gas laws but the Physical Sciences laboratory does not have the necessary equipment, hence the purpose is to use apps that assist learners in conducting the stated practical experiment. Learners will only be able to perform such experiments if there are mobile apps that are readily available to address experimentation regarding ideal gas laws. Thus, a clear purpose is determined by the availability of an app. However, there are challenges that prevent a user from using an app.

3.6.3 Accessibility

Accessibility plays a crucial role in selecting an app as mobile apps are not accessible to everyone (El-Glaly, Peruma, Krutz, Hawker & John, 2018:30). This is due to the inability of the developers to create apps that are accessible to everyone - even learners who do not have the relevant tools and skills to access learning apps. For this study, accessibility refers to the learners being able to easily obtain and use learning applications.

Even though an app can be available for downloading and meets the desired purpose, if it is not accessible to all learners in a classroom, then the learners without access may not reap the benefits of using that app. An internet-based app is not ideal for learners from low socio-economic environments as it limits access to learning content, especially apps that consume substantial amounts of data. Additionally, a paid app may not be accessible to learners from poor families. Furthermore, an internet-based app requires internet connectivity which therefore makes it difficult for all learners, and therefore the internet is not ideal for learning. In sum, when selecting this type of app learners are at a disadvantage and therefore not preferred in a learning set-up; it is best to choose an app that can be easily accessed by all the users.

3.6.4 Usability

For a mobile app to be classified as usable, it must meet the needs of a user, and must be user-friendly. In other words, the majority of the people should find the app easy to use, and the user interface (UI) easy to navigate. WhatsApp is a user-friendly app as it is easy to use, and it meets the communication needs by both teachers and learners. Powell (2014: 24) suggests that reading an app description can help guide the user understand the functionalities of the app. This is because the description page lists all the functions that an app can perform. Furthermore, it is easier to detect the limitations of the app from the listed functions.

Everyday users can determine if an app is usable by judging whether a particular computer system (app) meets their needs. The steps discussed above can be applied to guide learners and educators to select appropriate apps for classroom teaching-learning spaces, but the choice is still based on user-preference.

3.6.5 Software Preferability

Hui, Liaskos and Mylopoulos (2003:1) assert that different users have various levels of expertise, and therefore they also differ in what they prefer. Although a software developer and a Physical Science teacher may require spreadsheet software, this choice is influenced by the demands of the profession. Furthermore, user-preference may be influenced by other factors such as software popularity or comfortability. Once a software is downloaded and installed on a smartphone, the user's comfort in using the app determines if that particular app is deemed as relevant, and therefore it can be recommended for use. Canstello (2018) adds that app popularity is determined by the number of users. Varshneya (2013) indicates that app retention, via downloads can also be used to determine if an app is useful. Therefore, an app that has a large number of downloads or users, and a high retention rate, is regarded as popular. Apps like Facebook, WhatsApp and Twitter are specified as having large downloads; therefore, they can be regarded as being popular. However, there is limited available peer-reviewed literature which can be used to determine app popularity; therefore, this study used tech-websites to provide metrics used to determine app success and popularity.

Although app popularity, user comfort, and job demands influence the user preferability of a software, it is difficult to predict which app a user will select as 2 or more apps can perform the same task, but it is the preference of a user which will decide which app he/she is going to use.

For instance, Microsoft Office Suite and Libre Suite have word-processing that allows users to input text through writing, but Libre Suite is not as popular as Microsoft Office. Additionally, Facebook Messenger and WhatsApp messenger offer the same chat facilities, but WhatsApp is used more rigorously. Also, Microsoft Teams and Google Meet offer the same video-conferencing features.

In order to guide an educator in selecting an app for use, he/she must know the type of app needed, and the purpose for needing this app. This app must be available and accessible to potential users. However, the final choice lies with the educator or student who should select what he/she is comfortable with. As stated in principles of learning in chapter 2, learning occurs easily when learners are comfortable.

Although, there is a dearth of literature on how to select any app for use from Google Play Store, this study proposes a 5-step process (below): purpose of the app, availability of the app, accessibility of the app, app usability, and app preferability.

3.7 APPLICATIONS FOR THIS STUDY

This study utilised Google Classroom app, Physical Sciences mobile app (Grade 10 and 11), WhatsApp, and the School Planner app. No literature was found on the use of Physical Science mobile apps and the School Planner app. The only available information was found on Google Play Store. Therefore, for these 2 apps, non-academic sources were utilised. These apps were selected using the criteria discussed in 3.6 above.

Step 1: Purpose for selecting apps for this study

The TPACK framework illustrated the importance of planning (see 3.2.3.1) in a classroom and therefore an app that can assist learners and educators to plan effectively was required. Additionally, a need for effective communication was realised and the need for learners to constantly practice. The researcher also wanted apps that can be used to as a teaching and presentation platform that can also be used for sharing of course material. Therefore, this study selected apps to test the impact of planning, communication, practicing and sharing of resources on teaching and learning in a physical science classroom.

Step 2: Availability of apps

Although there were numerous apps available from Google Play Store, the apps which were to be used to facilitate planning, had to be relevant to the school life of a learners. They needed to have timetables, reminders, calendar and homework. Communication apps available had to provide communication that is cheap, have multimedia effect and allows communication in a group. Practice software was aimed at offering learners a chance to practice without increasing the teacher’s workload therefore putting the learners in control of their learning. the testing software must allow for learners to write tests online. The test can be multiple choice, long questions which also allow learners to upload content to be marked at a later date by an educator. Furthermore, this app must also make it possible for learners to see their mistakes and revisit it at any time. Additionally, this software must grade the multiple-choice tests and upload learner statistics to monitor learner progress in a subject. Apps must be reliable to use.

Step 3: Accessibility of apps

Numerous apps were accessible without the need to pay for a subscription fee. This meant the researcher could have selected any of the apps that met the intended purpose which were available for download.

Steps 4 and 5: Usability of apps, and software preferability

These applications were eliminated based on usability goals. For planning software, the *school planner app* stood out as it had all the specified needs. It can also be used in an offline platform therefore making it easier for use. The *School Planner for students' app* also met the criteria discussed, however the researcher preferred the *school planner app* as it had more downloads compared to the *school planner for students app*. In communication, learners already had the *WhatsApp* app installed. This app met the criteria discussed above, and since learners already had it installed on their smartphones, it meant that the app was popular and therefore could be used. The *Physical Sciences mobile app* provides questions and answers based on a topic, test and examination, so this app was preferred because it can help learners address topic needs. For instance, a learner can focus on momentum questions then compare answers with those supplied in the app.

3.7.1 The Physical Sciences Mobile App

The Physical Sciences mobile apps have been developed by JSDT solutions. This company has created a total of thirty-seven mobile applications from Grade 8 to 12 covering different subjects. All of the apps developed by this company have adverts and can be accessed without paying a subscription fee. The Grade 11 Physical Sciences mobile app was released in April 2018, while the Grade 10 Physical Sciences mobile app was released in 2019 (appbrain.com 2021b: online). According to the JSDT solutions (2019: online), these apps have the following key features: practice problems, June exams, exemplar, November exams, tutoring service, career guide, and tertiary institutions and bursaries. For the purpose of this study, the focus was on the practice problems. The practice problem tab allows the user to practise for any topic covered in Physical Sciences relevant to a specific grade. All problems are topic-based. Additionally, the questions are extracted from the National and Provincial question papers with memoranda as supplied by the DBE, therefore helping the learner master content from any topic of choice. This app is therefore SA CAPS-based. Information from the app page reveals that this app already has more than 100 000 downloads and was last updated on 18 April 2021.

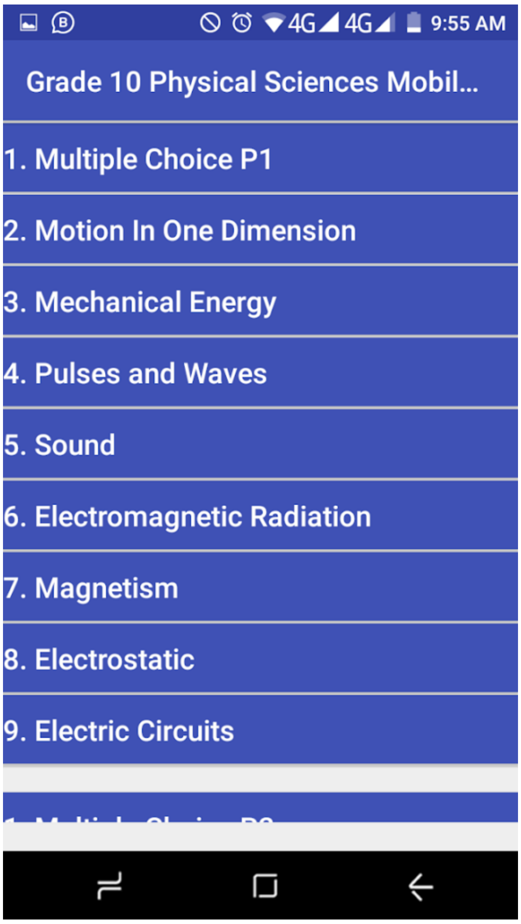

Figure 5: Physical Sciences mobile app for Grade 10 practice tab (JSDT Solutions, 2019)

There is no literature that indicates how to use this app in the classroom, nor is there literature on how this app can affect learning. However, the number of downloads indicates that these apps are fairly popular, and are being used by learners, and therefore the impact it has on learning can be investigated. In this study, content on two topics will be reviewed.

3.7.2 The School Planner App

The school planner app, like the Physical Sciences mobile app, has not been peer-reviewed; however, there are YouTube tutorials on how the app can actually be used. According to the app page on Google Play Store, this app has over 10 000 000 downloads worldwide, and it can be used by children of different ages from elementary school all the way to college. This app has the following key features (Dal Cin, 2022):

- Simple to use, works fast and it is intuitive
- Provides an agenda tab for homework, exams and reminders;

- Timetable tab;
- Calendar;
- Several types of themes;
- Backup services on Google Drive;
- Notifications for any assignments, tests, and reminders;
- Managing of grades, marks, and subjects; and
- Recording of lessons.

The agenda tab allows for setting agendas, homework planning, exams, and reminders. Additionally, users can choose the frequency they would like to receive reminders. Moreover, this app allows users to plan and record their timetable. The ability to select different themes means the app can be personalised for different users.

3.7.3 Google Classroom App

Sudarsana, Putra, Astawa and Yogantara (2019:2) state that Google Classroom is an online platform for teachers and students used for learning and enabling online collaboration. Shaharanee, Jamil and Rodzi (2016:1) add that this app allows educators to "create and organize assignments quickly, provide feedback efficiently, and communicate with their classes with ease". Google Classroom has both the mobile version as well as a web-version. The mobile version has been created such that it fits a smartphone screen. This app uses data, and is accessed through a Gmail account. Users must login with this account in order to gain access to the platform. Different researchers have document diverse ways this app can be used.

Firstly, it is important to understand the distinct roles that users can play using this platform. There are two types of users, a teacher and a student. A teacher needs to create a user-friendly classroom platform; it is then that a learner can join a class. A class can be joined by a link send through any communication medium such as a social networking site or through a class code. Each class is created by a teacher using a unique class code which allows users access only to that one particular class. Additionally, teachers can collaborate on this platform. A teacher can also be added on this platform. Moreover, a teacher can manage students' interactions from the app (Zhang, 2016: 57-59) which allows an educator to manage students in the following way:

- Add students manually to the classroom;
- Remove students from the classroom; and

- Emailing content to students through this platform.

Additionally, this app has the relevant features for educators including streaming for students, creating of questionnaire, announcements, assignments, grading of assignments, the sending of the YouTube link for teaching purposes (Iftakhar 2016:13). This platform is similar to a traditional classroom except that it is paperless. However, as this is an online-based software, it requires internet usage, therefore learners from low-socio economic families may possibly not benefit from this app. Additionally, although this app is paperless, the quality of the camera affects students uploads as an answer taken from a poor camera will not be clearly visible for a teacher to mark students' responses. Moreover, it is not possible to mark learners directly on the app; this makes it difficult for educators to highlight areas where learners made mistakes in order to help them improve. Teachers who are not techno-competent may struggle to set up the app for their learners.

However, studies report that teachers and educators are satisfied with the use of the app. Sudarsana et al. (2019:5) state that using Google "improves the teachers' and students' quality to use technology wisely, especially for learning processes, saving time, being environmentally friendly, overcoming distance of residence, increasing collaboration among students, timeless communication, and as a secure document storage". Shaharanee et al. (2016:5) add that students' view the use of this platform as being effective in promoting active learning while teachers state that it promotes collaboration in a learning environment (Iftakhar 2016:15). A search from different databases did not yield any literature on the usage of this app with regards to South African schools. Therefore, although the benefits and drawbacks of using this app have been documented by several researchers, more research still needs to be done to investigate how this app can affect learning in specifically South African schools.

The Google Classroom app was evaluated by sampling Grade 10 Physical Science learners before it could be recommended for classroom use. This app is similar to Blackboard applications. Although there are challenges in using this app, studies reveal that it has benefits and features that make it suitable for classroom usage. As this app is not subject specific, it puts an educator in control by forming different classes, creating and managing content, and monitoring learners in each class. Additionally, this app has more than 100 million installs (Google LLC, 2022) indicating that it is one of the most popular app.

3.7.4 WhatsApp

The WhatsApp application is regarded as a social networking app that provides immediate access to information (Zan, 2019:19). This app has the following key features:

- Offline messages which are saved on the user's mobile device and can be retrieved at any time.
- Multimedia messaging – users can send and receive videos, audio, website links, pictures and text messages.
- There is no limit to the number of messages which can be sent between users.
- It is inexpensive to use as it does not require substantial amounts of internet bundles to activate (Bere, 2012 cited in Gon & Rawekar, 2017: 19-20).

Bouhnik and Deshen (2014:229) believe that this platform allows teachers to share ideas about any challenges they face in the classroom while also providing access to learning materials. Doğan (2015:239) adds that WhatsApp groups between educators and parents increase the interaction between educators and parents thus facilitating easy feedback on students. Furthermore, communication between teachers and learners is extended beyond the classroom (Hershkovitz, Elhija & Zedan, 2019:74). Student-teacher communication beyond the classroom can be positive for learning. A learner is exposed to content offered by an expert in a field (teacher) which keeps students gainfully engaged. Additionally, multimedia messages make it easier for learners to visualise the content when it is discussed, thus making it simple to understand.

However, on the downside, this app makes it easier to transmit fake news rapidly. This is because content sent by users is not regulated and therefore any unconfirmed stories can be published on the group chat (Arun, 2019:32). Additionally, some users tend to send messages not related to a specific WhatsApp group's purpose thus inconveniencing all persons within the group. Furthermore, this platform can be used to humiliate and bully other learners. According to Aizenkot and Kashy-Rosenbaum (2018:4711), four types of bullying occurs on this platform:

- Verbal violence – insults, mockery, derogatory names
- Group violence – opening a group against another person
- Visual violence – using videos and pictures to humiliate a person
- Group selectivity – preventing a person from joining a group

Cyberbullying is an enormous problem worldwide. It lowers learners' self-esteem, and sometimes may lead to injury. Additionally, there may be conflicts between teachers and parents during regular interaction. Notwithstanding the challenges, this app is being used worldwide by a large number of people (as reported in 2.3.2 above) confirming that people find it most suitable compared to other communication apps. Additionally, cost associated with the use of these app is incredibly low, therefore it makes it affordable to a large number of people.

3.8 CONCLUSION

This chapter discussed related literature pertaining to the study's topic. It cautioned that before technology can be implemented and integrated into the classroom space, an educator must understand different models of technology integration such as TIPC, SAMR and TPACK, after which he/she can then select one which can be used as a guide to classroom teaching and learning. Studies reveal that the most suitable model in this regard is TPACK. However, this model is not clearly defined thus leading to numerous variations of its application. This chapter elaborated on diverse ways technology can play in education as explained by different researchers. However, for the purpose of this study, these roles were only limited to curriculum development and how technology can be used to impact learning in a Physical Sciences classroom. To further understand how effective technology can be in education, mobile technology integrations around the world were investigated. This was done by illustrating diverse ways in which mobile technologies can be used to impact learning in the classroom. It was evident that mobile technologies are integrated much more in developed countries than the developing countries. Additionally, different methods used to determine software usability were summarised, and the criteria used in selecting apps for the study were established. Lastly, the chapter compared and contrasted literature from different researchers regarding the apps explored in this study. The next chapter (4) provided the research design and methodology that were applied to investigate the role apps play in a Physical Science classroom.

CHAPTER FOUR

RESEARCH METHODOLOGY

4.1 INTRODUCTION

This chapter (4) described the research design and methodology adopted for the study. As mentioned in chapter one, the purpose of this study was to investigate the role of mobile applications in a Physical Sciences classroom, hence the research design and methodology were chosen to cohere with the study's aim.

Firstly, I listed the research questions, and then provided the rationale for the chosen paradigm to guide this study. I then elaborated on the design and methodology adopted for this study. This included the sampling criteria, research instruments, study site, data validity and reliability, and triangulation. This was followed by outlining the data collection strategies, and how the collected data was stored and analysed. Lastly, the study's limitations and ethical considerations were presented.

Given the nature of the research questions (see 4.2), I could not answer them by using either qualitative or quantitative methods. More reflective ways needed to be adopted, therefore a robust eclectic methodology was chosen. A mixed methods design is therefore relevant to guide this study.

4.2 RESEARCH QUESTIONS

The primary research question sought to gather data on how free mobile applications influence learning in Grade 10 and 11 Physical Sciences classrooms in the southern Free State. To unpack the primary research question, this study used both empirical and non-empirical study procedures.

4.2.1 The Aim of the Non-empirical Study

The aim of the non-empirical study was to gather information regarding the following research questions (see 1.4.2):

- How do principles of teaching and learning influence learning in a Physical Sciences classroom?
- How does a teaching approach impact learning in a Physical Sciences classroom?
- What is the role of the CAPS document in classroom learning?
- What is the role of the TPACK framework in education?

- What is the role of digital technologies in learning in the Physical Sciences?
- How has mobile technology been integrated in education?

4.2.2 The Aim of the Empirical Study

Gaskell (2000:349) believes empirical research methods "derive from the application of observation and experience to a research question". Empirical studies pose several advantages:

- Obtain preliminary evidence to confirm or refute hypotheses; and
- Control factors that may affect the study (Carver, Jaccheri, Morasca & Shull, 2004:4)

The empirical study aimed at answering the following questions as posed in 1.4.2:

- What are the abilities of the learners regarding selecting and accessing mobile applications for classroom usage?
- What are the abilities of the learners to test apps for suitability and applicability in the Physical Sciences classroom?
- What are the experiences of learners regarding the use of mobile learning applications?
- How does app usage in a classroom affect teaching and learning activities in a Physical Sciences classroom?

The first two questions above were aimed at discovering aspects of teaching and learning, and to inter-relate the nature of education and technology. The findings emanating from interrogating issues related to these questions enabled the researcher to suggest recommendations (see 6.4) regarding the use of mobile apps. The proposed questions were therefore sufficient to answer the primary research question.

4.3 RESEARCH PARADIGMS

Wilson (2001), cited in Hart (2010:6), defines paradigms as "a set of beliefs about the world, and about gaining knowledge that goes together to guide people's actions as to how they are going to go about doing their research". Rocco, Bliss, Gallagher, and Pérez-Prado (2003:20) view paradigms as being our notions of how the world is seen. The implication is that each researcher brings his/her own set of beliefs and assumptions to a research project which influences their approach in conducting the study. It is therefore important to clarify the belief and assumptions of the researcher to help understand how their findings emanated. Scotland (2012: 9) believes that each paradigm has its own set of views and have different assumptions of reality and knowledge which guide their approach in research which is reflected in their methodology. Mackenzie and Knipe (2006:2) state that the paradigm chosen by a researcher shows the intent, provides the motivation, and reveals the expectations for the research. Each paradigm focuses on three aspects: ontological assumptions, epistemological assumptions, and methodology.

4.3.1 Ontological and Epistemological Assumptions

Assumptions are regarded as beliefs necessary to conduct a study but cannot be proven to be true (Simon & Goes 2013:1). Hofstee (2006:88) believes that a researcher must state all the assumptions underlying a study; that is, the ontological and epistemological assumptions.

Ontology is regarded as the study of being (Crotty, 1998:10). Scotland (2012:9) clarifies that ontological assumptions are concerned with what constitutes reality. Guba and Lincoln (1994:107) add that ontological assumptions define the nature of the world and how an individual fits in that place, as well as the relationships that are prevalent in that part of the world. Ontological assumptions are significant in a study as they provide the researcher's stance on what constitutes reality. The reality is that learners gain knowledge in diverse ways, and therefore multiple strategies should be devised and utilised to help a learner gain knowledge.

Moon and Blackman (2014: 1170) state that "Epistemology is concerned with how people create knowledge and what is possible to know". Scotland (2012:9) elaborates that "Epistemological assumptions are concerned with how knowledge can be created, acquired and communicated; in other words, what it means to know". The different ontological beliefs imply that there may be differing epistemology beliefs for any individual which means that people acquire knowledge, create, and communicate knowledge differently. Hall (2013:73) maintains that "epistemology and methodology are related in that the epistemological position adopted constrains the type of data considered to be worth collecting and in the way that data is to be interpreted". Therefore, the chosen paradigm must allow the researcher to collect any relevant data suitable to solve the research problem. In this study, I collected both qualitative and quantitative data; a suitable paradigm must allow for the collection of both types of data. Accordingly, this study employed the pragmatism paradigm (see 4.3.2 below).

4.3.2 Pragmatism

Pragmatism focuses on what works. Rorty (1991:27) defines pragmatism as "relieve and benefit condition of man – to make mankind happier by enabling them to cope more successfully with the physical environment and with each other". Cameron (2011:101) regards pragmatism as being effective for mixed methodology as it offers the "middle position philosophically and methodologically". This implies that researchers can apply more than one method (both philosophically and methodologically) in a study to find answers to their research questions. The implication is that a researcher does not have to adopt constructive or positivistic ontological and epistemological assumptions, but rather assumptions that are necessary to provide answers to the research questions. Therefore, the research can incorporate both quantitative and qualitative data in a single study as they are not restricted by either qualitative or quantitative approaches.

Creswell and Plako (2017:13) believe that "Mixed methods research encourages the use of multiple worldviews, or paradigms, rather than the typical association of certain paradigms with quantitative research and others with qualitative research" - therefore, more than one paradigm can be used. Understanding that individuals are different in the way they make-meaning of the world around them implies that knowledge must be gained through individual actions and reflections. Observing the actions of a person in a particular environment informs the research that user-actions, coupled with their explanations, reveal their views of the world around them. Pansiri (2005:198) adds that "the researcher is advised to choose external reality and choose explanations that best produce best outcomes". The researcher believes that each individual has a specific way in which to see the world. This is better captured through the observation of participants (see 4.5.2.5). Knowledge is obtained from user-interaction of the software which can reveal what participants see and how they feel about it. This knowledge can then be used to inform the roles apps can play in a Physical Sciences classroom.

Pragmatism draws from constructivism as purported by Hein (1991:1) who points out that in constructivism, when thinking about learning, the focus must be on a learner and "there is no knowledge independent of the meaning attributed to experience (constructed) by the learner, or community of learners". Also, Li (2001:1) believes that in constructivism, learners develop an understanding of the work through direct observation, reflection, experimentation and how they interact with the environments around them to continuously challenge or confirm ongoing theories and beliefs. Both these paradigms emphasise the action and reflection of the learners in gaining knowledge. Furthermore, teaching and learning principles underpin the importance of active participation (see 2.2). A constructivist learning environment is defined as "a technology-rich, open place where a learner can use a variety of tools and information resources in pursuit of learning goals and problem-solving activities" (Li, 2001:2). Since pragmatism is concerned with what works, it involves practices that elicit results, as well as planning practical lessons that add value to the education of the learners. Additionally, the pragmatism learning approach uses both experimentation and experiential learning which enhance the skills learners acquire in Physical Sciences (see 2.4). Therefore, learners can experiment with different mobile apps in the classroom to explore incisively how technology can play an important role in a Physical Sciences classroom. These technologies can be used by learners to access educational resources which aid in the construction of new knowledge, while finding multiple avenues of engaging with each other socially to solve problems and generate ideas.

Pragmatism also draws from the positivism paradigm. Nekrašas (2001:59) believes that the two paradigms have a number of similarities which include realising that the source of knowledge is experience, and that the development of science is significant. Positivism is a study in the social sciences that relies more on scientific evidence and in pragmatism, as science is regarded as the foundational process of the natural world.

Pragmatism uses the best practices of constructivism and positivism. This paradigm is therefore appropriate for this study as it allows the researcher to collect data without restrictions. Mixed methodology can therefore provide a clear understanding of how apps can impact learning in a Physical Sciences classroom as both data types help paint a clear picture of the use of apps in classrooms. According to Dewey (1950), this is because "human action is capacity for meaningful and transformative activity within nature, and the justification of such a naturalistic conception follows a quite similar logic" (Alexandratos, 2021:9). Additionally, what people know is a result of a process of inquiry based on their beliefs and actions (Morgan, 2014:1048). What people believe in; influences the actions they take. The implication is that in this study, the role apps play in a classroom is determined through the actions of the learner (the manner in which they interact with the apps) which can determine what learners' beliefs are when it comes to app usage.

4.4 RESEARCH DESIGN

Research design is defined as a proposed plan to conduct research (Akhtar, 2016:68). It is a strategy that unifies all the different components of the study in a logical way to address the research problem. This includes the type of data to be collected, and how it will be collected and analysed to draw meaningful conclusions from the data. There are different approaches to research design: experimental, explanatory, descriptive, and exploratory. These approaches are linked to different designs like qualitative, quantitative, and mixed methods.

4.4.1 Mixed Methods Research Design

Tashakkori and Creswell (2007:4) define mixed methods as the gathering and analysis of both qualitative and quantitative data in a single study. The findings are then integrated, and inferences are drawn from the data. As explained above, both numerical and textual data must be integrated to provide a researcher with a clear understanding of the participants' behaviour. This integration can be conducted sequentially or concurrently. That is, a researcher can collect one type of data first, either qualitative then quantitative (sequential), or collect data at the same time (concurrent). In a sequential mixed design, the study involves steps in data collection, which can either be qualitative dominant or quantitative dominant (Kroll & Neri, 2009:40). Concurrent mixed methods involve gathering of both qualitative and quantitative data at the same time (Kroll et al., 2009:43; Small, 2011: 68).

		Implementation sequence	
		Concurrent	**Sequential**
Priority	**Equal status**	QUAL + QUANT	QUANT → QUAL QUAL → QUANT
	Dominant status	QUAL + quant QUANT + qual	QUAL → quant qual → QUANT QUANT → qual quant → QUAL

Figure 6: Mixed method design matrix (Andrew & Halcomb 2007, cited in Kroll & Neri 2009:38).

Figure 6 above indicates that when a researcher selects either concurrent or sequential design, both qualitative and quantitative methods may have equal status, or one method may be dominant.

A qualitative dominant mixed method is represented by QUAL + quant while a quantitative dominant is represented by QUANT + qual. Johnson, Onwuegbuzie and Turner (2007:124) believe that QUAL + quant research relies heavily on qualitative data collection techniques and "constructivist-poststructuralist-critical" techniques but recognises that the addition of quantitative data is of benefit to the study. QUANT + qual research relies heavily on the qualitative process of conducting research but also recognises the value of adding qualitative data to the research. Since QUANT + qual relies on the positivism paradigm, this implies that the study is neither qualitative nor quantitative dominant as both processes are used equally in one study. Doyle, Brady and Byrne (2009:180) believe that a researcher must first choose how qualitative and quantitative data is collected (concurrent or sequential) followed by the method that is dominant. Terrell (2012:260), in conjunction with Doyle et al. (2009), adds that selecting an approach depends on four factors:

- Theoretical perspective
- Priority of strategy (equal (QUANT + QUAL, qualitative (QUAL + quant) or Quantitative (QUANT + Qual)
- Sequence of data collection implementation (qualitative first or quantitative first or no sequence)
- The point at which data is integrated (at data collection, or at data analysis, or at integration or some combination)

The implication is that the priority of strategy determines diverse ways data is to be integrated, and when it is to be integrated. Concurrent and sequential strategies have diverse ways of mixing data. Examples of concurrent and sequential designs are:

- Sequential explanatory
- Sequential exploratory
- Sequential transformative
- Concurrent triangulation
- Concurrent Nested
- Concurrent transformative

4.4.2 Concurrent Mixed Methods

For the purpose of this study, the focus was on the concurrent triangulation method which involves collection of both qualitative and quantitative data simultaneously. Concurrent triangulation relies on triangulation of the data. Creswell et al. (2011:63) believes that there are four triangulation variants (triangulation design, triangulation design - convergence model, triangulation design - transformation model, and triangulation design - validating qualitative data model). This study applied the triangulation convergent design where qualitative and quantitative data are integrated at the analysis phase or interpretation phase, as depicted in the Figure 7 below.

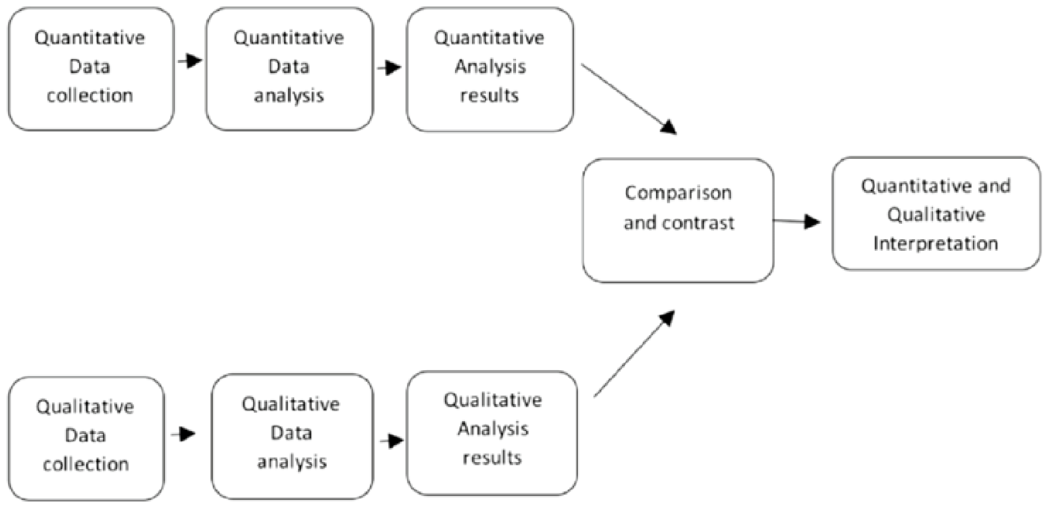

Figure 7: Triangulation convergent design (Cachay-Huamán & Ramírez-Hernández 2019:1344)

In this approach, both data types were collected separately, analysed separately, and mixed after the analysis of each data type. The analysis involved comparing and contrasting both data types in order to establish convergence. Additionally, this study used both data and methodological triangulation (see 4.5.6) to explain the findings. Imran and Yusoff (2015:389) add that the combination of qualitative and quantitative data increases the accuracy of the study's results. Furthermore, a researcher understands the research problem fully through mixed method research designs (Azorín & Cameron, 2010:95) by mixing both qualitative and quantitative data. The mixed methodology approach is therefore appropriate for discovering the impact apps have in a Physical Sciences classroom as the focus is placed on participants' behaviours (interaction with the apps) and their reflections (SUS questionnaire and app review questionnaire).

In mixed method design, qualitative data is collected and analysed using qualitative methods while quantitative data is collected and analysed through quantitative methods.

Qualitative methodology provides a researcher with the description of behaviours in the classroom while the learners interact with the apps. This is conducted through participant observations. Quantitative methodology provides the user rating of each recommended software which is then used to determine the usability of the software. The combination of both quantitative and qualitative data therefore informs the research on how the participants interacted with the apps, and how they feel about that particular app.

In addition, in the quantitative phase, participants reflect on the applicability of the app with reference to teaching and learning activities. To determine the usability of the recommended app, participants must also rate the usability of the app by using the usability system questionnaire (SUS) tool. The quantitative phase addresses the feelings of the user and applicability of the software to the teaching and learning in a Physical Sciences classroom. Both phases are then used to inform the roles apps play in a Physical Sciences classroom.

This study utilised the concurrent triangulation design. Both qualitative (observations) and quantitative data (SUS questionnaire, tasks and app review questionnaire) were collected simultaneously and were given equal status during methodological implementation (see data collection). Thereafter, data was integrated at the interpretation phase.

4.5 METHODOLOGY

Using a mixed method approach requires a thorough understanding of both qualitative and quantitative methods. Hofstee (2015:112) indicates that a methodology incorporates research instruments used in gathering data, their limitations, types of data gathered, and how data is to be analysed. Research instruments, data collection, and data analysis are covered in detail in 4.5.3, 4.6 and 4.7, respectively.

4.5.1 Population Interest and Sampling

Tuff and Tuff (2012:1) define population as “a group of individuals” with similar characteristics. Within a certain population, the interest is usually on a certain population that meets a criterion targeted by the researcher which is referred to as population of interest (Majid 2018:3). For this study, the population of interest was Grade 10 and 11 high school learners in the southern Free State schools.

Sampling is defined by Majid (2018: 3) as the process of selecting a representative group of individuals from a desired population. In this study, participants were sampled according to the random purposive sampling technique which “is the deliberate choice of an informant due to the qualities the informant possesses” (Tongco 2007:47). It is a non-probability sampling technique that samples participants on availability (Taherdoost 2016: 23). Members of the population of interest must meet certain criteria, such as being easily accessible and must be willing to participate in the study. According to Rai and Thapa (2015:6-9), there are seven methods of purposive sampling:

- Maximum variation
- Homogenous
- Typical case
- Extreme case
- Critical case
- Total population
- Expert sampling

Although each method holds several advantages, this study focused on homogenous sampling which is defined as "a sample whose units (e.g., people, cases etc.) share the same (or very similar) characteristics or traits; for example, a group of people who are similar in terms of age, gender, background, and occupation" (Rai & Thapa, 2015:7). Participants consisted of both male and female learners aged between 14 and 18 years from Grades 10 and 11. They were studying Physical Sciences at two schools in the Motheo District of the Free State province. Since this study is based on what impact mobile apps have in a Physical Sciences classroom, the sampling strategy was relevant for this study. However, to increase the credibility of the results, sampling was conducted randomly (Suri, 2011:8). Tongco (2007:152) adds that purposive sampling and random sampling may be combined to produce a powerful way of sampling. This can therefore lead to unique inferences emanating from the study. Although a combination of probability and non-probability sampling methods is rarely done, research reveals that it is effective, hence the reason for using it in this study.

4.5.2 Research Instruments

Research Instruments are tools designed to obtain data on a specific topic of interest for research purposes. Some researchers refer to instruments as methods. Methods are described as techniques or procedures used to gather data to find answers to the research question (Crotty, 1998:3), but some methods are more appropriate than others. A researcher must decide on the instruments that suits the data collection process best. Mixed methods design employs different tools to gather data during the research which include surveys, questionnaires (open- and close-ended questionnaires), observations and interviews (Johnson, 2012:2-5).

This research utilised the following tools: questionnaires (pre-session questionnaire, app review questionnaire and SUS questionnaire), observations (observation sheets), and task sheet.

4.5.2.1 Questionnaires

A questionnaire is regarded as a research instrument consisting of a series of planned questions for the purpose of gathering information from respondents (Parajuli, 2004: 53). Questionnaires can be distributed in several ways: by mail (post office or email), handed out to be returned, or through face-to-face communication while the researcher is present. Close-ended questionnaires include multiple-choice questions, Likert scale prompts, and 'yes/no' questions. These are pre-coded questions with pre-coded answers. These sets of questions can be used to provide quantitative data (even though the data gathered is text-based, it can be quantified). Open-ended questions allow the respondent to free expression (provide unique response). This provides the qualitative type of data as the respondents can use the provided space to fully state their point of view on the given question. A single questionnaire can make use of both type of questions. Depending on the type of study, a researcher decides the type of questions which are suitable for their study.

Questionnaires pose several advantages. Firstly, they are easy to distribute and save a lot of time in gathering data. Secondly, they are anonymous thus making it easier for respondents to express themselves. Thirdly, quick results can be obtained.

In this study, questionnaires were used as follows: firstly, to gather participants' information pertaining to their demographics and competence levels in using Google Play Store or the internet (pre-session questionnaire); and secondly, questionnaires were used to assess the software suability (SUS questionnaire) and applicability of the software in relation to the Physical Sciences (app review questionnaire). This data is then then quantified.

Questionnaires were also used to create a task sheet, and an observation sheet (see appendix U) which were distributed to the participants to begin part B of the study as stated in 3.3.5 above.

4.5.2.2 Observations

McClure (2002:5) describes observations as "a process that allows individuals to collect information about others by viewing their actions and behaviours in their natural surroundings". Kawulich (2012:1) views observation as "the systematic description of events, behaviours, and artifacts in the social setting chosen for study". Participants interaction with the applications was observed throughout the data collection processes. The researcher wrote notes recording all the actions witnessed while the participants used the product (see observation sheet appendix U) and reflected on their meanings. These observations formed part of the qualitative data.

4.5.2.3 Task sheet

A task sheet can be utilised to determine if the user was successful in performing a task. Although there are several metrics that can be used to indicate task success, including time-on-task and binary success (Tullis & Albert, 2008:66-73), this study chose binary success because this type of data was easier to analyse as it is binary and calculates averages of participants who completed a task successfully, while comparing it to those who failed to complete the task - this can reveal how an app performs. This binary success tool was used to discover if the participants will be able to use the app. This was revealed through the ability of the participants to navigate successfully while using the app. Therefore, this tool was used because it reveals how an app performs. Each task was engineered to test a certain functionality of the app. Participants failing to perform a task therefore revealed navigation challenges of the app. Lastly, this tool was used because it was easier to analyse the data (see data analysis 4.7).

4.5.2.4 Development of research instruments

The aim of this study was to explore the impact of mobile apps in a Physical Sciences classroom. To best explore the aim, the gathering of both qualitative and quantitative data was regarded as crucial as it paints a clear picture on how apps are used in class and how participants felt about the use of the recommended apps, as well as the type of apps participants were already using. Kalkbrenner (2021:2) suggests that when developing tools, a researcher must have a clear purpose as to the need for such tools in alignment with the aim and objectives of the study.

Qualitative data aimed at discovering how participants interacted with the apps, and how they felt about the apps, while quantitative data aimed at discovering software usability through user ratings and recommendations of the apps. As indicated in 3.5, usability studies assess the performance of the software and user satisfaction. Therefore, quantitative data was expected to inform on how the software performed in a Physical Sciences classroom and what role the apps played in enhancing the Physical Sciences lesson. The development of each tool was influenced by the results of the pilot study, as well as the reviewed literature.

According to initial findings and the previous literature, effective learning occurs when a learner is actively engaged in a class activity such that effective communication between a learner and a teacher is promoted. Additionally, learners must have access to relevant practice material, and learning activities must be thoroughly planned. This study assessed apps for the following functions: communication (WhatsApp), planning (through the School Planner app), practice (Physical Sciences Mobile app and Google Classroom app) in order to discover how apps can impact learning. Each tool was engineered for a particular purpose in the study. This included three questionnaires utilised in the study - the section below elaborates on the steps taken to develop each questionnaire, as well as to describe the additional tools used in the study.

Pre-session questionnaire

Hammer (2011:261) indicates that research must include participants' demographics including age and gender, as this helps the readers and researchers to determine "to whom findings generalize and allows for comparisons to be made across replication studies". Additionally, this information can assist in the analysis of secondary data. Furthermore, this data is used to determine if participants selected are a representative sample of the entire population (Lee & Schuele, 2010: 347). Questions one-to-five does include necessary demographics of participants in this study which makes it easier for the study to be replicated. However, consulted literature did not reveal any patterns in determining the participants' app and internet capabilities. For the purpose of this study, it was important to understand if participants used the Google app store to download their application, and what type of apps they have currently installed on their mobile devices. Validity of this tool is assessed in 4.5.2.2

This tool was developed to gather participants' information pertaining to their demographics and competence levels in using Google Play Store and/or the internet. Questions one-to-five were developed to discover if participants were high school students, their gender, age group, and if they were taking Physical Sciences as a subject as stated in the sampling criteria (see 4.5.1). It was required that all selected learners have a smartphone, hence question 6 was included. However, if it was discovered that learners did not possess a smartphone, then one was provided to them for the duration of the study (see cell phone contract appendix K). Questions 7 to 10 were aimed at discovering the ability of the learners to use internet and downloading of apps.

The pre-session questionnaire helped the researcher understand the participants' capabilities with regards to the use of mobile apps prior to the commencement of the study.

SUS Questionnaire

A system usability scale (SUS) questionnaire was used by software experts in the Human Computer Interaction field (see 3.5). For the purpose of this study, this questionnaire was used to determine participants' satisfaction with the recommended apps. These were the feelings of the user towards recommended apps after interacting with it as explained by Tullis (2013d:44). A standard SUS questionnaire was designed to comprise of ten questions. The SUS utilises scales ranging from strongly disagree to strongly agree (See appendix M). Participants must score (rate their feelings) each prompt from 1 to 5. There were 5 positive questions and 5 negative questions about the product being assessed. A SUS score must then be calculated in the end.

Accordingly, a SUS score is calculated (Tullis & Albert, 2013:138) as follows: "first sum the score contributions from each item. Each item's score contribution will range from 0 to 4. For items 1, 3, 5, 7, and 9, the score contribution is the scale position minus 1. For items 2, 4, 6, 8, and 10, the contribution is 5 minus the scale position. Multiply the sum of the scores by 2.5 to obtain the overall SUS score". A high SUS score indicates user satisfaction with the system.

This tool was used because it helped the researcher understand participants' feelings towards an app. Negative feeling may imply that an app should not be recommended for use in the classroom.

App review questionnaire

The app review questionnaire (see appendix O) was used to determine the applicability of the apps to teaching and learning in the Physical Sciences classroom. Participants had to rate whether the content covered on the app was relevant to teaching and learning activities in the Physical Sciences, and how the app assisted them with regards to teaching and learning (questions 1 and 2). Question 6 was generated in order to probe further into user satisfaction with the app. App recommendations are important as they indicate that the software meets user needs (He, Fang, Liu & Li, 2018:828). When a user is satisfied with the performance of an app, it attains a higher rating. Low rating means users of that app are not satisfied. Questions 3 to 5 aimed at understanding whether a recommended app is an offline application or an online application. This is because online apps imply that a user may not have access to it without internet connectivity, therefore putting learners at a disadvantage. Additionally, if an app contains adverts, it is important to know if their presence disrupted the participants when they used the apps.

This section, therefore, helped the researcher understand the role an app could play in a Physical Sciences classroom, and how participants felt about it. Additionally, the researcher gets to understand how the adverts affected the way the user used a recommended app. Therefore, the type of questions and structure of the questions were relevant for this study because they addressed the distinct roles apps play in a Physical Sciences classroom.

App discovery questionnaire

This section aimed at discovering diverse ways learners use to access apps. Learners had to document all the steps they used to discover an app and download it on their cell phones. This was necessary for this study as it revealed different methods learners applied to acquire apps. This tool was therefore relevant for use in this study.

Observations (observation sheet)

Observations aimed at gathering qualitative data about the interaction of the learners with the recommended apps. The observation data included learners' facial expressions, and how participants interacted with the apps as observed by the research team (the researcher and 2 assistants). The observation data included the date and time of the observed phenomenon. The observations revealed participants' behaviours, and whether they completed the assigned tasks. Facial expressions revealed the mood of the learner while using apps which can be used as an indicator to assess whether learners were struggling to use any of the apps. Observing how learners used the recommended apps revealed whether they could successfully use the apps, and if they encountered any navigation issues. Furthermore, this technique also informed the researcher how each app can best be utilised in a Physical Sciences classroom.

Task sheet

Task sheets were created to help participants test an app. Task sheets revealed if a participant will be able to use the apps. Participants were allotted a specific time-frame to perform a certain task (see task sheet appendices P1 to P3). This data was then used to determine the percentage of participants who completed tasks successfully. This determined if the participants were able to use the app or learnt how to use the app. Moreover, the results were used to promote app usage in the classroom. Data collected from the task sheet is binary, and therefore quantitative in nature.

4.5.2.5 Validity and reliability of research instruments

Bordeianu and Morosan-Danila (2013:274) regard validity as "the extent to which the instrument measures what it is intended to measure". Maree (2016:122) indicates that validity is achieved in research study when a researcher is transparent about the process used in data capturing processes.

The tools developed in this study helped to gather data which was relevant to answering the research questions which contributed to transparency. The SUS questionnaire was believed to be very reliable (Cronbach Alpha Constant of 0.91 and 0.70 as recommended by Peres, Pham & Phillips, 2013:193). Since this tool has been used extensively by experts in the HCI field, it is therefore assumed to be reliable as they are often used to determine the success of the task being performed. Tullis and Albert (2008:70) state that each task must be worded carefully and unambiguously for users to understand what they must do. This instrument is valid as it was confirmed during the pilot study. Additionally, participants knew exactly what they must do, and when the task had to be completed (see task sheet).

The app review questionnaire and the pre-session questionnaire contained questions developed by the researcher. However, the planning of these questions was based on the literature and the pilot study conducted before the commencement of this study.

In observations, a researcher must decide what phenomenon is to be observed, and the type of observation to be done (Cruz & Koch, 2012: 3). For this study, a systematic process (see data collection 4.6) was executed to identify what to record and when to record it. Additionally, a template produced by Maree (2016:92) on the observation technique indicated the actions observed, and the thoughts of the observer about the meaning of the action observed. This study made use of this template which enabled the research team to record any relevant information during the data capturing process. Furthermore, it allowed for a detailed capturing of data from observations and provided a thorough reflection on the observed behaviour of participants' app interactions. The observation sheet was then regarded as valid because it allowed the research team to measure any behaviour that occurred in the classroom, which fostered the provision of detailed explanations of learner behaviour while interacting with the apps. Furthermore, it simplified the analysis of each set of data in an organised manner according to the situation. In addition, the pilot study was used to confirm the effectiveness of this tool.

The data, coupled with the observational data, provided clarity on how each app was used in study, the feelings of the participants towards the use of the recommended apps, and the answers to the research questions. Additionally, the SUS questionnaire revealed the app usability, while the app review questionnaire addressed the applicability of the app to learning in the Physical Sciences.

Maree (2016:40) believes that using multiple strategies can enhance data quality. This study engaged multiple tools to collect data thus allowing the research to examine the same scenario. The study employed the use of triangulation to enhance data validity. Additionally, the research tools were peer-reviewed by four Physical Science teachers and two language educators to evaluate both the relevancy of the questions and their applicability to the Physical Sciences, and the appropriateness of the language for both qualitative and quantitative data collection tools.

In qualitative studies, it is difficult to measure the reliability of the research. However, Lincoln and Guba (1985:288) point out that "it is better to think about the dependability and consistency of the data" as the data is subjective to the researcher's ontology and epistemological views. To ensure data dependability, the data analysis process was documented allowing the reader to see how the researcher arrived at the conclusions and interpretations as advised by Maree (2016:124) while consistency was achieved through the use of the research plan.

For quantitative research, it is easy to replicate the results. In this study both qualitative and quantitative data were collected.

The reliability of the data collected was achieved by minimising researcher bias and participant bias. Participants were encouraged to provide honest responses. The researcher made all participants feel welcomed and did not at any point coerce them on what type of responses were expected. Furthermore, participants were encouraged to report the researcher to the school principal and the UFS Ethics Committee if there was any misconduct perpetrated. No incentives were promised to any participant, and participants were ensured of the anonymity of the information garnered during data collection processes.

Researchers tend to have their own biases guided by their views. The researcher can look at the data and make different conclusions than what the data shows. To reduce researcher bias, the data was gathered by employing several tools which were validated by experts (Physical Sciences and English teachers). Additionally, the research strictly followed a research plan throughout the study. Furthermore, the study implemented both data and methodological triangulation. Moreover, the above experts reviewed the research tools extensively before the study could commence in order to ensure that the tools measured exactly what they set out to measure. The educators can therefore be regarded as experts as they taught Physical Sciences and had at least five years of experience in teaching the subject. The English subject teachers ensured that the language used in the questionnaires was reader-friendly for learners in Grades 10 and 11. These research tools therefore were regarded as being dependable to use in this study.

The next sections (4.5.3.3 to 4.5.3.5) discussed how each tool was used in this study, as well as their benefits.

4.5.3 Study Site

The study was conducted in two different schools in the Motheo District. Both schools are Government sponsored. School A is situated in a town called Wepener which is a hostel-based school that also accepts day scholars. It enrols learners from neighbouring towns such as Hob House, as well as those from Lesotho. The school performs well, according to the principal: the matric pass rate for the last 3 years ranged between 55% and 95%.

School B is a low-performing school based in a town called Dewetsdorp. It offers meal plans for its learners daily and is located in a part of the town. Learners live in close proximity to the school. Participants from the School B were mostly from disadvantaged socio-economic families, while School A learners belonged to both high-income families as well as those from disadvantaged families.

Although the study was conducted at two schools, they serve as a fair representation of the population in the Southern Free State as there are hostel and non-hostel-based schools. The schools that manage their own hostels tend to be financially well-resourced compared to non-hostel Government schools. These schools (40 km apart) were selected because they are easily accessible thus making it easier and inexpensive for the researcher to access both research sites thus enabling smooth, trouble-free, and thorough data collection processes.

4.5.4 Research Plan

To determine the effective strategies for data collection and analysis, a research plan was created. The researcher requested a meeting with the schools to inform and seek permission to conduct the study. Once permission was granted, the researcher then communicated with the Physical Sciences educator about the possibilities of involving learners in the study. An information session was then arranged with the possible participants where the researcher answered all of their questions. Each participant was required to obtain permission from the parent/guardian (assent) before participating in the study (see appendix E). Two study timelines were generated to suit the participants from each site. These timelines indicated when each school will be visited, and what activity will take place (see table 7 below). Constant communication followed between the researcher and subject educators. This was established to ensure that the research was based on topics which were supposed to be covered as guided by the ATPs. The apps chosen were based on the topic which was being presented in class at the time. According to the revised ATP generated by DBE, the following topics were taught in Physical Sciences for each grade (10 and 11). The observations commenced when topics such as electricity and magnetism were being taught (see appendices Q, R and S).

Each day began with the screening of participants and researcher at the gate as required by Covid-19 pandemic protocols. Participants were then ushered into a classroom where the study was conducted. Social distancing, the wearing of masks, and sanitising was maintained at all times. Table 7 below shows which topics were covered, and how many sessions the researcher conducted with participants from each site.

Table 7: Study timeline

School	**Grade**	**Start date**	**End date**	**Duration in minutes**	**Start time**	**Number of sessions**	**Apps involved**
App discovery							
A	10	01/09/20	01/09/20	45	14:30	1	Participants to discover their own apps
A	11	01/09/20	01/09/20	45	15:30	1	
B	10	02/09/20	02/09/20	45	14:30	1	
B	11	02/09/20	02/09/20	45	15:30	1	
App testing							
A	10	03/09/20	05/09/20	60	14:30	2	All 4 of the recommended apps were tested during this period
A	11	03/09/20	05/09/20	60	15:30	2	
B	10	08/09/20	11/09/20	60	14:30	2	
B	11	08/09/20	11/09/20	60	15:30	2	
Teaching and App usage							

School	Grade	Start date	End date	Duration in minutes	Start time	Number of sessions	Apps involved
A	10	14/09/20	18/09/20	45	14:30	5	All 4 recommended apps were tested during this period
A	11	14/09/20	18/09/20	45	15:30	5	
B	10	21/09/20	25/09/20	45	14:30	5	
B	11	21/09/20	25/09/20	45	15:30	5	

Participants were provided with internet connection to proceed with app discovery. This internet connectivity was made available for participants to acquire apps from any source. In app testing, participants downloaded the apps in class. Two apps were tested per day. On the first day the participants assessed WhatsApp first, then School Planner app. On the second day, the Physical Sciences apps were assessed along with Google Classroom app.

The table below indicates the sequence of events during app testing (described above).

Table 8: Planned activity and techniques sequence for part B app testing

Planned sequence	Planned activity and technique used
1st	Recommend an application to be tested
2nd	Observe participants' interaction with the applications
3rd	Provide participants with SUS questionnaire for reflection on the recommended software

A lesson plan was followed to guide teaching activities in the classrooms. Learners had to come to class ready to be taught with their notebooks. Learners were then taught and were given activities on the apps.

This series of events from Table 8 above was repeated until all the apps were tested for stage B. The participants were provided with a copy of the planned schedule. This made it extremely easy for participants to prepare as they knew which topics had to be covered, and at what time the study was supposed to be conducted. Once data collection was completed, the data analysis process commenced by analysing both forms of data using the steps mentioned in 4.7 (data analysis).

The research plan guided the teaching of topics which were observed including which apps to access in terms of the topic.

4.5.5 Triangulation

Triangulation refers to the gathering of data by using more than one data source to describe the same instance (Maree, 2016:122). It assesses the consistency of findings obtained through different instruments and increases the chance to control, or at least assess, some of the threats or multiple causes influencing the results. In mixed methods, triangulation is necessary to improve the validity and reliability of the data. Additionally, triangulation is conducted to refute, enrich, confirm, and explain the data (Noble & Heale, 2019:67). This study utilised the methodological triangulation technique.

Methodological triangulation is defined by Kimchi, Polivka and Stevenson (1991:365) "as the use of two or more research methods in a single study". Jack and Raturi (2006:346) indicate that this method is normally chosen because of:

- Completeness – any single method of gathering data has inherent flaws and therefore using more than one method reduces flaws associated with each method as qualitative and quantitative methods complement each other.
- Contingency – new or complex phenomenon dictate the choice of methodology adopted in a study. A qualitative study helps to understand the phenomenon. This understanding can therefore lead to diverse ways in which data can be quantified which helps a researcher to determine the hypothesis to be tested via quantitative methods.
- Confirmation – the use of multiple methods and observers reduces intrinsic bias which may be associated to a single observer or single method.

Mixed methods assist the researcher to understand how the participants interact with the recommended apps, and their feelings towards the use of the app. These interactions reveal the roles each app can potentially play in the classroom, and the suitability of the app to learning in a Physical Sciences classroom.

Participant behaviour is observed by the researcher. Participants then reflect on their use of the software through tools mentioned in 4.5.2. Qualitative data analysed through thematic analysis where suitable themes are generated while quantitative data is analysed using quantitative data analysis strategies (See data analysis 4.7). User reflections are then compared with their interaction with the software to provide a complete understanding on how users felt about using that particular software.

4.6 DATA COLLECTION

Johnson (2012:1) describes data as "any form of information, observations, or facts that are collected or recorded". Data collection is therefore the process of gathering or collecting information through any data collection tools available to the researcher. Johnson and Onwuegbuzie (2004:21) maintain that both qualitative and quantitative data "provide stronger evidence to reach a conclusion through convergence and corroboration of findings", therefore increasing the reliability of the elicited data.

Data was collected by engaging three different tools: questionnaires, task sheets, and observations which were guided by the task sheet. The data gathering processes comprised of software discovery, software testing, and software usage. It is the belief of the researcher that to use software, it is significant to know how to find them, and where to find them; hence, software discovery was enacted. Furthermore, each app must be evaluated against relevancy in the subject, and applicability (usage of apps). In addition, to effectively testing the app, one must know how to use it (app testing).

Apps are used by people, so how the people view an app is important as it may persuade them to use or drop the app. It is therefore important to measure user experience while using apps. User experience (UX) has 3 characteristics:

- user involvement,
- user interacting with a product or software, and
- how the user interacts with the system is measurable.

"User experience takes a broader view, looking at the individual's entire interaction with the object, as well as the thoughts, feelings, and perceptions that result from that interaction" (Tullis et al., 2013:5). Participants experience in testing an app was therefore crucial for this study as it revealed how participants thought of the recommended apps. These feelings and the participants' interactions were therefore used to inform the role apps play in a Physical Sciences classroom.

To conduct the app testing phase, participants were assigned a series of tasks to perform. In order to determine if the task was completed successfully, the participant had to finish the assigned task in two-to-five minutes depending on the task. The testing time was determined through the pilot study, and by the researcher testing the apps himself. Participants' interactions were observed as they performed these tasks.

The tasks revealed whether participants could navigate successfully within the app. To determine if a task was performed successfully, binary success was used. According to Tullis and Albert (2008:66), binary success is used to determine task completion if the success of the task depends on the user completion of the task. If participants completed the task successfully, they were given a pass symbol for the task, and a fail symbol if they did not complete the task.

Learners had to test the apps first, then use the actual apps in the classroom. Once all the apps were tested, they were used in teaching and learning activities in the classroom. Teaching and learning activities required effective planning, so the researcher prepared a lesson plan for use in this study (see appendix V). The lesson plan was then sent to the subject educators at, the chosen sites as well as to an additional Physical Science teacher who is a colleague of the researcher. As a Science educator, I (as the researcher) also have a minimum of 5-year experience in lesson planning. The purpose of the lesson plan was to ensure that the data gathering process was the same across both sites to ensure the successful replication of a possible study.

I taught participants from both sites during this process. I introduced the topic *Electricity and magnetism* to both Grade 10 and 11 participants. As per ATPs (See 2020 ATPs in appendices Q and R), this was the topic that had to be covered during the time of the study. Participants had to attend a formal class presented by me. The ATPs indicated that learners must complete a minimum of 5 informal activities. After having taught 4 lessons on this topic, 3 assignments, 2 class exercises, and 1 informal test, were prescribed.

Data was collected using tools mentioned in 4.5.2. The application of each tool in this research was extensively discussed (above). Data gathering processes followed a research plan as indicated in 4.5.4. the data gathering process began with the pilot study conducted in 2019 with a class of 18 Grade 12 learners (see pilot study 4.6.1). As indicated in 4.5.2, the data from the pilot study and literature study helped to identify and develop data collection instruments for the study.

4.6.1 Pilot Study

The pilot study used 18 Grade 12 learners from a school in the Motheo District in 2019. Participants were asked to download the Google Classroom app onto their phones. Participants were then asked to answer a multiple-choice test where they were observed by the researcher and the school principal. Furthermore, the researcher uploaded class content on this platform for students to use. Findings revealed that participants knew how to use the app for test purposes. However, test scores indicated that learners must be provided with sufficient time for them to practise. Furthermore, adequate planning was required if learners were to improve on their test scores. Additionally, communication is essential for effective learning to occur.

The results of the pilot study guided the researcher to choose an appropriate approach for this study. This also assisted in choosing relevant apps to be used for this study. Also, this was used to generate the tools which were used in this study, thus enhancing validity. Participants were then divided into groups of 8, based on the numerical order of the participation code during app testing. Different testing times were allocated for each participant. Care was taken not to allow the participants to mingle during the data collection process. Participants had their mobile data turned off, therefore no electronic communication took place.

4.6.2 Qualitative Data

The first step to data collection was gathering participants' demographic data which was conducted by using the pre-test questionnaire. Participants were ushered into a classroom where they sat down as indicated in the research plan. They were then provided with the pre-session questionnaire. Upon completion, the participants returned the questionnaire to the researcher and the research assistants.

Qualitative phase had two parts: part A and part B. In part A, participants accessed apps based on the topic of their choice (See app discovery questionnaire). This exercise identified the different routes participants employ to access apps for use; this informed the study on whether learners know how to access apps on their own. In part B, participants were given a list of apps to download (see research plan). Their interactions were then observed. Further, participants reflected on their use of the apps which revealed to the researcher about participants' attitudes or opinion of a certain type of software.

4.6.2.1 App discovery questionnaire

This questionnaire was used in part A of the data gathering process. Here, participants in their groups were provided with internet connectivity, in addition to an app discovery questionnaire.

Participants were allocated 10 minutes to discover apps based on a certain topic; for instance, an app that can assist them in understanding electricity. The participants' behaviours were then observed. Thereafter, participants had to reflect on the steps taken to access each app, including mentioning all the apps they discovered. Furthermore, participants had to take a screenshot of the app to give to the researcher. Upon completion of this task, participants were thanked and ushered out of the test venue.

4.6.2.2 Participant-observations

The research plan indicated the order in which participants interacted with the apps. Observations were used for both app testing and app usage in the classroom.

App testing

After the installation of an app, participants were provided with a task sheet. Participants interaction with a relevant software was then documented in the observation sheet. The research team recorded observed behaviour and reflected on their possible meaning. Each task was allocated a suitable time (see research plan 4.5.4). Once these tasks were completed, participants had to reflect on their experience with the SUS questionnaire.

App Usage

Participants used the recommended apps during classroom activities. The use of these apps and participants' behaviour in the classroom, were then recorded in the observation sheet.

The observed behaviour involved body language, ability of the user to perform a task successfully, how the user navigated through the app, and how each app was used in a classroom set-up.

4.6.3 Quantitative Data

To collect quantitative data, this study utilised the app review questionnaire, task sheets, and the SUS questionnaire. Each questionnaire was used as follows:

4.6.3.1 App review questionnaire

Participants rated the relevancy of the content to its applicability to the Physical Sciences learning activities by circling an appropriate response on a 5-point Likert Scale. Secondly, participants had to tick appropriate boxes to indicate the functionality of the app. Furthermore, participants had to tick boxes indicating on whether the app used ads, and whether those adverts were distracting. Lastly, participants were asked if they would recommend the app using a 5-point scale. Participants were then provided with a SUS questionnaire.

4.6.3.2 SUS questionnaire

Participants were given a SUS questionnaire to provide reflections after testing a recommended app. Participants circled or crossed a relevant response based on a 5-point scale with values ranging from 1 to 5. This questionnaire had a list of 10 questions with 5 positive questions and 5 negative questions. Upon completion of this process, participants were then thanked and ushered out of the premises where their transport was waiting.

The data gathering process used the tools mentioned above. The data gathered was analysed based on relevant strategies for analysis of each data type (see 4.7).

4.6.3.3 Task sheets

Participants were provided with task sheets to test their ability to use the recommended apps. The order of the tasks is indicated in the see research plan (see 4.5.4).

Participants had to perform a maximum of 4 tasks to test an app (See task sheet). Each app had its own tasks as the apps were different. Participants had to write 'yes' in the task completion box to indicate task success, and 'no' to indicate an incomplete task. These tasks were performed on the recommended apps with the help of the task sheet during the app testing phase.

4.6.4 Distribution of Questionnaires and Task Sheets

I personally distributed the questionnaires and collected them. These questionnaires and task sheets were distributed to participants on site. Participants from School A were given questionnaires at school A, and participants from school B were given theirs at school B. All questionnaires handed out were returned completed to the research team on the same day they were handed out.

4.6.5 Conducting Observations

The observations were conducted by a team consisting of 3 people. This team included me, and 2 matric learners. These observers were briefed about the study beforehand, and were taught how to execute observations. All observations were recorded (as notes) and thereafter analysed to make-sense of the phenomenon that was observed. All observations were conducted on stipulated sites during part B of the research. Our role as observers was not to interfere, but to be present in case participants needed assistance.

4.6.6 Rationale for Using the Mixed Research Design

Mixed methodology was suitable for this study as it allowed the collection and analysis of different, but complementary data types in the same study. Furthermore, it offered diverse ways for data integration therefore promoting processes that led to relevant interpretations. Through mixed methods, the researcher was able to incorporate both qualitative and quantitative data types to gain a clear understanding on how apps impacted learning in a Physical Sciences classroom as it revealed how each app was used, what each app is used for, and the feelings of the participants towards these apps. Additionally, mixed methods were believed to have the following benefits according to Doyle, Brady & Byrne (2009:178-179):

- Triangulation
- Completeness
- Offsetting weakness and proving a better inference
- Answering different research questions
- Hypothesis development and testing
- Instrument development and testing
- Illustration of data
- Explanation of findings

These benefits were ideal for use in this study.

4.7 DATA ANALYSIS

Data gathered through mixed methods depend on both qualitative and quantitative data analyses. In convergent designs, both qualitative and quantitative data are collected at the same time and are given equal priority. Qualitative data was analysed using qualitative analysis methods, and quantitative data was analysed using quantitative analysis methods (See convergent mixed method design in 4.4.4). Qualitative findings and quantitative results were then compared and contrasted before any interpretations of the data could be made.

4.7.1 Quantitative Data Analysis

The questionnaire data was comprised of both close- and open-ended questions. Open-ended question strategies are covered later in the section. The close-ended questions consisted of both Likert Scale questions, 'yes/no' questions, and check checklist.

A 'COUNTIF' function was used to count the *yes and no* responses, and to count male and female participants. Additionally, this function was used to extract participants' responses on the scale questions (see applicability question and question recommendation question in app review questionnaire). Through the use of this function, description statistics were gathered such as the total number of people who gave a score of 1 from each scale which then allowed the researcher to make claims based on the data. This data was then presented using graphs to indicate how people rated the apps.

Although results from the SUS questionnaire contained scale data, they were analysed differently. This was because a SUS score was calculated from the scale data using the steps mentioned by Tullis and Albert (2013:138). The SUS scores of the participants for each app were then averaged to determine the usability rating of the apps.

The binary data generated through the tasks were recorded on Excel. Firstly, the data was coded as follows: fail (task not completed successfully) was given a score of 0, and pass (task completed successfully) was given a 1. The averages of participants who scored 1s and 0s were then calculated. Additionally, confidence intervals based on binary data were calculated. This data was presented using the percentage of participants who completed each task as advised by Tullis and Albert (2008a: 67). In order to calculate confidence intervals on the binary data, this study made use of Sauro's calculator which can be accessed on measuring.com. This calculator calculated confidence intervals using the adjusted Wald method. I also calculated confidence intervals on binary data based on the steps mentioned by Tullis and Albert (2008), and the results were similar to the confidence intervals when using Sauro's calculator. Therefore, Sauro's calculator and Tullis and Albert's (2008) confidence intervals were similar - any of the two can be used to calculate confidence intervals when dealing with binary data.

The quantitative data was presented through graphs and tables to help the research derive meaning of the data and make suitable summaries of the data. Additionally, the SUS questionnaire results were subjected to further statistical review. The ease of use of the 4 recommended apps was compared to the impact of the apps on learning using the ANOVA tests, after which it was subjected to the Bonferroni post hoc test. These tests were based on the following hypotheses:

- It is easier to use the Physical Sciences mobile app in teaching and learning than WhatsApp, Google Classroom, and the School Planner app.
- Apps have a positive impact on learning in a Physical Sciences classroom.

These statistics were elicited by using Microsoft Excel as the analysis tool. This data was interpreted together with the qualitative data to provide a clear and complete interpretation of the data.

4.7.2 Qualitative Data Analysis

As stated in data collection section (see 4.6), part B involved participants testing recommended apps. Participants were observed and were also required to reflect on their experiences – these observations produced qualitative data. The qualitative data collected from both sites were then stored in a safe until the data collection process was completed. Since the data was sorted, it made it easier to analyse participants' views on each app. Furthermore, the researcher spent 6 months analysing data collected through observations. This process involved reading and rereading each observation made by the researcher. The data was then transcribed into a journal, after which the observational data was coded based on predefined themes. These themes were categorised as installation issues, app usage, and user satisfaction as depicted in Table 9 below. Each major theme identified included sub-themes.

Table 9: Themes for the study

Installation issues	App usage	Satisfaction
No email	Correct use of the app	Body language
Storage issues	Incorrect use of the app	
Software not supported	Navigation issues	

However, any additional behaviour that did not fall under these predefined themes required the researcher to form new themes based on the collected data. An additional theme was uncovered during the data gathering process (behavioural issues). Therefore, both priori coding and emergent coding were used. Elliott (2018:2855) states that a pragmatic researcher may use both in a large study. This study was guided by the pragmatic paradigm and since the data collection tools allow for additional data to be captured which could not be predetermined as to where it will fall, it made sense to include emergent themes.

Literature studies in UX indicated that to test the impact of a computer system, both performance and user satisfaction must be tested, and therefore the tools were developed to test both performance and user satisfaction.

I first started capturing participants' responses on Excel. I then inserted the data into the pre-set themes. The data from both journals were compared and contrasted. This data was then recorded in a 'final journal' which was then used to report the data from the qualitative phase.

In part A, participants had to discover apps based on a topic of their choice. For this section, the data was coded into the following themes: browser, Google Play Store and sharing software. I first encoded the data onto the Excel spreadsheet. The data was then integrated into the themes mentioned above, and then securely stored in a journal. This data was then used to inform how participants found and installed apps into their smartphones.

After the analysis of both qualitative and quantitative data types, the data from both qualitative and quantitative was then mixed to make interpretations and derive meaning of the data.

4.8 ETHICAL CONSIDERATIONS

In studies involving human subjects, there are certain guidelines that must be followed. Bell and Bryman (2007:71) propose that to maintain ethics in research, the following points must be adopted:

- No person must be subjected to any form of harm
- Participants must be treated in a respectful manner
- Full consent should be obtained from all stakeholders' prior to commencing the study
- All data and participant-identifies should be treated as confidential and private.

Fields and Calvert (2015:464) add that the informed consent must include information, voluntary "choice and decision-making capacity". When subjects are being recruited, care must be taken as to protect vulnerable participants which includes minors. Furthermore, Research must be truthful, transparent, and fairness must be displayed when selecting participants. Additionally, participants have the right to know how their data was going to be used, and who will have access to it. Ethical considerations adopted in this study are discussed below. In this study, ethical procedures were followed from the recruitment of participants until the research was completed (see consent forms, Appendices D and E).

4.8.1 Permission

Consent to commence with the research was granted by the University of the Free State Ethics Committee (Appendix C). Permission was also granted by the Director of Education (Department of Basic Education) as shown in Appendix B. Additionally, permission to enter and use the school sites was granted by the schools' principals (Appendix I and J). The school principals and subject educators allowed the researcher to recruit participants for the study.

4.8.2 Confidentiality and Privacy

Participants were assured that all data was kept confidential, and their identities will not be revealed. To mask their identities and maintain anonymity, all participants were assigned a code/pseudonym for the duration of the study. Learners were assured that the information they shared will not be revealed to anyone. Additionally, hardcopies of their data were stored in a locked cabin and all soft copies were secured in a password-protected file in the researcher's laptop only to be accessed by the researcher and his supervisor. The data, including backups, was to be deleted and destroyed after 5 years. All hard copies were to be shredded. However, the data will be shared with the research ethics review committee, if required. To maintain confidentiality, the information was not shared with any of the educators. The researcher took all the necessary steps to safeguard learner-data and to protect their identities.

4.8.3 Voluntary Participation and Informed Consent

The researcher explained in detail the nature of the study to the participants, and what their role in the study would be. Additionally, participants were made aware of their rights, and were also informed that they can exit the study at any time without any consequences. However, it was also explained to them that the data captured up to the point where they left the study would be used. Assent from minors via the parents had to be obtained as the study focused on learners between the age of 14 and 18. The research leaflet and copies of signed assent and consent forms are attached (Appendices F, G and H).

4.8.4 Protection from Harm

The researcher must protect all the participants from all harm, physical and psychological. Firstly, the participants must be separated from the learners who were not participants in the study. This was achieved by ensuring that all the sessions were conducted after school hours when the non-participants were away from the school premises. Any form of bullying was to be reported to the principal immediately, and the offenders would be removed from all study processes. If the researcher witnessed a crime, the duty was to report it to the school. The researcher strove to be respectful and cordial, and sympathetic whenever necessary towards all the learners. Honesty, integrity and transparency were maintained throughout the course of the study.

4.8.5 Post Research Relations

The research will be made available to the DBE. The ethical clearance certificate granted through the DBE stated that the researcher must present the findings to the DBE after the conclusion of the study. Additionally, the dissertation will be accessible through the Kovsie Scholar platform of the University of the Free State. Participants will also have access to the findings, on request.

4.8.6 Collection of Smartphones on Loan

The learners who did not have a cell phone at the beginning of study and were loaned one, had to return the phones as per agreement. The collection was done secretly as to not embarrass learners who did not have smartphones. Learners were called into the principal's office where they handed over the phones back to the researcher.

4.9 COVID-19 PROTOCOLS

As the study was conducted during the Covid-19 pandemic, the researcher and participants had to abide by all the Covid-19 rules and regulations set by the Department of Education [DoE] (Appendix F). All the participants and researchers had to wear a mask or shield, social distancing was adhered to, and participants and researchers had to be sanitised before entering and leaving the premises. The classrooms and equipment were also sanitised before and after the study. Lastly, all persons involved in the study had to adhere to the mandatory screening on a daily basis (see Appendix G).

4.10 CONCLUSION

This chapter focused on clarifying the methodology, paradigms, and assumptions adopted in this study. Additionally, methods of analysing the data were discussed along with ethical considerations adopted in this study. The methodology involved the concurrent mixed method design which was both qualitative and quantitative data such that all data was collected at the same time. This data was collected via observations, SUS questionnaire, and app review questionnaires. Participants were selected through random purposive sampling. Qualitative data was analysed through thematic analysis where data was coded into relevant themes which was then fed into a qualitative analysis software. Qualitative data was analysed in Excel through descriptive analysis and inferential statistics. The following chapter (5) focused on the data presentation, analysis, and the interpretation of the findings based on methods discussed in this chapter (4).

CHAPTER FIVE

DATA ANALYSIS AND INTERPRETATION OF FINDINGS

5.1 INTRODUCTION

This chapter presents an analysis of the data based on the research questions of the study. These questions led to the determining of the role free learning mobile apps play in a Physical Sciences classroom. As discussed previously in chapter 4, both qualitative and quantitative types of data were analysed separately using appropriate data analysis methods for each data type. The data was presented through tables, charts, texts, and numbers. Further, the data was qualitatively dissected into suitable themes which were then analysed. Lastly, hypothesis testing was also applied on all quantitative data.

For the empirical study, the TPACK framework allowed me to take the role of the teacher. My technological knowledge led to the selection of apps which were to be tested in the empirical study. These apps were based on pedagogy requirements based on my teaching experience together with my knowledge of the content which is taught in the physical sciences classroom as informed by CAPS. TPK was also used to create the lesson plans which were used in class. Although, I would have loved to test how different educators apply this theory in their classroom, my knowledge was sufficient for this study as the focus on helping learners acquire and use apps to enrich their learning of physical sciences. Teachers application of TPACK can therefore be tested in future studies.

5.2 DATA COLLECTION TECHNIQUES

This research study utilised questionnaires, observations, and document analysis to collect data. Document analysis addressed the non-empirical questions in the study (4.2.1), whereas the questionnaires and observations were employed to provide answers to empirical questions (see 4.2.2).

Data analysis commenced with the pre-test questionnaire which was used to gather preliminary information about the participants and their demographics. This questionnaire was used to investigate the demographics of the participants and their level of exposure to learning apps. Then, participants' interactions with the recommended software was analysed through observations, the SUS questionnaire, app discovery questionnaire, task sheet, and the App review questionnaire. This data was used to inform the role apps could play in education, and to measure user satisfaction. All data gleaned from the above processes was divided or in line with the specific research questions of the study.

5.3 PARTICIPANTS' DEMOGRAPHICS AND PRELIMINARY FINDINGS

A pre-session questionnaire (see appendix L) was used to gain insight into the demographics of the participants, their details of cell phone possession, and their experiences before participating in the study. All participants had to be Physical Sciences learners in Grade 10 and 11.

5.3.1 DEMOGRAPHICS

The study consisted of 72 participants from Grades 10 and 11 from 2 different schools in the Motheo District. Initially, 95 participants displayed an interest to participate in the study; however, 10 withdrew due to Covid-19 restrictions while the remaining 15 failed to show up on any of the days dedicated to the data gathering process by citing study reasons. Of the 72 participants, 42 were sampled from Grade 10 and the remaining 30 sampled from the Grade 11 (see table below). Table 10 below shows the number the participants per grade, total number of participants in each grade, and total number of participants sampled from each site.

Table 10: Number of participants per site

School	Grade 10	Grade 11	Total number of participants per school
School A	21	13	34
School B	21	17	38
Total	42	30	72

The intention was to recruit 50 participants for the study; however, as more participants showed interest in taking part in the study, the numbers were revised.

Additionally, the study sampled more female participants than male participants: 73.6% (53 of 72) of the participants indicated their gender as female, while 25.0% (18 of 72) comprised of male participants, and 1.4% (1 of 72) indicated other for gender (see figure below).

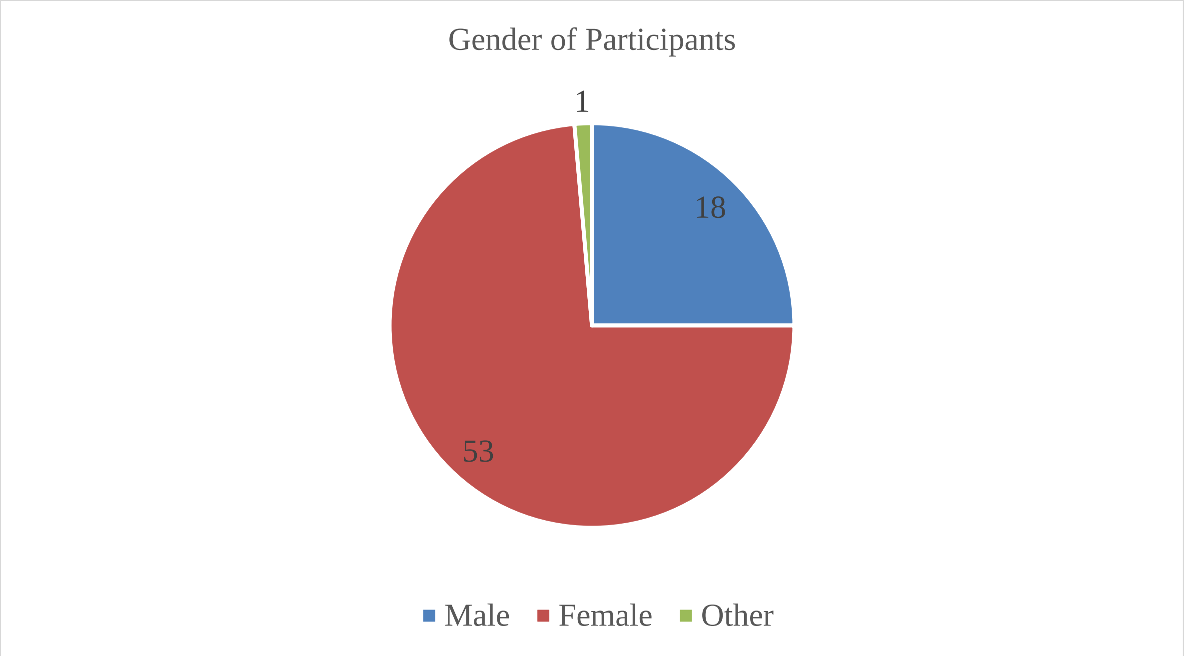

Figure 8: Participants' gender

The large female turn out could be attributed to the fact that both schools had more female learners in their Physical Sciences classes as confirmed by the class lists gathered from both sites.

Participants' were grouped into the following age groups: 11-13, 14-16 and 17-18. The summary of the participants ages is presented in the Figure 9 below. The study sampled more participants in the 17-18 age group (n = 44, %=61.1), fewer in the 14-16 age group (n = 28, %=38.9), and the least in the 11-13 age group (n = 0, %=0).

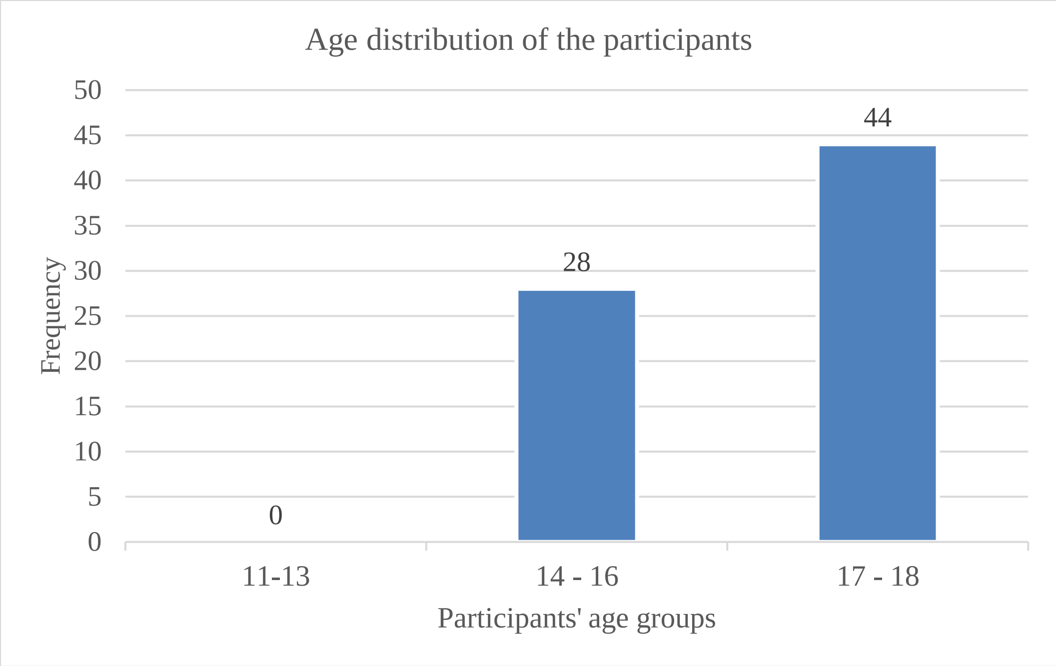

Figure 9: Participants' age groups

5.3.2 Cell Phone Possession

Participants had to indicate if they possess a cell phone or not before they could take part in the study. The results for this variable are illustrated in Table 11 below. The results indicated the types of responses participants had to choose from and the frequency of the answers provided.

Table 11: Participants cell phone possession statistics

		Frequency	
Variable	**Type of responses**	**n**	**%**
Do you own a cell phone?	Yes	68	94.4
	No	4	5.6

Of the 72 participants, the majority had their own cell phones (n= 68 %=94.4) which they could use in the study. The 4 remaining participants were each lent a cell phone by the researcher which they had to use for the duration of the study. This implies that 94.4% of the participants had a smartphone which was 2.6% less than the 97% indicated by Kreutzer (2009:48) in chapter one. However, this supports the statement that learners do possess smartphones therefore reinforcing the point that smartphones could be used to impact learning in a classroom. Participants who did not have a smartphone had to sign an agreement witnessed by their guardians (see appendix K) indicating if they were willing to be part of the study. These devices were lent to them and were in their possession for the duration of the study. Upon completion of the study, all the smartphones were collected and returned to me.

5.3.3 Participants' Experiences Prior to Participation

Participants' experiences prior to the study only focused on 3 items:

- Internet Usage
- Frequency of downloading apps from Google Play Store
- Category of apps downloaded

As indicated in chapter 4, it was of vital importance to understand the experiences of learners in using apps before the study could commence. This experience would then be used to determine if there was any training needed for the participants prior to commencing the study. These findings were also used for the development and selection of research tools.

5.3.3.1 Internet usage

In order to discover the ability of the participants to use the internet, participants had to rate their internet usage by selecting either of the four options listed below: Never, rarely, often and very often. The frequency of the occurrences of these responses are represented in the Figure 10 below.

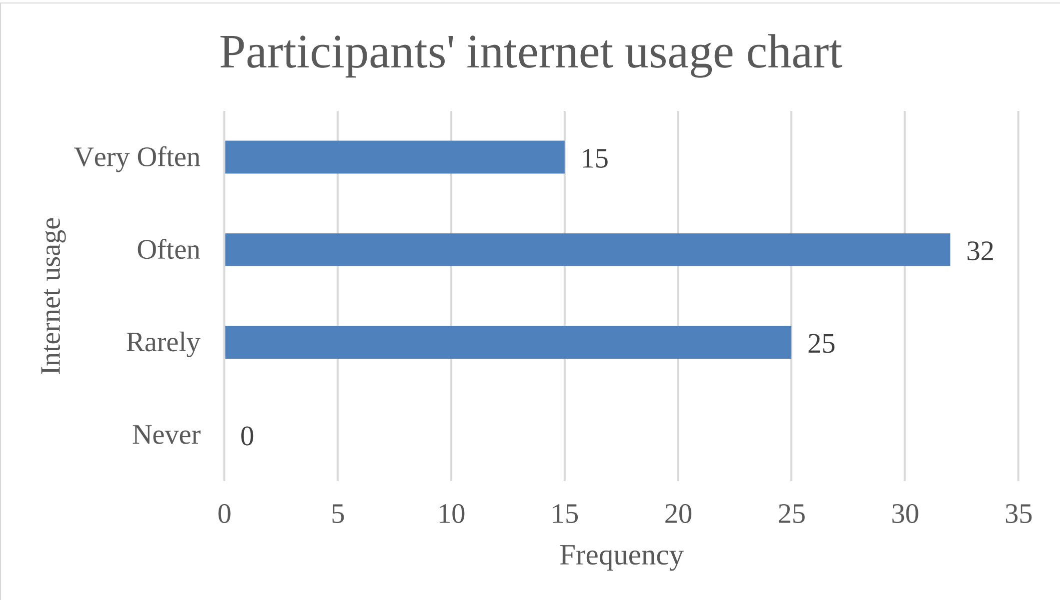

Figure 10: Participants' internet usage habits

As depicted in the Figure 10 above, 34.7% (25 of 72) of the participants indicated that they rarely use internet, while 65.3% (47 of 72) of the participants indicated that they use the internet frequently. The frequent internet users consisted of 44.4% of the participants, while 20.8% were infrequent users. This indicated that all the participants could use the internet thus reducing the period of time required for training. Further, this implied that they might know how to access apps from the internet, whether from Google Play Store or any of the search engines.

5.3.3.2 Frequency of Downloading Apps from Google Play Store

Participants had to indicate their frequency in downloading apps. Their responses were provided with the same response type mentioned in 5.2.3.1 above, from *never* to *very often*. The frequency of each response was recorded, and the results are illustrated in the Table 12 below.

Table 12:Frequency of app downloads

How often do you download apps from Google Play Store?	Frequency (n)	Frequency (%)
Never	10	13.9
Rarely	33	45.8
Often	26	36.1
Very Often	3	4.17

A few participants indicated that they had never downloaded apps from Google Play Store before (n=10, %=13.9), while 45.8% indicated that they rarely download apps from Google Play Store, and 36.1% indicated they often download apps from Google Play Store. The results from Table 12 above also implies that 13.9% of the participants may not have a Google-based email, or may not know how to use it to download apps from Google Play Store. For the remaining set of participants, the impression created was that they have a Google-based email, hence they are able to download apps from the Google Play Store. App frequency download could be influenced by user app preference.

From the responses above (Table 12), it was clear that only 13.9% of the participants never downloaded an app, indicating that 86.1% of the participants know how to download an app. To further investigate participants' experiences, the next section assesses the type of apps downloaded by the participants.

5.3.3.3 Categories of app downloading

Although apps fall under numerous categories, for the purpose of this research, the app categories were limited to four: games, educational apps, social networks and others. Participants had to select the category of apps from the list. There was no limit to the number of categories participants could select. The results are summarised in Figure 11 below which displays the frequency of apps downloaded in each category. These frequencies are displayed in the bar graph, therefore making it easier to detect high frequencies.

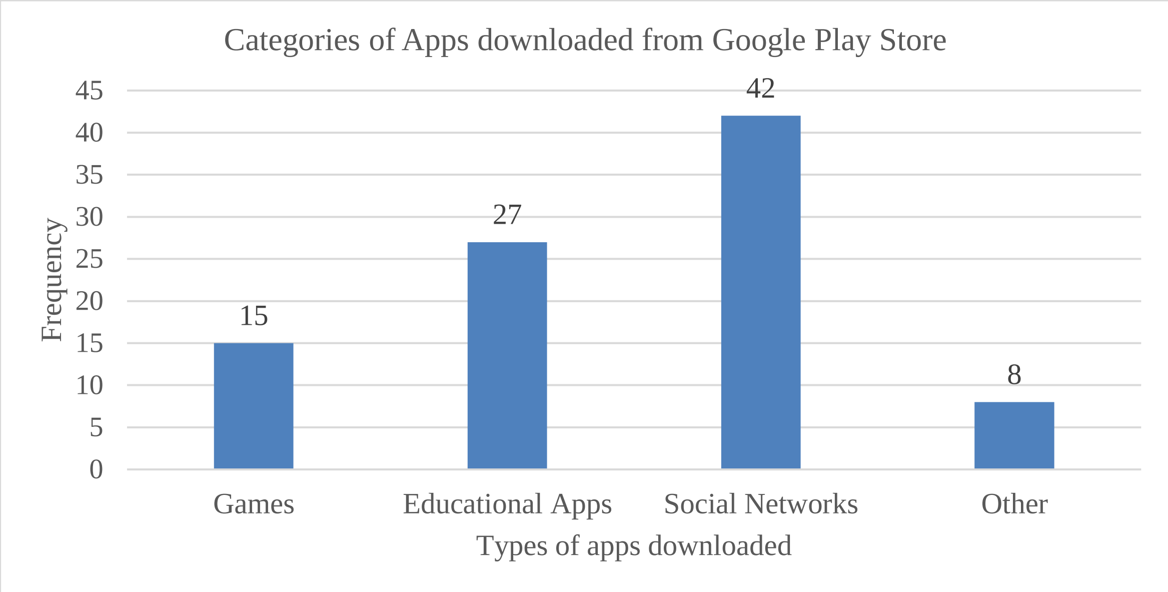

Figure 11: Categories of apps

Participants indicated that they download social networking apps more (n = 42, % = 58.3) than any other category from the app Store. The educational apps category ranked second (n=27, %=37.5), while the games category ranked 3 (n=15), and the 'other' category ranked last (n=8). Social media networks are commonly used by teenagers and therefore it came as no surprise that this was a popular category. The results further illustrate that participants were aware of educational apps which they were already using.

Furthermore, it indicates that the participants are aware of the various categories and can navigate their way through Google Play Store, thus implying that they can find apps to download on their own. This ability to find and download apps was investigated in section 5.4.1.

The initial findings indicated that participants were familiar with app discovery and the downloading of apps. Also, unexpectedly, even the 4 participants who did not have smartphones initially, knew how to download apps, therefore they will not be disadvantaged in performing any of the tasks required in the study.

Participants were also asked to list any of the apps they use for learning. The purpose of this exercise was to establish if participants were aware of educational apps, and to confirm that they indeed are using them. Even though participants had to provide the names, I only captured the statistics of learners who have installed educational apps.

Therefore, it can be concluded that 94.4% of the sampled population possess the necessary devices to use in the classroom. Fortunately, learners know how to find the necessary apps therefore less training was required on how to use the internet.

5.4 EMPIRICAL FINDINGS ALIGNED TO RESEARCH OBJECTIVES

My main research question required the understanding of all the processes necessary to provide suitable teaching and learning in a Physical Sciences classroom linked to how apps are used. In other words, the study's questions had to be relevant to teaching and learning in terms of mobile app usage. This research therefore employed non-empirical and empirical study methods. The aim of the non-empirical study was to be realised through answering the first six research questions (see 4.2.1), while the aim of the empirical study was realised through answering the last four research questions. The literature review in chapters two and three served the non-empirical purpose of the study. These findings are elaborated in the next chapter (see 6.3.1). The objectives below serve the empirical purpose of the study.

5.4.1 Empirical Research Objective 1

Determine the abilities of the learners to select and access mobile applications for classroom usage

Knowing how learners acquire apps was particularly important for this study. As stated in chapter one, there are over 230 000 apps which are specified as learning apps in Google Play Store. Therefore, it was critical to investigate how learners installed apps on their phones. To guide the participants an 'App discovery questionnaire' was used (see appendix N). Participants had to find a total of three apps in ten minutes from any topic of their choosing. Data from observations was also used.

5.4.1.1 Results on the acquisition of apps for classroom usage

In order to guide participants in obtaining necessary apps, they had to indicate the topic that they were finding challenging on the questionnaire. Participants then had to find appropriate apps that could assist them on the topic. The topics participants chose are indicated in Table 13 below, in addition to their frequencies.

Table 13: Frequencies of topics used to guide the choice of software

Topic	Frequency (n)	Frequency (%)
Electricity	14	19.4
Electrostatics	43	59.7
Quantitative aspects of chemical change	11	15.3
Other	4	5.6

A large number of participants chose electrostatics as the topic that challenged them (n =43, %=59.7). When the data-gathering process was conducted, electrostatics had just been completed in Grade 10, while electricity was still being taught in Grade 11 in both schools (see ATPs appendix Q). Therefore, it could be a possible reason for them choosing a particular topic as it helps them to identify apps. As the topic was used for guidance purposes only, the gathering of data was of not much significance as this was not the focus of the study. This exercise was aimed at assessing whether participants would be able to find apps in Google Play Store but due to the enormous number of apps housed within the Store, a topic had to be used to limit the possible apps available to download.

Although participants selected different topics to download apps in line with the topic of choice, it was necessary to determine how many apps they managed to download, since the ability/inability of the participants to download apps could impact app usage in the classroom. Table 14 below shows the frequency statistics of downloaded apps and the total number of learners who managed to download apps.

Table 14: Number of apps downloaded

Variable	Frequency	
Number of apps downloaded	**n**	**%**
0 apps	0	0
1 app only	2	2.78
2 apps only	25	34.72
3 apps	45	62.50

Of the 72 participants, 45 were able to find 3 apps, 25 managed to find 2 apps, and 2 participants managed to download only one app. All participants managed to find at least one app. Most of the participants (n= 45, %= 62,50) managed to find and access all 3 apps within the stipulated time, while 34.72% managed to find 2 apps, and 2.78% of the participants managed to download 1 app only. This section revealed that participants were able to find apps on their own; therefore, indicating that participants can find apps for classroom lessons with minimal guidance from the educator.

Also, participants had to indicate the steps they followed in accessing the apps.

A participant from site A indicated the following:

> ***App 1***
>
> *I opened Google Play Store, then I typed Electricity Grade 11. I picked an app from the list that was provided, then installed the app.*
>
> ***App 2***
>
> *I selected an app from the list then installed that app.*
>
> ***App 3***
>
> *I selected a different app from the list.*

Several participants used the same steps as above (Table 15 below). However, additional methods were also uncovered during the data analysis of the app discovery questionnaire.
A participant from site B indicated the following:

> ***App 1:***
>
> *I opened google (search engine) then typed apps in electrostatics Grade 10. I opened a link. Downloaded the app and installed it.*

Both participants managed to access apps, but used two different means. Table 15 below summarised the total number of learners who used the either Google search engines or Google play store.

Table 15: Frequency of the search software used by participants to discover apps

Google Play Store		**Google search engine**	
Frequency of tool used			
(n)	**(%)**	**(n)**	**(%)**
63	87.5	9	12.5

Table 15 above shows that majority of the participants (n=63, %=87.5) used Google Play Store to download apps. Apps acquired through a Play Store are regarded as safe to download as they are constantly checked if they possess malware, therefore this data reveals that the majority of participants know how to find apps (62,50%) by accessing using safe spaces. From the observational data, participants appeared to use the steps mentioned above, but there was also a third method used which they did not mention – those who received apps from friends. The following apps were used to send an APK to another participant: *Share It App* and *Google Files*. In order to send files, participants needed to have the same sharing software, then only could they connect to each other through sharing apps.

Table 16: Reflections on app transfer

Situation	Action observed	Reflection on actions observed
App discovery process at site A	MSS23 opens Google files, then waits for connection to be established with a recipient. Grade 11 Physical Sciences mobile app was then sent to a recipient in the form of an apk.	• Participants received a message via WhatsApp from a classmate asking if acquired apps can be send to the recipient. • This is because the recipient could not find the necessary apps, and therefore felt they had to try another method necessary to complete the task • Participant did not know how to download apps
App discovery process at site A	MSS01 opens Play Store then types electricity to access apps for Grade 11. MSS01 then downloads and installs Grade 11 study guides from the app list	Participant is able to use a given topic to find necessary apps

The observational data confirmed the results discussed by MSS01 above, which indicated that participants engaged Google Play Store to find mobile apps for use as indicated above. In addition, participants utilised file-sharing software such as *Google files* and *Share It* apps.

In order for participants to share files or apps, they must have the same sharing software installed on their phones. Connection has to be established between the 2 devices, then only can the sender share the file with the recipient. The recipient must also accept to receive the file, otherwise app transfer will not occur. Connection was established when they both opened the sharing apps, then the sender selected ‘send’, and the receiver selects ‘receive’. Connection was established via Bluetooth. Once connection was established, the sender selected files or apps to share. Apps were sent as APK files.

It was evident that participants knew how to find apps from a mobile app housing store such as Google Play Store or through a friend via a software sharing app. Sharing software therefore allows for apps and educational resources to be distributed in the classroom by both the educators and learners. Additionally, this does not require internet connectivity, and makes it easier for learners from all socio-economic environments to have access to the files. It is evident that learners know how to access apps, thus teachers will not have to devote much time training learners on app acquisition.

5.4.2 Empirical Research Objective 2

Determine the procedures to assess app suitability and applicability for classroom usage

In order to answer research question 2, the app review and SUS questionnaires were used. The app review questionnaire was used to investigate the suitability and applicability of the recommended apps for teaching and learning activities in a Physical Sciences classroom. Studies revealed that software must be user-friendly in order to be regarded as applicable. The SUS questionnaire aided the study in measuring the usability of the recommended apps; and therefore added more evidence to the suitability of the apps.

5.4.2.1 App suitability and applicability to learning

In order to investigate the applicability of apps for learning, participants made use of the app review questionnaire. Participants had to first rate the relevancy of the content to the subject of Physical Sciences by using a 5-point Likert-scale ranging from *strongly disagree* to *strongly agree*:

- 1 = Strongly disagree
- 2 = Disagree
- 3 = Neutral
- 4 = Agree
- 5 = Strongly agree

For the four different categories of apps, the results are displayed in Table 17 below:

Table 17: Relevancy of the content to Physical Sciences

	Name of apps							
The content covered in the app is relevant to my chosen topic	**Physical Sciences Mobile app**		**WhatsApp**		**Google Classroom app**		**School Planner app**	
	(n)	**(%)**	**(n)**	**(%)**	**(n)**	**(%)**	**(n)**	**(%)**
Strongly disagree	0	0.0	0	0.0	1	1.45	12	16.7
Disagree	4	5.56	3	4.17	0	0.0	1	1.39
Neutral	9	12.5	12	16.7	5	8.20	14	19.4
Agree	23	31.9	26	36.1	27	44.3	25	34.7
Strongly agree	36	50.0	30	41.7	30	49.2	20	27.8

Table 17 above shows the relevancy of the app content to influence learning in the Physical Sciences app. Frequencies of participants' responses are captured and recorded using the "COUNTIF" function as stated in chapter 4. As illustrated in Table 17 above, more participants agreed that the content grasped through the recommended apps was of relevance to learning in the Physical Sciences classroom. In Physical Sciences 81.9% (n = 23 + 36 = 59) of the population agreed that the content in this app had a significant influence in Physical Sciences learning, while 77.8% (n = 26+30 = 56) believed that content gained through WhatsApp was valuable when learning in the Physical Sciences classroom. In addition, 45 people (25 agreed and 20 strongly agreed) that the School Planner content was relevant to learning. The same can also be said about the Google Classroom app as 93.5% of the participants believed that the app content was relevant to learning in a Physical Sciences classroom. It was evident that participants believed that this app assisted learning in the Physical Sciences classroom as they valued the content and its relevance to the subject.

The second part was to investigate the content gained through each app, and what role it could play. Participants had to indicate how the recommended apps assisted them by selecting any of the roles listed in Table 18 below which summarises the different functions the app could play in a Physical Sciences classroom. Participants had to consider any the options listed below. Since each app could possess more than one function, participants could select any option relevant to the app being they used. Frequencies of app functions are shown in the Table 18 below:

Table 18: App functionality results

	Name of apps							
App functions	**Physical Sciences Mobile app**		**WhatsApp**		**Google Classroom app**		**School Planner app**	
	(n)	**(%)**	**(n)**	**(%)**	**(n)**	**(%)**	**(n)**	**(%)**
Communicate effectively at low cost	5	6.94	72	100	2	3.28	3	4.17
Provided topic notes	30	41.6	4	5.56	44	72.1	3	4.17
Provided practice problems and answers	70	97.2	8	11.1	61	100	2	2.78
Videos	3	4.17	6	8.33	0	0	3	4.17
Exams and memos	66	91.7	6	8.33	2	3.28	1	1.39
Plan effectively	7	9.72	4	5.56	3	4.92	71	98.6
Practice problems only	12	16.7	2	2.78	0	0	2	2.78
Other	19	26.4	3	4.17	3	4.92	26	36.1
Totals	**72**	**100**	**72**	**100**	**61**	**100**	**72**	**100**

All participants indicated that they could communicate effectively in an inexpensive manner by using WhatsApp. This was compared to the 6.94%, 3.28% and 4.17% who indicated that they could communicate effectively by using the Physical Sciences, Google Classroom, and the School Planner app respectively. Descriptions of the Physical Sciences mobile app and the School Planner app indicated that they do not possess communication functionality, therefore, 93,06% and 95.83% of the participants were able to test the Physical Sciences mobile app and School Planner app accurately. In contrast, WhatsApp and Google Classroom possess communication functionalities. Participants (%=96.72, n= 66) were unable to determine the communication functionality of the Google Classroom app. This implied that participants could not locate this particular functionality, or they did not value the advantage of communicating inexpensively.

In addition, 41.6 % of the participants indicated that the Physical Sciences mobile app can be used to access notes on certain topics. This notion was not evident when pitted against the app description. However, the majority of the participants could clearly test that the app did not provide notes on the topic being explored. Additionally, most participants indicated that the WhatsApp and the School Planner apps could not be used to access notes. This implied that participants focused on mainly on the communication feature of WhatsApp, but not on what could be communicated in terms of academic material. School Planner predictions were correct as listed on the app description page. Additionally, 72.1 % of the participants indicated that topic notes could be transmitted using the Google Classroom app.

To further illustrate the applicability of the apps to learning in a Physical Sciences classroom, I found it best to summarise the rest of the functions on each application. This provided a better readability, and therefore easier for the reader to understand. Most of the participants believed that Physical Sciences and the Google Classroom apps provided practice problems and memos (n = 70, %=97.2 for the Physical Sciences mobile app, and n=61, %=100 for the Google Classroom app) in addition to enabling the viewing of exam problems which also come with memos (See Table 18 above). Additionally, 98.6% of the participants indicated that the School Planner app provided effective planning for classroom organisation. It was evident that participants were able to assess the applicability of the apps as they related to Physical Sciences. Moreover, participants found that WhatsApp provided communication at low cost, while the School Planner could be used to provide effective planning. Also, the Physical Sciences mobile apps could provide learners with exam questions and practice problems for each topic, therefore motivating them to practise or revise for tests and examinations. As such, participants could assess the content, and how it was applicable to learning in a Physical Sciences classroom.

In order to demonstrate the suitability of the applications for use in Physical Sciences lessons, participants had to indicate if the app consumed data after being downloaded. This revealed whether an app is offline-based or works in an online platform. Participants had to choose between *yes/no* responses to indicate if the apps required internet connectivity for usage after download. Table 19 below presents the frequency of *yes/no* responses to the question; for example, does this app use data after download for the four recommended apps?

Table 19: App consumption of data after downloading

Variable	Name of app							
Does this app use data after download?	***Physical Sciences Mobile app***		***WhatsApp***		***Google Classroom app***		***School Planner app***	
	(n)	**(%)**	**(n)**	**(%)**	**(n)**	**(%)**	**(n)**	**(%)**
Yes	5	6.94	72	100	57	93.44	8	11.1
No	67	93.06	0	0	4	6.56	64	88.9
Totals	**72**	**100**	**72**	**100**	**61**	**100**	**72**	**100**

Table 19 suggests that after download, WhatsApp and Google classroom apps function only in an online platform, as most of the participants indicated that they require internet connectivity for use. In contrast, the Physical Sciences and School Planner apps were classified as not requiring internet connectivity to use by majority of the participants: 93% of the participants indicated that the Physical Sciences app did not require data to use, and 88.9% indicated that School Planner did not require internet access, which means that these apps can be used in any school in South Africa, even in regions that lack access to the internet which makes them ideal for use.

Participants also reported on apps that contained adverts which they found to be distracting. Participants indicated that only the Physical Sciences mobile (n=65) and the School Planner (n=56) apps contained adverts, but only 10% found the adverts to be disrupting on the Physical Sciences mobile app, and 22.2% found the adverts on School Planner app to be disturbing. Therefore, these 2 apps may contain advertisements, but most participants did not find them too distracting, which makes the apps suitable for classroom usage.

Furthermore, participants had to rate their likelihood of recommending the 4 most popular apps to their peers. Findings revealed that participants were more likely to recommend a product they are happy with (see 3.5). These results are displayed in Table 20 below.

Table 20: App recommendation

Variable	Name of app							
Would you recommend this app to anyone?	***Physical Sciences Mobile app***		***WhatsApp***		***Google Classroom app***		***School Planner app***	
	(n)	**(%)**	**(n)**	**(%)**	**(n)**	**(%)**	**(n)**	**(%)**
Strongly disagree	0	0	3	4.2	2	3.3	5	6.9
Disagree	4	5.6	4	5.6	1	1.6	17	23.6
Neutral	5	6.9	10	13.9	13	21.3	12	16.7
Agree	16	22.2	18	25	22	36.1	22	30.1
Strongly agree	47	65.3	36	50	23	37.8	16	22.2
Totals	**72**	**100**	**72**	**100**	**61**	**100**	**72**	**100**

It was evident that participants were satisfied with the recommended apps. A large number of participants (87.5%) indicated that they would strongly agree to recommending the Physical Sciences mobile app to their peers (with n = 16, % = 22.2 agreeing and n=47, %=65.3), while 75% of the participants would recommend WhatsApp, 73.8% would recommend the Google Classroom app, and 52.8% would recommend the School Planner app. To further illustrate the satisfaction levels of the participants, a SUS score was used (see 5.3.2.2 below).

5.3.2.2 Investigating the participants' satisfaction with recommended apps

Studies by Brook (1996:6) and Tullis et al. (2013) revealed that SUS scores can be used to determine the rate of usability of a computer system. This study applied the SUS questionnaire tool in order to understand participant recommendation scores (in 5.3.2.1 above) by comparing the two scores while also revealing how satisfied participants were with the recommended apps. As indicated in 3.6, a high satisfaction score on the app means the app is easy to use or learn from. These apps were judged on the SUS score scale recommended by Bangor et al. (2009, as cited in Kauffman 2013:139) which is illustrated in Table 21 below.

Table 21: SUS score and usability rating

SUS score	Usability rating
Less than 50	Not acceptable
Between 50 and 70	Marginally acceptable
Above 70	Acceptable

Table 21 above indicates that if an app is found to have a SUS score below 50%, then it is not acceptable, and therefore the app cannot be recommended for use as it is not user-friendly.

However, an app with a SUS score of above 70 is regarded as acceptable for use. As stated in chapters 3 and 4, SUS scores are highly reliable and can be depended on as they are used by experts in the HCI field to test any computer system for usability. Usability, therefore, is important for this study as it also informs on the app suitability for its use in a Physical Sciences classroom.

The SUS questionnaire scores were calculated using the techniques mentioned in chapter 4. These scores were tabulated, and a rating was provided. Each participant's score was recorded, and an average score for each app was determined. Even though the SUS questionnaire contains Likert-scale data, it is analysed differently. A guideline on how to calculate the SUS score was indicated in chapter 4. Table 22 below only shows the abbreviated scored per application. It depicts a SUS score for the Physical Sciences mobile app.

Table 22: SUS Score regarding Physical Sciences mobile apps

Participant code	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	SUS Score Calculator
MSS01	5	1	5	2	5	2	4	1	5	2	**90**
MSS02	5	1	4	1	5	1	5	1	3	1	**92.5**
MSS03	4	2	3	1	4	3	3	1	4	3	**70**
MSS04	5	2	4	1	4	1	4	3	4	1	**82.5**
MSS05	2	2	3	2	4	3	2	4	3	3	**50**
MSS06	5	1	5	1	5	1	5	1	5	1	**100**
MSS07	4	3	4	2	2	2	5	1	4	1	**75**
MSS08	4	3	3	1	5	3	4	1	5	1	**80**
MSS09	5	1	5	1	5	1	5	5	3	5	**75**
……………………………………………………………………………………											
MSS88	5	2	3	1	5	1	5	1	5	2	**90**
MSS89	5	3	5	5	5	3	3	2	5	3	**67.5**
MSS91	5	5	5	1	4	1	3	2	4	3	**72.5**
MSS92	5	1	5	1	5	2	5	1	5	1	**97.5**
MSS93	5	1	4	2	4	2	5	1	5	2	**87.5**
MSS95	5	1	4	1	5	1	4	2	5	4	**85**
						Average SUS score					**70.42**

Table 22 above shows the response provided by each participant to the 10 SUS questions, including the total score of the participants. The table is ‘compressed’ for readability purposes. The Physical Sciences app had an average SUS score of 70.42. As this score was above 70, this app was regarded as highly acceptable for use. In section 5.3.2.1, 87.5% of the participants indicated that they would recommend this app to their peers. The Physical Sciences mobile apps are then regarded as both applicable and usable for learning in a Physical Sciences classroom.

Since all of the relevant apps were tested for usability, 3 additional tables of data for each app (similar to the Physical Sciences mobile app) are recorded. However, it would be redundant to display the same table four different times for different apps. These tables were therefore attached as appendices. Table 23 shows the SUS scores and rating of the 3 remaining apps. Just like with the Physical Sciences mobile app above, the SUS score of each participant was calculated, and an average score for each app was determined. Table 23 below shows the ratings of each app as determined by their average scores.

Table 23: SUS ratings

Name of an app	SUS score	SUS rating
WhatsApp	72.47	Acceptable
Google Classroom app	74.21	Acceptable
School Planner app	61.49	Marginally acceptable

It was evident that no app was classified as being unacceptable since all SUS scores were above 50. Additionally, both WhatsApp and Google Classroom apps were found to be highly acceptable by the participants as they had scores of above 70. This implies that the 2 apps can therefore be recommended for use for learning in a Physical Sciences classroom. The School Planner app received a marginal acceptability score indicating that participants still believed that it can still be used for learning in a Physical Sciences classroom but in a limited sense. The apps tested in this study were found to be applicable and suitable for use in a Physical Sciences classroom.

In order for learners to determine the usability of the apps, they must assess the quality of content to learning to determine which role the app was going to play. Further, participants must assess if an application includes adverts, and how those adverts affect the quality of the apps' usability. Also, participants must be willing to recommend an app to a peer which will imply that a learner is satisfied with the app.

An analysis of variance (ANOVA) was conducted between the Physical Sciences, WhatsApp, Google Classroom, and the School Planner apps to compare their ease-of-use. As the SUS questionnaire focused on aspects of ease-of-use and learnability, the intention here was to test how easy it would be to learn how to use any of the recommended apps.

H_0: It is equally easy to use WhatsApp, School Planner, Google Classroom and the Physical Sciences mobile app.

There was a significant difference between ease-of-use at the p <0.05 level for the 4 apps [F (3, 273) = 8.541, p =0.0000193]. To understand this significance, a Bonferroni correction was conducted. Studies (Armstrong, 2014:502; Benavoli, Corani & Mangili, 2016:3; Shan & Gerstenberger, 2017) reveal that this test is used to indicate exactly where this significant difference occurs when comparing multiple items, and it must be reported whenever there is a significant value using the ANOVA test. The Bonferroni correction results are illustrated in Table 24 below which shows the different groups of apps and their 'p-values'. Table 24 also shows if there is any significant difference between the 'Bonferroni alpha' and 'p-value' for each group. Since the ANOVA test was performed with 95% confidence intervals, the implication is that the Bonferroni correction (α) value is 0.008333.

Table 24: p values for app comparison

Groups	p value	Significance
Physical Sciences Mobile App vs WhatsApp	0.47812	False
Physical Sciences Mobile App vs School Planner App	0.00162	True
Physical Sciences Mobile App vs Google Classroom	0.16618	False
WhatsApp vs Google Classroom	0.39433	False
WhatsApp vs School Planner	0.0000420	True
Google Classroom vs School Planner	0.0000221	True

This test revealed the following: there is no difference between WhatsApp and the Physical Sciences mobile app (p = 0.478, α = 0,008333). The implication is that it is equally easy to use the 2 apps mentioned above. Additionally, this test revealed that it is equally easy to use WhatsApp and Google classroom app (p = 0.394, α = 0,008333), and equally easy to use the Physical Sciences mobile app and Google Classroom app (p = 0.166, α = 0,008333). As

WhatsApp is popular and recognised and used universally, the implication is that people using this app would find it relatively easy to use the Physical Sciences mobile app and the Google Classroom App.

However, there were significant differences discovered between the following app combinations pertaining to ease-of-use: WhatsApp and School Planner app ($p = 0.0000420$, $\alpha = 0{,}008333$), Physical Sciences mobile app and School Planner ($p = 0.00162$, $\alpha = 0{,}008333$), and School Planner and the Google Classroom app ($p = 0.0000221$, $\alpha = 0{,}008333$). These differences suggest that a person who is able to use WhatsApp, Physical Science mobile, and Google Classroom apps may find it difficult to learn how to use the School Planner app.

The tools mentioned in this section did not reveal all the participants' experiences while testing the apps, but showed how an app can be assessed to be of value to learning in a Physical Sciences learning environment. User experience can also inform research on how participants interacted with the applications, which can further reveal the extent to which an app can be regarded as usable in a Physical Sciences learning environment. This is investigated in the next section.

5.4.3 Empirical Research Objective 3

Investigate the experiences of learners regarding the use of mobile learning applications

Participants' experiences included installation failures during the accessing of apps and app performance testing. These experiences were documented via task sheets and observations. To avoid confusion in the data collected for analysis, this section is divided into part A and part B, while Part C was answered in research question 4. As mentioned in chapter 4, part A solely focused on software discovery by the participants, while part B concentrated on apps recommended by the researcher, hence it relied on the task sheet and observations**.** I hereunder discussed the experiences of the participants observed during the software discovery process (Part A). The shift is then made to Part B where I depended on task sheets and observations.

5.4.3.1 Participants' experiences during software discovery and app usage

The section relied on observational data. Participants experiences fall under 2 categories: inability to install apps, and incorrect use of the software. I listed all the factors that led to complications in installing certain applications, then I discussed the incorrect use of software in the Physical Sciences classroom. Although app usage in classrooms is covered in detail in research question 4, it was necessary to include it in this section as it informed the study on the incorrect use of software.

(i) Inability to install or use recommended software

There were numerous factors that contributed to participants not being able to install apps on their smartphones; however, for this study, it was discovered that 3 factors contributed to participants not being able to install apps on their phones. Participants experienced one or two of the following problems:

- Not having an email account
- Storage issues
- Software incompatibility

These problems are discussed in detail below.

(a) Absence of an email account and/or forgotten passwords to email accounts:

Acquisition of an app from an app store requires that participants must have an email address which will be used for both identification, and provide access to the user. However, there are diverse ways apps can be installed on a phone without the need for a play store, but these methods which will be discussed later in the chapter are considered to be unsafe. During the course of the study, it was observed that some participants had trouble continuing with software discovery due to them not having access to the Google Play Store. One observer responded:

> *Participants are unable to download apps because participants are not signed into Google Play Store. The student had forgotten the password while other participants did not have a google account.*

This made it difficult for participants to participate in the study as without access to Google Play Store they could not download the necessary app. Since the task was for participants to find the necessary application without any assistance from the researcher, participants were encouraged to explore different means in order to access apps.

Although participants had smart phones, email accounts are not a necessity, hence some of the participants did not have them.

(b) Storage issues

All cell phones have storage capacity created within the phone. Storage limits the amount of information and/or apps that can be stored in a phone at once; for instance, a phone with a storage capacity of 2 gigabytes can only hold information or apps not exceeding 2 gigabytes. The implication is that any downloaded app or any picture captured, will add to the amount of information already being stored, thus reducing the phone's available memory. One observer commented:

> *Participant was unable to install an app. Participant's phone has full capacity and therefore participant must release some memory.*

Seven participants were unable to install apps due to low storage space available on their smartphones. When participants tried to install the apps mentioned above, a message popped up indicating that they did not have enough storage space on their devices. This message also suggested what they can do in order to free-up some space. It recommended a list of apps which can be deleted in order to free-up more space. Participants received the following message as depicted by the screenshot below, which may differ depending on the smartphone type, but all of them generally mean the same thing.

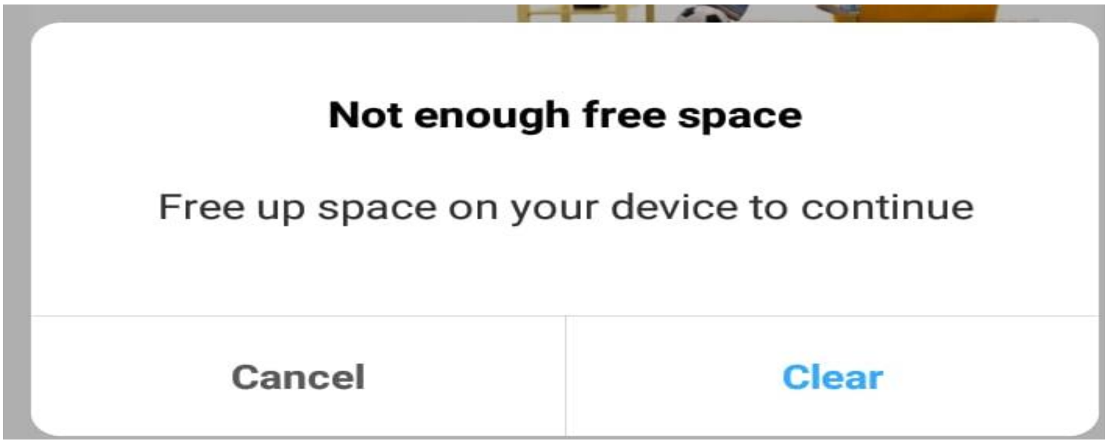

Figure 12: Storage full message from Redmi 4A smartphone

The implication is that participants had to delete some of the apps installed on their mobile devices or delete huge files like pictures and videos. This was a challenging task as participants were not willingly going to delete their personal files and memories.

> *To fix this problem, Participants (n = 14) transferred their files to an online storage facility using their email accounts. However, 2 participants deleted their videos to make space for additional apps.*

This implied that participants are aware of back-up systems which can store their data so that they have additional storage space on their phones. However, not all participants were aware of different ways to back-up their information, hence the deleting of personal information in order to accommodate additional apps on their phones. Although the first 2 problems participants faced could easily be fixed, the last problem did not allow the researcher nor the participants with ample solutions. When software was not compatible to a smartphone, there were only few solutions available.

(c) Phone not supporting the relevant software

As explained in chapter 1, a smartphone runs on a specific operating system. Most of the mobile phones used by learners relied on an android-based operating system. For security purposes, operating systems are upgraded, and some apps may stop working due to this update. However, there are situations where apps cannot run on earlier versions of the operating system. An observer commented:

> *Two participants reported that a file could not be installed on the mobile phone as the 'file was not supported'.*

Both participants were using android 4.0 (Ice Cream Sandwich) operating system. The issue was that the operating system running on their mobile devices was not compatible with the School Planner app as it required a minimum of android 4.1 (Jellybean) OS for the app to be installed or run smoothly on the phone, and therefore this app could not be installed. Additionally, WhatsApp could not be installed on these phones as it has similar restrictions as the School Planner app. Even though the Physical Sciences mobile app required the android 4.03 operating system, these participants could not install this app as well. Hence, a decision was taken to lend them compatible phones. In this study, problems pertaining to the updating of an operating system were not encountered.

(d) The incorrect use of the software

Participant-observations on the use of any of the 4 apps was classified as either a good practice or inappropriate for learning. Participants were given activities to complete by using their mobile phones. They were expected to work independently, similar to when they are given a quiz in any formal class. From the Google Classroom app, they had to answer a multiple-choice test based on 'electricity and magnetism'. From the Physical Sciences app, learners had to solve 'practice problems' relating to the topic on electrostatics. The list of practice problems are also attached as an appendix. Inappropriate practices are outlined below in Table 25 showing the names of the apps, and how each app was used incorrectly.

Table 25: Incorrect and inappropriate use of apps

WhatsApp	Google Classroom	Physical sciences mobile app
Sending messages asking for answers Sending answer screenshots in a quiz to fellow classmates	Taking screenshots of quizzes and sending them to classmates	Copying directly from the answers without attempting the work first.

These practices were observed across the 4 classes of participants chosen for the study. An observer stated:

Three participants were caught sending screenshots to friends through WhatsApp. These were answers to an online quiz on Google Classroom. Looking at the participants' phones, *it was discovered that one participant had asked for help from 3 others through WhatsApp*. Additionally, it was evident that most of the cheating occurred through the use of the WhatsApp software. The Physical Sciences mobile app was also used incorrectly. It was observed:

> *Four participants in Grade 10 appeared to finish most of the activities faster than all the other participants; however, it was found that they were actually copying answers directly from the app without first attempting them*. Grade 11 classes, *two learners were caught copying answers directly from the memo tab*.

As explained in the literature, this app is used mainly for practice. Going straight to the answers does not provide a true reflection on whether a learner understands the topic or not. To use it correctly, learners must attempt problems first, then compare their answers with the ones provided on the app.

It can therefore be concluded that participants experienced the following: firstly, they could not install software due to not having enough storage space; secondly, they did not have access to Google Play Store due to them not having an email address; and thirdly, not knowing how to reset a forgotten password. Further, communication software makes it easier for learners to collude in the classroom. Literature studies also informed on the bullying nature of communication software, and how it can impact negatively in the classroom. This implies that giving a learner a test via a cell phone as an aid may prove to be difficult because it will not be easy to control collusion.

5.3.3.2 Participants' experiences during app testing

To investigate the participants' experiences during this phase, task sheets and observations were utilised. This study used 2 task sheets (Appendix P). Each task was designed specifically for a particular app. The results were analysed per task. As stated in 3.6, the 4 apps were chosen based on the roles apps could play in the classroom as informed by literature (see chapter 3).

I commenced by discussing results based on the different tasks participants had to perform for this study. I then discussed the observations based on the predetermined and emergent themes as mentioned in 4.7. The pre-test questionnaire informed the study on the participants' experiences prior to engaging in the study. Experiences cover everything that occurred from the moment they downloaded and installed apps.

The task sheet data investigated the ability of the participants to perform given tasks. The unit of measure was *Task Success*. A task was declared as either passed or failed. A pass was awarded when the task was completed successfully in the specified time; if not, it failed. There are 4 reasons that would declare a task to be regarded as unsuccessful:

- Failing to complete the task on time
- Marking the task as successfully completed but not completed
- The facilitator stopping the user because time had elapsed.
- Participant giving an incorrect answer

These tests began with the Physical Sciences mobile applications.

(i) Physical Sciences mobile app task sheet results

Although Grade 10 and 11 classes used different apps, the tasks focused on the topics and tabs that were common in each app as to not disadvantage any of the participants. It was therefore insignificant to classify the results as either Grade 10 or 11 as the 2 groups were testing the same variable. Table 26 below shows results of the frequency of participants responses to each variable that was investigated.

Table 26: Frequency of Physical Sciences mobile app task sheet responses

Task number	Variable	Frequency of correct responses		Frequency of incorrect responses	
		(n)	(%)	(n)	(%)
1.	How many practice problems are there in electrostatics?	60	83	12	17
2.	Take a screenshot of the electricity long question from the November 2016 examination paper and SHOW it to the researcher	55	76	17	24
3.	State the question listed as 4.1 from the 2019 1 June exam paper	58	81	5	19
4.	Write down the correct ANSWER to question 1.4 from the September 2019 test.	55	76	17	24

It was evident from Table 26 above that the majority of the participants knew how to navigate through the app as evidenced from the successful completion of all tasks. As indicated in Table 26 above, 83% of the participants completed task 1 successfully, while the rest of the tasks had at least a success rate of 76%. The implication was that participants would find it easy to use this app. Additionally, the substantial number of participants who successfully completed the tasks provide further evidence as to why this app was regarded as acceptable (5.3.2.2 above) due to the rating of more than 70. The first question required the participants to navigate through the practice problems. The majority of the participants was able to find practice exercises on any chosen topic, therefore waiving any assistance from an educator. Additionally, participants showed that they could find any of the exam papers (questions and answers). These experiences therefore indicate that navigation will not be an issue concerning this app; therefore, this app could be utilised successfully in a Physical Sciences classroom.

While participants were busy with the tasks, the following additional behaviours were observed: a *few (n=2) participants appeared to scratch their heads in task 2. This could be a sign that such participants were finding the tasks as difficult*.

Participants were then informed that they could progress to another task as the previous tasks were proved difficult. Additionally, *5 participants had marked a task as complete, but the task was not completed successfully*. It was therefore simple to identify participants who struggled to perform tasks. This does indicate that for this app to be used, a few participants might require training to get used to the app navigation tabs, therefore they needed guidance to master the app's functions which will in turn increase their motivation to learn.

(ii) School planner task sheet results

Participants had to perform 4 tasks by using this app. Similar to the Physical Sciences mobile apps mentioned above, each task had to be performed within a specified time. Additionally, a frequency-of-tasks schedule was completed for recording purposes. The table below illustrates the results from the given tasks. For readability purposes, the tasks are numbered as tasks 1 to 4 instead of the long questions from each question. The first task from the school planner task sheet is represented by task 1 and so on and so forth. Table 27 below shows the frequency of the number of learners who completed each task successfully.

Table 27: Frequency of School Planner app task sheet responses

Task number	Variable	Frequency of correct responses		Frequency of incorrect responses	
		(n)	(%)	(n)	(%)
1.	Set a reminder to study for the Physical Sciences informal test (choose any date that's suitable to you)	67	93	5	7
2.	Add 5 fictitious teachers' names in the app	45	63	27	37
3.	Add 5 school subjects Each subject must have only one teacher (use one teacher 'created' in task 2)	42	58	30	42
4.	Create a day-school timetable on the app using the subjects chosen in task 3	30	42	42	58

It is evident from Table 27 above that most of the participants (93%) completed task 1 successfully, more than all the other tasks. This implied that participants found it easier to set reminders on this app, more than perform any other task. Only 45 of the 72 participants could create fictitious teachers' names on the app, and 42 participants could add 5 subjects successfully onto the app. Task 4 was layered on tasks 2 and 3, and therefore it made sense that only 42% of the participants could complete this task successfully. Hence, less than 64% of the participants could complete tasks 2 and 3. These scores further inform the study as to why only 52% of the participants stated that they would recommend this app to their peers, which led to a low SUS score rating as compared to the rest of the recommended apps. Thus, comments were articulated such as:

Participant left task 4 unanswered. Participant failed to select the correct tabs.

Observations and task sheets revealed that the majority of the participants quit completing task 4. This behaviour observed above, was seen throughout the study as the majority (n= 42, %=58) of the participants handed in their task sheet without task 4 being completed. The implication was that more than 50% of the participants found this task to be difficult, hence the task had a 42% completion rate. It was therefore evident that parts of the app were simple to use as evidenced by task 1, while others may require some training before they can be utilised. The implication is that in order to realise the full functionality of the app, more time must be dedicated to training participants on how to use this app. Task 1 indicated that the setting of reminders was easy for participants to follow, which implies that they might be able to use the reminder tab to perform scheduled tasks which can enhance their academic performance.

Due to time-constraints, participants were not able to perform tasks on the Google Classroom app. Since most of the participants were already using WhatsApp, it was unnecessary to create a task sheet for WhatsApp. Additionally, the app functionality was already documented in 3.7.4.

5.4.4 Empirical Research Objective 4

Determine how app usage in a classroom affects teaching and learning activities in a Physical Sciences classroom

Research questions 1 to 3 revealed participants' experiences in accessing the apps for classroom usage and determining if the app was suitable for classroom usage. This section reviewed the recommended apps in a classroom setting, and the results for questions 1 to 3 together with observations, were used to answer these questions.

This session commenced with the planning phase. Since participants had issued their contact details on the consent forms prior to the study, I was able to open a WhatsApp group to facilitate communication with the different classes I was going to teach:

- Grade 10 research Group
- Grade 11 research Group

The purpose of the formation of WhatsApp groups was to promote constant and timeous communication among all participants in order to prepare for the sessions. I arrived on site 30 minutes earlier in order to screen the participants before the session could commence.

Participants were then taught by the researcher, but under the supervision of their educators. Each lesson was dedicated to a specific group of learners as evidenced as per lesson plan (see lesson plan appendix).

In the app review questionnaire (see research question 3), the majority of the participants indicated that the content gained through the Physical Sciences mobile app was relevant to learning in a Physical Sciences classroom.

As indicated in Table 18 (see 5.4.2.1), participants indicated that the app provided them with practice problems and answers, as well as exam papers and memorandums. *Observations revealed that these problems were topic-based therefore making it easier for participants to practice problems on any topic of their choosing (as long as it was Physical Sciences) at any time as indicated by the graph below*.

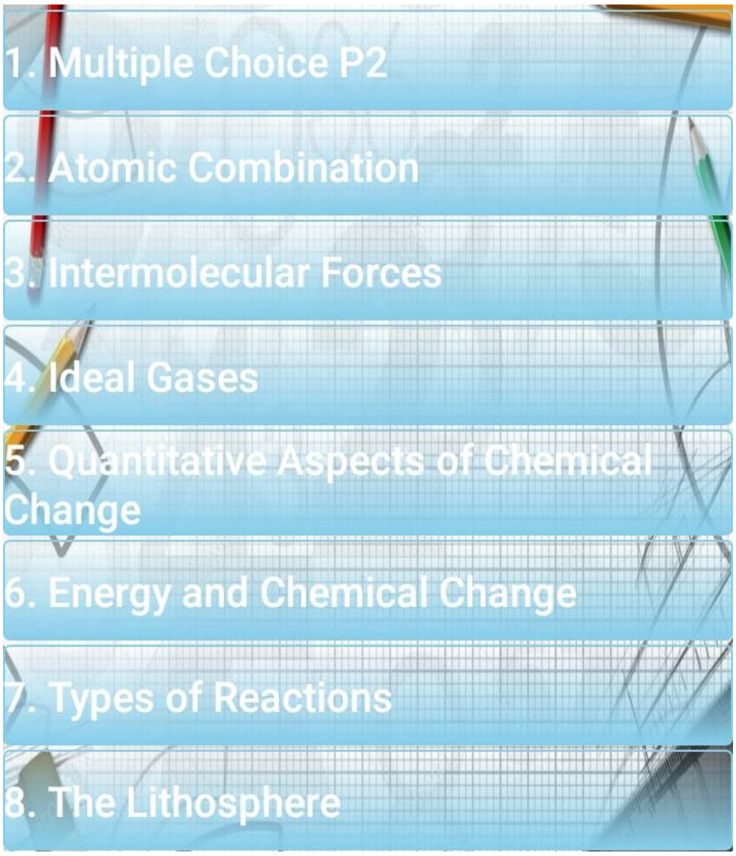

Figure 13: Grade 10 Physical Sciences app topic list

As indicated in chapter 4, one of the topics observed was the quantitative aspect of physical change. Participants would then select practice problems from the app, then choose option five from the practice problems. Below is an example of a practice problem attempted by the Grade

10 classes. Visible in Figure 14 below, is an option to hide answers, as this option is only available when participants click the *view answers* tab.

QUESTION 5 (Start on a new page.)

Hydrogen peroxide decomposes at room temperature according to the following balanced chemical equation:

$$2H_2O_2(aq) \rightarrow O_2(g) + 2H_2O(\ell)$$

5.1	What does the (aq) represent in the equation above?	(1)
5.2	Identify the type of reaction above. Choose between PRECIPITATION and REDOX. Give a reason for the answer.	(2)
5.3	Is the reaction an example of a *physical* or a *chemical* change?	(1)
5.4	Define the term *one mole* of a substance.	(2)
5.5	If 4 moles of hydrogen peroxide decomposes, calculate the volume of gas formed at STP.	(4)
5.6	Calculate the number of oxygen atoms in H_2O_2 if 17 g of H_2O_2 decomposes.	(4) **[14]**

Hide Answers

Figure 14: Questions on chemical change

Figure 15 below presents answers for the activity in the Figure 14 above.

5.1 An aqueous solution. ✓/*'n Waterige oplossing.*✓ (1)

5.2 Redox. ✓
Electron transfer took place. ✓/
Redoks. ✓
Elektron oordrag het plaasgevind. ✓ (2)

5.3 Chemical change. ✓/*Chemiese verandering.* ✓ (1)

5.4 The amount of substance having the same number of particles as there are atoms in 12g C-12.✓✓
Die stofhoeveelheid wat dieselfde getal deeltjies het as wat daar atome in 12g koolstof-12 is. ✓✓ (2)

5.5 $H_2O_2 : O_2$
$2 : 1$
Therefore $n(O_2)= 2$ mol ✓

$n = \frac{V}{V_m}$ ✓

$2 = \frac{V}{22,4}$ ✓

$V = 44,8 dm^3$ ✓ (4)

5.6 $n(H_2O_2) = \frac{m}{M}$

$= \frac{17}{34}$ ✓

$= 0,5 mol$

$n = \frac{N}{N_A}$ ✓

$(0,5)(2) = \frac{N}{6,02 \times 10^{23}}$ ✓

$N = 6,02 \times 10^{23}$ atoms ✓ (4)

[14]

Figure 15: Answers to questions in Figure 14 above

Further, each set of questions came with solutions as indicated above. Participants attempted a problem, then used the solutions provided on the app to check how they performed on answering that particular problem. This provided learners with enough practice material to perform on their own, which may have helped to boost their scores. The exams and memorandums section can also assist in preparing learners for an exam. Furthermore, participants can practise with minimal intervention from an educator, thus making it easier for participants to revise for exams without time and venue limitations.

By perusing the type of questions based on this app, it provided opportunities for classroom activities as the app contains diverse types of questions at different levels of difficulty; Questions range from level one to level 4 in complexity. These questions and possible answers created on the app have been tested by the researcher (a Physical Sciences educator); and they appear to be fair. Furthermore, they inform learners exactly how marks will be allocated regarding each activity. The exams have the same structure as the practice problems. Furthermore, there are more than 20 questions on each topic, thus giving learners sufficient practice which may in turn foster better performance in the subject.

This app can therefore be used to advantage to assist learners in grasping content learned in classroom. Additionally, this app can be used without the intervention of educators, thus reducing the workload of educators while inspiring learners to be in charge of their learning. However, this app cannot be used without the guidance of the teacher in classroom as the experiences of some of the learners indicated that they copied the answers directly without first attempting the questions on their own – these calls for intervention to assist struggling learners with the understanding of subject content. This app is beneficial for practice purposes but cannot be used for testing as participants are able to see the answers easily. When used incorrectly, this app may not provide a true reflection of the learners’ understanding of a topic, therefore making it difficult for educators to identify areas where learners are struggling in order to provide remediation. However, when used astutely, it reinforces curriculum understanding by providing learners with numerous questions, solutions, and elaborate steps to reach the solution; this teaches the learners problem-solving skills while also reducing the need to print materials for use, thus saving the schools’ money.

WhatsApp on the other hand, was used mostly by me as a communication tool to inform the learners on what to prepare for the upcoming classes. It was used to enquire about the learners’ whereabouts. Participants were encouraged to send answers to the researcher regarding any practice problems they attempted on their own. It was therefore evident that the content sent through this medium was of value to learning in a Physical Sciences classroom as indicated in research question 3. However, WhatsApp is a communication app and therefore it can play a vital role in a Physical Sciences classroom. Additionally, participants assisted in the screening as per Covid-19 protocols, it led to the lessons commencing on time. This app can therefore be used to provide a constant flow of communication in the classroom.

I therefore agree with Means (1993:5) and Kozma (2000:5) that apps can be used to cover curriculum while promoting effective communication as indicated by the majority of the participants when discussing roles that WhatsApp could play in a classroom. Furthermore, this communication is inexpensive, which therefore makes it ideal for use.

Although this app proved to be useful in classroom communication, it also engendered disruptions. For example, one participant *answered up a WhatsApp call right in the middle of the session*. Also, participants frequently sent messages between each other although observations could not reveal what the discussions were about. A few participants (n=*3) participants took selfies and updated their statuses.* Such distractions defeat the purpose of the lesson as participants shift their attention to receiving messages. Additionally, observations indicated that the apps were used to copy answers from the memoranda.

Even though there were some distractions caused in the classroom due to the use of this app, only a few participants were found to be guilty of this. WhatsApp made communication affordable and convenient to access subject content as confirmed in literature.

As the remaining 2 apps do not require data use, this makes them ideal to be used anywhere, including places that struggle with internet connections. However, School Planner and the Physical Sciences app are reported to contain adverts. Only 5.7% of the participants claimed that the adverts were distractive while using the Physical Sciences mobile app, but no participant found adverts to distractive on School Planner. Observations revealed that these adverts appear at the bottom of the app, thus distractions were minimal.

Participants indicated that the School Planner app can provide effective planning in a classroom (Figure 16 below).

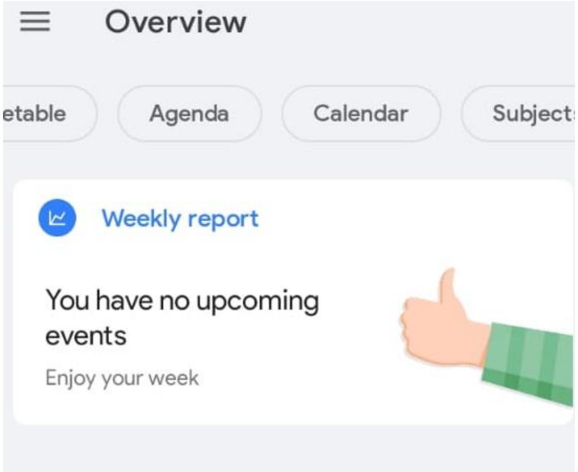

Figure 16: The School Planner app - overview (Google, 2021)

Although all participants could locate the timetable tab, it proved to be difficult. An observer commented:

Participant scrolled up and down. The participant was probably looking for a button that says add teacher and/or subject.

The observed behaviour was often seen from some (n=14) of the participants. This behaviour arose because some of the participants failed to accomplish tasks 2 and 3 which were needed to complete task 4 as indicated in 5.3.3.2. Additionally, the overview did not present all the app features, yet this is the welcome screen whenever participants used the app which therefore became problematic to discover the rest of the app functionalities. However, some of the participants could set their timetable, while the majority could clearly use the agenda to set reminders as informed by task 1 in section 5.3.2.1. Participants were instructed to complete practice problem 1 of question 3 as homework, hence the reminder feature proved to be invaluable. A teacher can also use this app to plan academic work. For example, the teacher can schedule assessment dates and learners can be reminded to prepare for the assessment.

Although the app was not used fully, participants appeared to know how to use it. It is the view of the researcher that they only picked what was relevant, and what they understood. More features of the app could not be explored due to time constraints linked to Covid-19 restrictions, as well as to allow participants ample time to focus on their studies. Perhaps the app can be incisively reviewed in future studies in order to completely understand what an educator and learners can accomplish when using it. However, participants revealed that this app is beneficial for use in the classroom as it offers opportunities to sufficiently plan, especially in classroom matters between educators and learners.

The Physical Sciences, WhatsApp, and Google Classroom apps can therefore be used in combination to improve student engagement. These three apps offer opportunities to plan, communicate, and practice at any point - therefore learning is extended beyond the classroom. Additionally, these apps were accepted for use by all the participants as they are user-friendly. However, these apps could not be used to test the knowledge the learners possess in each topic. Although further reviews on the google classroom app could not take place, the results from the pilot study indicated that the apps can be used for testing purposes. A teacher must login to the platform before setting a test. A teacher can vary the type of question – from multiple-choice to long questions. Setting of the questions is time-consuming which reduces learner-teacher contact time. However, for multiple-choice questions, a predetermined answer must be coded in by the educator for feedback and corrective work. A teacher can therefore set several multiple-choice practice exercises which will benefit the learner in understanding content prior to class tests. Each task can be scheduled on a specific date, but learners only have to respond when the task is available.

This app is online-based therefore it is costly to operate so it cannot be accessed in low socio-economic schools. It can also be used to assist in classroom planning as it uses the Google Calendar which automatically goes to the calendar of learners in each class.

Apps can therefore be used to plan classroom events, engage with topic problems and exam questions, facilitate communication between educator and learners, and test learners' understanding of each unit of a subject topic. However, apps must be monitored as they can be distractive when learners constantly communicate with those outside the class, and when copying is evident.

5.5 CONCLUSION

This chapter provided an analysis of both qualitative and quantitative data types. Data was gathered through observations and questionnaires (pre-test questionnaire, SUS questionnaire and App review questionnaire, and task sheets). Participants prior experiences indicated that they can all use the internet, download apps, and that they owned smartphones. Observations during the study indicated that participants could acquire apps in three different ways, so with such options few participants experienced challenges when installing apps. These challenges only arose because participants had forgotten their email passwords, not having enough storage space on the phone, and their phones did not support the relevant software. Participants used apps to communicate, practise, and to plan. However, the use of the apps also promoted collusion, and sometimes caused distractions in the classroom. Participants proved that they could find apps (software discovery questionnaire) and could also rate the quality of the software based on ease-of-use (SUS questionnaire) and quality of the content (App review questionnaire).

Although participants could rate any app they installed, analysis based on the four recommended apps were captured, while the others were ignored. This is because participants would have used the same tools to measure the quality, satisfaction, and content of the apps downloaded from the recommended software. The UX results revealed that the four recommended apps were regarded as acceptable therefore proving that they can be recommended for use in the classroom as they are user-friendly.

To further investigate the use of the apps, app review questionnaires were used to rate their content, and to make recommendations on their use. These investigations revealed that such apps can be used for different purposes in the Physical Science classroom which include providing notes, facilitating proper planning, access to revision questions and answers, online tests, exam question papers, and memorandums. Therefore, the impact of these apps on the Physical Sciences classroom can be immensely positive as they can be used to assist learners enormously in academic work. Importantly, educators can benefit also by developing best-practice, while learners are afforded ample practice time and opportunities to properly plan their academic programme. The nature of these apps proved that they can also assist learners and educators in times of crises; for example, during the Covid-19 pandemic as they consumed little or no data (except the Google Classroom app) therefore making them ideal to use anywhere since they are inexpensive to use. The next chapter (6) provided conclusions emanating from the results obtained via data collection processes which will be used to suggest recommendations pertaining to the use of mobile applications in classrooms.

CHAPTER SIX

DISCUSSION OF FINDINGS AND CONCLUSIONS

6.1 INTRODUCTION

This chapter discussed the key findings in line with participants' responses and researcher observations in chapter five. It provided a summary of the research procedures, followed by a discussion of the key findings. Also, the recommendations and limitations of the study were articulated. Importantly, the methodological approach which centred on usability studies that are rarely explored in education, was elucidated on. The interpretation of the research findings was related to the literature reviewed in chapters two and three. The recommendations emanating from how technology can impact the teaching and learning of the Physical Sciences were proposed to guide future studies. Lastly, the conclusion to the study was presented.

6.2 SUMMARY OF RESEARCH FINDINGS

This study investigated how free mobile applications impacted learning in Physical Sciences classrooms in Grades 10 and 11 by exploring learners' ability to find and test apps for suitability and applicability. As explained throughout the study, global benefits of technology have been realised, yet in South African schools technology is barely used to address the many challenges that learners face, such as the perennial shortage of textbooks. Studies revealed that South African schools lack the necessary resources to exploit technology. However, cell phone technology facilitates easier access to technological inventions (apps) which can aid teaching and learning activities in high schools, thus reducing the need for expensive computer hardware. Furthermore, most of these apps are accessible for free which therefore does not require schools with limited budgets to spend money on apps for learning. This study provided evidence that using apps in the classroom can positively impact learning in Physical Sciences classrooms.

The Technology and Technological Pedagogical Knowledge (TPACK) framework assisted the research in unpacking the type of previous knowledge that is required to successfully implement apps in the classroom. Such TPACK principles indicated that an educator must be familiar with technologies that are available, and how they can be used to impact pedagogy. Additionally, understanding of PCK assisted the researcher to grasp how content can be taught in a classroom in order to achieve better results. Further, PCK was informed by the CAPS document. Therefore, a thorough understanding of CAPS implies that the skills that learners must acquire through technology should be guided by the CAPS requirements. The TPACK framework therefore informed the study in how technology can be implemented in schools to enhance the quality of teaching and learning activities. Additionally, the teaching and learning principles played a critical role in this study as it outlined the roles of both educator and learner. This, therefore, assisted the researcher to understand how technology can be used in the classroom, whether to enhance teaching and learning, or to act as a substitute. Moreover, understanding the role of technology in teaching allowed the research to investigate how apps are utilised to accommodate different learning styles and teaching techniques.

This study's research methodology was underpinned by the pragmatism paradigm which allowed the researcher to elicit both qualitative and quantitative data without being restricted, as this paradigm focused only on what worked. Furthermore, it was regarded as being most effective for a mixed method study (Johnson & Onwuegbuzie, 2004), and therefore allowed the research to attain the best possible outcome (Pansiri, 2005). This paradigm, therefore, allowed the researcher to collect and analyse data with ease, as there were no ontological and epistemological assumptions that restricted data collection processes.

The study employed mixed methodology to investigate how mobile applications impact learning in Physical Sciences classrooms. Through the mixed methodology approach, I collected both qualitative and quantitative data thus gaining in-depth information on how apps influence learning in the Physical Sciences. Qualitative methodology provides a researcher with the description of behaviours in the classroom during learners' interactions with the apps. This study utilised the observation sheet where learners' behaviours were recorded, and I reflected on their meanings to provide qualitative data. Additionally, the app acquisition questionnaire was also used to provide qualitative data which therefore ensured the mixing of the qualitative data. Quantitative data informed the study on the usability of apps to learning in the Physical Sciences. Quantitative data was used to determine how suitable the applications were for learning Physical Sciences by assessing the app functions, and how they could be incorporated in learning. Data collection consisted of three stages: app acquisition, testing, and usage in the classroom. In app acquisition, I used observations and a questionnaire. stage two utilised three questionnaires while app usage made use of observations. Overall, 72 participants were involved in this study from two sites. Participants explored different ways of accessing apps: they tested, rated apps, and then used apps in the classroom. The tools of the study facilitated responses that informed the type of functions apps performed in a classroom, including gaining insights about their satisfaction levels and understanding the processes that led to their particular assessment of the apps.

These processes were aimed at answering the main research question: *What effect will the use of free mobile learning applications have on learning in a Grade 10 and 11 Physical Sciences classroom in the southern Free State?* This question was answered by attempting to answer 10 secondary research questions. Six of the proposed secondary research questions were used to dissect previous literature in order to understand the principles that guide teaching and learning across the globe. Table 28 below summarises the instruments used in this study, including the research questions aligned to each question.

Table 28: Secondary research questions aligned to research tools

Research Question	Research Instrument
1. How can mobile applications be acquired for classroom usage?	Observations
	App acquisition questionnaire (open-ended questions)
2. How can learners determine the suitability and applicability of apps for classroom usage?	App review questionnaire (closed-questions)
	SUS questionnaire (closed-questions)
3. What are the experiences of learners regarding the use of mobile learning applications?	Observations
	Task sheets
4. How does app usage in a classroom affect teaching and learning activities in a Physical Sciences classroom?	Observations
	Analysis from questions 1 to 3

To answer the first research question as indicated on Table 28 above, I had to use app acquisition software together with observations. Observations revealed participants' success in acquiring apps by stating the reasons that led to the success or failure in accessing them. Furthermore, this allowed for data to be mixed, hence reinforcing credibility in the methodology adopted for the study. In research question 2, the questionnaires led to eliciting quantitative data. Data triangulation could also be attained thus strengthening the trustworthiness of the data gathering process, and the quality aspect. Research question 3, required the participants to test the recommended applications which was conducted through app-specific task sheets. These tasks revealed whether participants were able to complete their given tasks successfully, which then informed the study on whether participants were capable to use apps in the classroom, depending on the success of each task. Observations were used to confirm the results from these tasks. This provided both qualitative and quantitative data.

Lastly, answering question 4 depended on observations and interpretation of results emanating from research questions 1 to 3. Observations were used to determine how each app was used in the classroom, and to reveal participants' behavioural patterns while using apps. The results from the secondary research questions assisted in unpacking the main research question which led to suggesting recommendations for future research.

6.3 FINDINGS ALIGNED TO RESEARCH OBJECTIVES

The influence of ICT on the designing of educational policies since 1996 (Vandeyar, 2013:3) by the DoE has seen significant invested efforts on how ICT can boost economic growth. Furthermore, e-Education policies were introduced into South African schools in an effort to transform teaching and learning activities (DoE, 2004:1). This, therefore, informs us of educational policies which assist ICT implementation to promote quality in teaching and learning activities.

Although there are stipulated policies, schools from low socio-economic areas do not have the necessary hardware to exploit technology in teaching-learning situations. Therefore, this creates a digital divide across the nation. Research has demonstrated that more efforts are being made in tertiary institutions in order to bridge the digital gap in education. The use of smart phones could perhaps be used to mitigate the cost of computer hardware which is necessary for ICT implementation in schools. Since 97% of the learners have cell phones, therefore e-Education should be encouraged in all South African schools. Hence, the DBE has already made efforts in training teachers and subject advisors in using technology effectively.

The key findings in alignment with the following research objectives, were outlined:

- Investigate how principles of teaching and learning influence a Physical Sciences classroom;
- Investigate how teaching approaches impact learning in a Physical Sciences classroom;
- Investigate how the policy stipulations of the CAPS document influence teaching and learning in a Physical Sciences classroom;
- Determine the role of the TPACK framework in science education;
- Assess the role of digital technologies in education;
- Investigate how mobile applications have been integrated in education;
- Observe the abilities of learners to select and access mobile applications for classroom usage;

- Evaluate procedures that can be used to assess app suitability and applicability for classroom usage;
- Investigate the experiences of learners regarding the use of mobile learning applications; and
- Determine how app usage in a classroom influences teaching and learning activities in a Physical Sciences classroom.

6.3.1 Findings of the Literature Review

The literature review provided answers related to the first 6 questions in 1.4.2. The research was directed by research objectives:

Objective 1: Investigate how principles of teaching and learning influence learning in a Physical Sciences classroom

Teaching principles guide communication between learners and educators in a Physical Sciences classroom. As such, teaching principles emphasise that subject matter must be organised which implies that learning must be based on the learners' prior knowledge in order to help them learn effectively to acquire new knowledge (Brody et al 2020). Additionally, teaching has to be commenced at a level that is suitable to the learner which provides motivation to learners. It was suggested that learners are motivated to learn when:

- they are involved in the setting of goals,
- different methods are used to teach, and
- they perform tasks that challenge them. (Hammer 2001 and Thoron 2020)

The above motivational factors reinforce the process of learning as they consider the aspirations and needs of the learners, in addition to enhancing learner-performance and learner- behaviour. A positive attitude towards learners helps them to perform better because they believe that their actions are valued by an educator. Therefore, Physical Sciences educators must therefore praise, reward, and encourage learners when they excel. Additionally, timeous feedback, and a clear remedial intervention plan must be implemented to those who were below par.

The last principle of teaching highlighted the role of teaching techniques in a classroom. An organised and creative presentation of classroom content engenders interest in learners to gain a deeper understanding of subject matter. This may be enhanced by adopting and eclectic approach as a teaching technique which considers learners' prior knowledge.

This study adopted learning principles proposed by Moss (2006), and then compared and contrasted them with those of Brody et al. (2020); both were found to be generally similar. The learning principles indicated that teaching and learning had to be based on learners' understanding by being actively engaged in the education process. Furthermore, the classroom environment had to be challenging and supportive to the learner. Additionally, classroom partnerships must enhance learning which must shape social and cultural contexts.

Teaching and learning principles therefore provided guidelines for a better understanding of the learner in the classroom in order to engender knowledge-creation.

Objective 2: How teaching approaches impact learning in a Physical Sciences classroom

Teaching approaches affect how knowledge is acquired and created in the classroom. In this study, both teacher-centred and learner-centred approaches were discussed. In a teacher-centred approach, which is textbook-driven, an educator is the primary source of knowledge. This method was found to be appropriate for large, crowded classrooms. However, research indicates that this approach leads to boredom thus reducing the motivation of the learners to engage in challenging learning activities.

A teacher-centred approach in a Physical Sciences classroom implies that learners are afforded limited responsibilities, while a teacher is viewed as the only leader who is responsible for the organisation of the classroom and the setting of rules. In contrast, a learner-centred classroom highlights that learners must be in charge of their learning by being actively engaged in the learning process via collaboration between learners and educators. Learner-centred environments view an educator as a facilitator of knowledge who promotes critical-thinking, creativity, innovation, and communication skills. However, this approach was found to be difficult to employ as it compromised the educator when the curriculum was left unfinished as learners have unique learning styles to imbibe knowledge and skills. On drawback of learner-centred classrooms is that they become noisy because there is constant talking in collaborative processes.

Objective 3: Investigate how the CAPS document influences teaching-learning in a Physical Sciences classroom

The CAPS guidelines inform an educator about the skills learners must acquire in a Physical Sciences classroom. According to the CAPS guidelines, curriculum learning is seen as being continuous, hence prior knowledge gained in the previous grade formed the basis of the acquisition of new knowledge in the current grade in a Physical Sciences classroom. Further, the CAPS listed the resources that must be utilised in a classroom, the topic duration, and the type of assessments that must be conducted. This therefore assists educators in understanding how much time they must spend on each topic, thereby ensuring thorough planning. Understanding the skills learners should acquire influences the teaching techniques used in class since learners grasp content in different ways, therefore teachers must vary their teaching techniques.

The CAPS guidelines therefore assist in choosing the appropriate teaching technique to be adopted based on the type of skills learners are expected to acquire for a particular topic. The teaching techniques that can be used in a Physical Sciences classroom include practice and repetition, classroom discussions, direct instruction, problem-solving, and the scientific method. Each technique has its own advantages over other techniques.

Objective 4: Determine the role of the TPACK framework in education

The TPACK framework is integral to understanding how to assimilate technology in teaching and learning processes. It is viewed as very influential in understanding the type of knowledge educators must possess in order to teach with the aid of technology. The TPACK model was found to have seven knowledge areas (see 3.2.2), and according to this model, an educator must be *au fait* with the following knowledge areas when teaching with digital technology:

- Pedagogical Knowledge (PK)
- Content Knowledge (CK)
- Pedagogical Content Knowledge (PCK)
- Technological Knowledge (TK)
- Technological Pedagogical Knowledge (TPK)
- Technological Content Knowledge (TCK)
- Technological pedagogical content knowledge (TPACK

This emphasises that an educator must be able to apply different pedagogical techniques to assist learners to acquire knowledge. Further, an educator must exhibit mastery of the learning content in order to facilitate knowledge-creation in a learner, and how to effectively teach the content of a specific subject. Hence, teachers must also understand the type of digital technologies, and how to use and apply them for classroom teaching. In this regard, TPACK assists educators to effectively teach lessons through digital technologies by informing them on the type of specific ICT knowledge they must possess which enables an educator to apply more than merely a teaching technique to enhance learning.

The TPACK framework plays a crucial role in the organisation of classroom activities such as lesson planning which must also include the type of technology to be used to effectively teach with minimal distractions. Since this framework can benefit education in terms of choosing relevant technologies for classroom lesson-delivery, educators are obliged to develop their TK.

The application of this model in this study allowed me to select apps to be tested basing myself on the subject matter to be taught which was guided by CAPS and pedagogical practices. Through learner experience of the mobile applications, I was able to experience first had how technology can be infused in learning activities. I can therefore add that the classroom experience helped develop my TPK.

Objective 5: Investigate the role of digital technologies in education

Digital technologies play a vital role in the teaching and learning processes, and in the development of the new curriculum. When digital technologies are used in a classroom, the focus must be on how to effectively integrate them into teaching and learning – which may lead to new curriculum planning and the transformation of teaching and learning processes. Digital technologies were viewed as transformative capabilities to learning in a classroom in that they promote collaboration between learners, supplement traditional teaching techniques, and provide assistance to learners from disadvantaged backgrounds with textbook support. However, digital technology, in addition to being expensive to buy and maintain, may also provide confusing and misleading information, hence we need to caution learners to verify or check the authenticity of all information.

Objective 6: Investigate how mobile applications have been integrated in the education

Mobile devices were discovered to have numerous advantages which therefore led to their adoption in a classroom. This was because they made it easy to access and share educational resources. This study highlighted how mobile technologies were adopted globally. Mobile devices run on mobile applications. This study reviewed how mobile applications have been integrated in the education sector in different parts of the world (see 3.4). Mobile phones foster the enhancement of learning through the integration of social media classroom spaces, by using shared calendar, gamified learning, creation of digital content, and incorporation of multimedia. Additionally, integration of mobile applications in the classroom decreases communication gaps among teachers, parents and learners (Thomas, O'Bannon & Bolton 2013).

This research has shown that over 90% of the learners downloaded apps in the classroom to access educational apps, calendar, and the calculator app. Additionally, studies showed that the use of mobile apps helped improve learners' assessment scores. Also, apps have been integrated into the education system to provide learners with timeous feedback and computer simulations. The use of SMSs made learners aware of everything taking place in class. Additionally, mobile apps have been used to help learners improve their critical-thinking skills by introducing android-based puzzles which helped to arouse learner-interest in the classroom. Moreover, by allowing learners to bring their own devices into the classroom for educational purposes, active participation was engendered. Mobile apps like Google Classroom promoted access to learning content that they did not understand. Hence, mobile apps have been integrated worldwide in the education sector because of their advantages.

In the South African context, mobile apps have been used to address book shortages through the siyavula.com apps. These apps allow for the downloading of Physical Sciences books free of charge, therefore promoting the access to learning materials. Mobile apps therefore position learners to be in charge of their learning. Mobile apps can therefore assist in the planning of curriculum through the calendar apps, accessing subject content, improving communication among stakeholders, while allowing for the differentiation of teaching techniques. However, mobile apps were found to be disruptive, may encourage cyberbullying via communication apps, and learners may find it easier to copy. This therefore meant that the use of mobile apps in a classroom must be controlled in order to limit deviant behaviours.

Document analysis was applied to successfully achieve the first 6 objectives. The findings indicated that the teaching principles conscientised us on the roles of the teacher regarding learning in the classroom. Additionally, teaching principles indicated that subject matter must be organised logically as to assist learners in gaining new knowledge. Furthermore, learners must be motivated to acquire knowledge and skills as this influences the quality of academic performance. Accordingly, reward and praise encourage good behaviour in a classroom therefore making it easier for adequate and meaningful teaching to take place. Also, learning principles indicated that a teacher must know the processes of how learners formulate new knowledge. For learners to gain new knowledge, the classroom environment must be supportive and challenging. In addition, the principles of teaching and learning highlight that interactive classroom participation must be encouraged to enhance communication as well as better academic results.

The CAPS informed the study on the type of skills learners must acquire in the Physical Sciences. The education of the learner was seen as an ongoing process, and that learners' prior knowledge must serve as a foundation for new knowledge to be acquired. The TPACK framework was used to help guide technology implementation.

6.3.2 Findings of the Empirical Study

The empirical study provided answers related to the last 4 questions asked in 1.4.2. The research was directed by research objectives.

6.3.2.1 General findings of the empirical study

The empirical study's findings indicated that apps can be used in a Physical Sciences classroom to effect better communication between the educator and learners. This was because communication through apps like WhatsApp are cheap to use, therefore making communication affordable. Additionally, the School Planner app was used to assist teachers and learners to plan thoroughly and logically. Also, the Physical Sciences mobile app assisted learners in gaining sufficient practice of the subject matter, hence leading them to master the Physical Sciences subject content. Moreover, Google Classroom allows for assessment to be conducted anywhere, and at any time, which makes it easier to track learner-performance and assessment statistics to detect subject content that learners found difficult.

6.3.2.2 Findings of the empirical study regarding the research objectives

As discussed in 6.3.2.1 above, the four recommended apps played a role in the Physical Sciences classroom. The empirical findings were based on the last 4 objectives as described below:

Objective 7

To investigate competences of learners to acquire apps for classroom usage, the following objective was used.

Determine the abilities of the learners to select and access mobile applications for classroom usage.

Findings indicated that participants knew how to find mobile applications by accessing Google Play Store. Notably, 100% of the learners managed to find at least 1 app in a specified time. This showed that learners knew how to navigate through app stores, hence less time will be required in training such learners for classroom app usage. Prior to participating in the study, all participants indicated that they used the internet, with 65.3% of the learners indicating that they use internet often or very often. Since all the participants knew how access the internet, this showed that they also knew how to acquire apps. Of note, 85% of the participants acquired apps through Google Play Store by following 3 steps:

- Opening Google Play Store
- Typing the title of the topic
- Choosing an app from the list of suggested apps

This proves that even if a learner does know any specific app which can be used to assist to acquire knowledge on any topic, the title of the topic can therefore be used as a reference. Further, over 86% of the learners indicated that they had downloaded apps from Google Play Store prior to participating in the study. Therefore, accessing apps through Google Play Store was the most popular method of acquiring information for classroom learning.

Learners also engaged the internet browser to search for apps. Participants opened the search engines and typed apps for a specific topic and grade: for instance, *apps for electrostatics Grade 11.* More than 12% of the learners claimed to have used this method. Additionally, Participants acquired apps through sharing software (Share.it and Google Files). In order for participants to share apps (apk) through sharing software, they had to use the same 'sharing' software, and connection had to be established before apps could be shared.

The confirmation was that learners knew how to find apps on their own. Research indicated that app stores house more than a billion apps which would make finding a specific apps a difficult task. However, knowing the name of the app or a relevant topic, may assist learners to find apps.

Learners must therefore find apps on their own to access knowledge on their subject. In this regard, it was to understand Physical Sciences content better without the teacher's supervision. Additionally, the use of sharing software implies that a teacher can download an app and then share it with the rest of the class which reduces costs related to downloading software.

Since learners demonstrated a variety of ways to acquire apps, the implication is that DBE must make concerted efforts to promote app usage; not on training learners and educators on how to acquire apps. Furthermore, teachers must use TPACK to also look for suitable apps which can be used to assist learners in content acquisition, after which they can recommend the apps to the learners. Importantly, these apps must foster skills in the Physical Sciences as indicated in CAPS, in addition to promoting safe environments for the acquisition of apps.

Objective 8

To investigate steps learners can follow to determine if an app is suitable for use in a Physical Sciences classroom, I was guided by the following objective:

Determine the procedures that can be used to measure app suitability and applicability for classroom usage

Findings indicated that learners were able to determine the suitability and applicability of the apps for learning in Physical Sciences classrooms. Participants (62.5 %) rated the content offered through the 4 recommended apps as being relevant to learning in a Physical Sciences classroom. The first step in determining if an app is applicable is by evaluating the content accessed through the app; and second, the functions of the apps should be assessed to inform the roles each could play.

Table 29: Functions of the app

Name of the app	Functions of the app
WhatsApp	Communication at low cost
Google Classroom app	Practice notes
Physical Sciences Mobile app	Practice for specific topic related problems Practice exam papers
School Planner app	Effective Planning

Over 98% of the participants viewed the School Planner app as being relevant as it facilitated effective planning. Literature studies indicate that ICT can also be used for planning purposes. Since learning requires adequate planning, this app is therefore relevant for the promotion of effective learning in a Physical Sciences classroom. Participants indicated that the Physical Sciences Mobile apps could be used to practise answering previous exams papers and topic-specific questions - it provides both questions and answers (memos) for learners to determine how a solution was arrived at. WhatsApp, which is a low-cost app, should be used for communication purposes. The implication is that in order to determine if an app is applicable, the purpose the app is to fulfil, must be specified. The School Planner app is effective because it is used to plan activities for the betterment of learning since it implements the planning role in curriculum delivery. Therefore, knowing why an app is needed, is critical in determining if it will be applicable for use in a Physical Sciences classroom.

Although all 4 apps were found to be invaluable in the learning of the Physical Sciences, only the Physical Sciences Mobile app and School Planner app were suitable for use in an offline environment as they did not require internet access, and thus were suitable for low socio-economic families. WhatsApp data bundles also make it ideal to provide inexpensive effective communication in the classroom. Notably, participants found the adverts on each app to be less distractive, therefore reinforcing its suitability. Moreover, at least 52% of the participants recommended all 4 apps as being suitable for their peers.

The SUS ratings revealed that participants found the recommended apps easy to use and simple to learn how to use. This meant that these apps are advantageous for use in a Physical Sciences classroom as learners know how to use them without training. These results reveal that there is free software that can be used in curriculum implementation to improve teaching and learning, as suggested in e-Education policies. This free software also has content that adds value to Physical Sciences learning in the classroom without being distractive with adverts. Lastly, tests designed by HCI experts can also determine if an app is usable and suitable for use.

Objective 9

In order to explore the experiences of learning in using apps, I adhered to achieving the following objective:

Investigate the experiences of learners regarding the use of mobile learning applications.

Participants experiences were categorised into three: app acquisition, app testing, and app usage in the classroom. While acquiring and installing software, participants encountered three hurdles: accessing email accounts, storage issues, and software incompatibility. Learners were unable to download software from Google Play Store as they could not login because they did not have a Google-based email account which implied that an email account was not seen as a priority for learners in high school, and that learners did not view Google Play Store as the only facility where apps could be acquired; hence, the availability of the ‘sharing’ software (6.3.2 above) as another method used in app acquisition. Teachers must therefore help learners in creating a Google-based email account for them to access safe environments to acquire apps for classroom usage.

Participants also experienced storage issues, as the error message encountered by the participants indicated that they had no storage space, and they needed to release stored information on their devices to continue with downloading. This meant that online storage facilities should be promoted so that learners will install apps and not be required to delete their stored memories (photos and videos) but can transfer them to an online storage facility to access them wherever they want to. Also, software incompatibility issues hampered the selection of apps for classroom usage. The technology knowledge (TK) through the TPACK framework assumes that the thorough knowledge of technology means knowing the system requirements so that all learners will be able to install the software with ease. Additionally, an educator must know the type of devices that learners use before an app can be recommended for use.

Findings revealed that participants (76%) knew how to use the Physical Sciences Mobile app. Most participants were hindered by navigation challenges within the software itself, therefore the Physical Sciences Mobile app was preferred for its ease-of-use as revealed by the SUS score of 70. The task scores indicated that most learners could use the practice problem features without the help of the teacher, therefore making it easier for learners to use the app at their leisure. this positions the learners to be in control of their learning when they solve 'practice' problems. However, if participants use this app incorrectly, it can give a false impression on the mastery of the content therefore confusing the teacher. To exacerbate matters, some participants copied the answers without attempting to answer the questions on their own.

With the School Planner app, findings revealed that participants found it moderately acceptable for use as revealed with a SUS score of over 60; but only 52% of the participants would recommend the app to their peers. Additionally, most of the participants (58%) found it difficult to complete task 4 successfully, therefore training is required to assist them in using the app. At least 64% of the participants were able to complete tasks 1 to 3 successfully which proves that participants generally know how to navigate through the app. However, the SUS scores revealed that more time should be dedicated to training learners on how this app could be used in order to implement its full functionality to facilitate planning in the classroom and beyond.. Furthermore, this implies that participants were able to set reminders for tasks to be done later. Furthermore, Participants were able to interact with the app to create their own timetables to manage their studies effectively.

Participants' experiences revealed that learners know how to use the Physical Sciences and the School planner apps. Even though I did not get to review WhatsApp extensively, findings extracted from WhatsApp studies revealed that this app promotes effective communication as it allows an educator to send messages to the learners simultaneously (through WhatsApp groups). Additionally, a variety of multimedia sources could be activated including videos, pictures, and web links. Hence, a teacher, for example, can use this app to communicate announcements about test dates to all learners at one stroke of the button. Also, a link from YouTube can be sent to the learners to gain practical skills. However, studies also revealed that cyber-bulling, collusion, and distractions are challenges that occur within this medium. This does not imply that this app promotes cheating, but instead it communicates that a learner has the potential to cheat, cyberbully, and become distracted; therefore its use must be controlled.

Similar studies, together with the pilot study's results revealed that Google Classroom can be used to send content to the learners in the form of notes. Additionally, for testing purposes, usage of this app allows the teacher to set a wide range of questions, in addition to pre-set memorandums so that the system can mark the learners' responses on its own. This app can therefore be used to increase contact time between the teacher and a learner as more time can be spent on teaching. Furthermore, tests can be carried out anywhere, therefore taking learning beyond the classroom.

Objective 10

To investigate the impact mobile applications have on learning in a Physical Sciences classroom, I pursued the following objective:

Determine how app usage in a classroom affects teaching and learning activities in a Physical Sciences classroom

Literature studies indicated a variety of ways in which mobile applications can impact learning. In this study, the 4 recommended apps were examined extensively to describe their roles; especially the impact they would have on learning in a Physical Sciences classroom.

Key findings revealed that the Physical Sciences Mobile apps used in this study can be fruitfully used for practice purposes as they provide learners with exam-type questions to revise for informal and formal assessments. This is supported by Elliott (2018:308) who claims that "teachers can also use technology tools to administer both formal and informal assessments". Furthermore, learners are presented with a step-by-step explanation of the solution process on every problem. Since each question is topic-based, this app can help enhance the learner's mastery of the content from the 6 knowledge areas stated in CAPS. Moreover, the set of questions addresses the 4 cognitive levels.

The Physical Sciences Mobile app is useful especially for schools that lack resources as it reduces the need (and costs) to print material for learners. Additionally, it reduces the workload of the teacher while providing learners with an opportunity to constantly practise at their own pace. It affords learners revision time to adequately prepare for exams as all cognitive levels are addressed in each topic. The use of this app can also improve the motivation of learners who are diffident about answering questions as they will begin to feel more confident when they compare their solutions with the ones provided by the app. Learners recognise their mistakes immediately therefore, they self-remedy their incorrect responses.

This app therefore informs the curriculum by allowing learners to gain skills through practice. Additionally, it leads to innovative teaching practices that incorporates the use of technology in a physical sciences classroom.

Findings reveal that WhatsApp informs the curriculum by providing effective communication in a classroom. This app offers an educator to communicate with the learners with ease as a message can be send to all learners at the same time. Furthermore, this app can be used to transform pedagogical practices. A teacher can send a YouTube link to learners to prepare for a practical activity. Schools that lack resources can still help learners set up practical apparatus using YouTube content which be send through WhatsApp. Furthermore, this app can be used to help learners on what to prepare for the next class or assessment dates. The list of communication media which can be transmitted through this app includes documents, pictures, videos and audio. Use of this app in a physical sciences classroom therefore has the potential to impact both teaching and learning activities. This app can therefore be used to increase communication between peers and educator with learners. This is because this app is easy to use, and it is supported by majority of smartphones used by learners. Furthermore, learners are already using this app and therefore no training will be required on how to use this app. WhatsApp can also be distractive and offers learners easier way to copy. Learners can communicate in a test without the knowledge of an educator therefore making it difficult for teachers to discover the learners who cheat in a test. Additionally, this app can disrupt learning as constant messages coming into the learners' phones mean attention is being taken away from the learning material therefore disadvantages the learners. However, the benefits of this app revealed that this app can impact teaching and learning activities positively and can also lead to the transformation of teaching and learning activities in a physical sciences classroom.

With regards to the school planner app. Findings revealed that this app aid curriculum implementation by providing effective planning for learning in and outside the classroom. This app allows a learner to set a timetable and reminders. It uses a calendar therefore reminders can be grouped by specific dates. Additionally, it allows the participants to personalise reminders. This is an offline based app therefore it can be used anywhere and anytime. Teachers and learners can use this app to plan curriculum goals which are to be achieved at a later date together. Furthermore, it puts a learner in control of their studies. A learner can set a study timetable which can guide a learner's study programme. Consequently, a teacher and a learner can be prepared for teaching and learning in and out of the classroom.

Combining the use of these 3 apps (mentioned above) means that proper planning is insured regarding teaching and learning activities. Additionally, effective communication takes place between an educator and a learner. Further, learners have access to practice content at all times. Education is transformed without the use of expensive software and hardware, therefore making education cheaper and accessible. This makes it easier to realise the objectives of e-Education since learners are ensured of acquiring 21st century skills.

Google Classroom allows for assessment to proceed anywhere as a learner does not have to be in a classroom to take a test. Additionally, a learner away from school can still receive class slides (notes) through Google Classroom and WhatsApp. However, WhatsApp requires internet connection therefore it is not ideal for use especially for schools that have limited resources but offers teachers the opportunity to assess learners' understanding of the topic wherever they are which promotes communication between learners and educators. Moreover, a teacher can send remedial content to address learners' problem areas.

The 4 recommended apps in this study can therefore provide innovative ways to transform teaching and learning activities. They can also influence the development and implementation of pedagogy in the Physical Sciences classroom. A learner and a teacher plan together in terms of preparing learning activities. Furthermore, learners and educators know exactly what is expected when all classroom activities are planned and communicated to all stakeholders. Learners know what type of assessments are to be conducted, and when; therefore, assisting learners to prepare ahead of due dates. This therefore enriches the educator's TK and TPK.

6.4 STUDY'S LIMITATIONS

The data collection process could only progress until 30 September 2020, which limited the time for garnering data. The challenge prevented me from comparing how the same group of learners would progress in the following years while utilising apps to complete learning activities. This would have therefore informed the study on the long-term impact of using mobile applications in the Physical Sciences classroom. Additionally, this study did not assess apps with similar functionality in order to determine which app could be best suited for use in the classroom. This is because the number of apps housed in an app store is over a billion, therefore making it difficult to compare apps with similar features. Additionally, the purpose of the study was to discover what impact apps would have on learning, therefore focusing on app-suitability defeats the purpose of comparing apps. This study also focused on schools in close proximity to each other in order to expedite the gathering of data. This, therefore, did not afford me the opportunity to assess how app usage can impact schools from different quintile levels. 72 participants sampled is not enough to give a true reflection of physical science learners therefore results cannot be generalised to the Free State Province as a whole.

6.5 RECOMMENDATIONS AND IMPLICATIONS

The findings indicated that mobile applications have a positive impact on teaching and learning. These findings led to suggesting recommendations that can be used to guide the creation, revision and implementation of policies regarding learning in a Physical Sciences classroom.

6.5.1 Recommendation on Policies

The e-Education policies aimed at equipping education stakeholders in using ICT to transform teaching and learning. However, a lack of resources in schools hindered the full implementation e-Education policies. Additionally, and e-Education policy is seen as being ‘invisible’ in schools (Vandeyar, 2013:1) therefore educators have not accessed it yet. I recommend that workshops become mandatory for all teachers to be trained in the use of e-Education and how it can impact learning in the classroom. This is because teacher training helps improve teacher performance in the subject (Ali and Hamza 2018:239). Workshops therefore can help teachers improve their skills in app acquisition and effectively implementation of apps in schools. Furthermore, policies on app usage in a classroom must be workshopped as the resources (apps) are already available to implement new policies. Learning facilitators visit schools regularly and such school visits can also be used to monitor the implementation of mobile application policies, and how educators are adapting to teaching by integrating technology into curriculum delivery. Furthermore, teachers are already using *Microsoft Teams* to attend discussions on memoranda, so the same tools can also be used to guide teachers on the implementation of the curriculum through policies generated for app usage. This information can also be downloaded into the Physical and Technical Sciences website for teachers and learners in the Free State where they can access it at any time (https://hwscience.blogspot.com/).

This study encourages the application of e-Education policies to assist teachers in the implementation of the curriculum by using technology. However, policies on mobile apps in education must be studied to grasp how technology can be used to guide curriculum implementation. Therefore, policies that guide app usage lead to not only the creation of new technologies that meets the learners' needs in a Physical Sciences classroom, but also equips learners with 21st century skills, thus accelerating the transformation of the education process.

Lastly, policies must encourage the use of cell phones in schools and should stipulate when to use them in order to minimise distractions in classrooms.

6.5.2 Recommendations and Implications on Learning

Mobile applications provide resources to learners for content acquisition, and transmission of knowledge and skills for usage. This can therefore lead to innovative ways in which curriculum can be implemented. Mobile applications allow for adequate planning to occur in the classroom such that all stakeholders are always informed timeously of school events, among others. As such, communication between educators, learners, and parents is smoothly facilitated. A learner has access to learning materials wherever he/she goes; therefore, learning occurs everywhere (Steel 2012). Additionally, this utilises devices that learners already have, thus reducing the burden on schools to purchase expensive equipment to make integrate technology into lessons.

I recommend that the DBE promotes the use of mobile applications to support and enhance learning. Teachers must then be encouraged to find useful apps that can be incorporated in the teaching and learning activities of the Physical Sciences. These apps should be assessed and then recommended for dissecting each topic in a subject of choice.

6.6 FUTURE STUDIES

For future studies we should incorporate the use of the eye-tracking software which will pinpoint exactly what the participants observe while using apps. Additionally, more apps should be explored to assess how they can impact learning in the classroom. Future studies should also consider ways in which curriculum can be accessible to a learner, anytime and at any place, by downloading all the resources into the learner's cell phone. Lastly, I recommend the development of an app that can incorporate all the necessary tools that a learner in Physical Sciences can access offline.

6.7 CONCLUSION

The South African Department of Education (DoE) realised the role technology can play in the economic growth of the nation. Policies have been created in order to help schools benefit from using technology to implement curriculum. The e-Education policy was created with a vision of transforming teaching and learning through ICTs. However, this policy appears to be inaccessible, therefore it becomes difficult to implement. In addition, schools lack the necessary hardware to integrate ICT into teaching and learning processes.

South African schools regarded cell phone usage in the classroom as not being ideal for learning as they disrupt the learning processes. This, therefore, makes it difficult to initiate discourse on the use of cell phones to facilitate learning. The teaching and learning principles, however, indicate that education must be organised so that learners become motivated by being in a stimulating classroom atmosphere which promotes learning. Furthermore, the CAPS document informs teaching and learning activities on the content to be taught, and how it can be assessed. The TPACK framework can be consulted to promote technologies which can be used in the teaching and learning in the Physical Sciences classroom.

Findings revealed that mobile applications can be used to facilitate adequate planning in the classroom, help learners prepare for exams, and improve communication between teachers and learners. Additionally, use of apps does not require the school to spend money on buying and maintaining expensive hardware such as laptops. Using mobile applications can therefore transform the way Physical Sciences is taught while bringing resources closer to the learners by encouraging learning to take place everywhere and at a convenient time. Lastly, the DBE must therefore invest in training teachers in identifying and assessing relevant free technology for use in the Physical Sciences classroom. This technology must be user-friendly, inexpensive, and be a substitute for textbooks to enhance teaching and learning.

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Appendix A: Title registration

Prof Jan Nieuwenhuis
Director: Directorate of Postgraduate Studies
Faculty: Education
PO Box 339, Bloemfontein 9300, Republic of South Africa
+27514017550
27827889637
NieuwenhuisFJ@ufs.ac.za

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA

Inspiring excellence. Transforming lives.

12 December 2019

Mr. MJ Tsie (2011106131)
tsiemj@hotmail.com

Dear Mr. Tsie

APPLICATION FOR TITLE REGISTRATION

Discipline: Education Science and Technology
Study Code: M Ed (EDST8900)
Title Exploring the use of mobile learning applications in the Physical Science classroom

Congratulations! Your title registration application was accepted without any corrections to be made. You may use this latter to apply for ethical clearance. The following general comments were made for your consideration.

Research Title	Accepted
Introduction/Background Context of the study	The student has presented relevant information to contextualise the study. If you use terms such as 'millennials' you need to define it.
Research problem, questions/hypotheses/aims and objectives	Please ensure that the main research question and the aims are better aligned
Literature Review/Conceptual or Theoretical Framework	The alignment between the use of constructivism and the use of quantitative data analysis needs to be reassessed as these terms are from different research paradigms.
Research Methodology	Well presented
References	Fine

Yours sincerely,

Prof Jan Nieuwenhuis
Chair: CTR committee

Ms CS Duvenhage
Secretary: CTR committee

Appendix B: Ethical clearance from UFS

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS UV

GENERAL/HUMAN RESEARCH ETHICS COMMITTEE (GHREC)

14-Aug-2020

Dear Mr Motlatsi Tsie

Application Approved

Research Project Title:
Exploring the use of mobile learning applications in the Physical Sciences classroom

Ethical Clearance number:
UFS-HSD2020/0403/1508

We are pleased to inform you that your application for ethical clearance has been approved. Your ethical clearance is valid for twelve (12) months from the date of issue. We request that any changes that may take place during the course of your study/research project be submitted to the ethics office to ensure ethical transparency. furthermore, you are requested to submit the final report of your study/research project to the ethics office. Should you require more time to complete this research, please apply for an extension. Thank you for submitting your proposal for ethical clearance; we wish you the best of luck and success with your research.

Yours sincerely

Dr Adri Du Plessis
Chairperson: General/Human Research Ethics Committee

Adri du Plessis 2020.08.14 13:08:48 +02'00'

205 Nelson Mandela Drive
Park West
Bloemfontein 9301
South Africa

P.O. Box 339
Bloemfontein 9300
Tel: +27 (0)51 401 9337
duplessisA@ufs.ac.za
www.ufs.ac.za

Appendix C: Ethical Clearance from the Department of Education in the Free State

Enquiries: MZ Thango
Ref: Research Permission: MJ Tsie
Tel. 051 404 9257/ 9207 / 082 537 2654
Email: MZ.Thango@fseducation.gov.za

education
Department of Education
FREE STATE PROVINCE

Panorama Hostel
Carroll Street
Dewetsdorp
9940

Dear Mr. Tsie

APPROVAL TO CONDUCT RESEARCH IN THE FREE STATE DEPARTMENT OF EDUCATION

This letter serves as an acknowledgement of receipt of your request to conduct research in the Free State Department of Education.

1. **Topic:** Exploring the use of mobile learning applications in the Physical Sciences classroom.
2. **List of schools involved:** Louw Wepener and Metsimapholi Secondary Schools.
3. **Target Population:** 30 learners in grade 10 and 20 learners in grade 11 doing Physical Sciences at the selected Secondary schools.
4. **Period of research**: From date of signature of this letter until 30 September 2020. Please note that the department does not allow any research to be conducted during the fourth term (quarter) of the academic year. Should you fall behind your schedule by three months to complete your research project in the approved period, you will need to apply for an extension. The researcher is expected to request permission from the school principals to conduct research at schools.
5. The approval is subject to the following conditions:

   4.1 The collection of data should not interfere with the normal tuition time or teaching process.

   4.2 A bound copy of the research document or a CD, should be submitted to the Free State Department of Education, Room 319, 3rd Floor, Old CNA Building, Charlotte Maxeke Street, Bloemfontein.

   4.3 You will be expected, on completion of your research study to make a presentation to the relevant stakeholders in the Department.

   4.4 The ethics documents must be adhered to in the discourse of your study in our department.
6. Please note that costs relating to all the conditions mentioned above are your own responsibility.

Yours sincerely

DR JEM SEKOLANYANE
CHIEF FINANCIAL OFFICER

DATE: 28/07/2020

RESEARCH APPLICATION BY MJ TSIE, PERMISSION LETTER 23 JULY 2020. MOTHEO DISTRICT

Strategic Planning, Research & Policy Directorate Private Bag X20565, Bloemfontein, 9300 - Old CNA Building, Room 318, 3rd Floor, Charlotte Maxeke Street, Bloemfontein

Tel: (051) 404 9283 / 9257 **Fax:** (086) 6678 678

www.fsdoe.fs.gov.za

Appendix D: Parental Consent form

RESEARCH STUDY INFORMATION LEAFLET AND PARENTAL CONSENT FORM

DATE

01 May 2020

TITLE OF THE RESEARCH PROJECT

Exploring the use of mobile learning applications in the Physical Sciences classroom.

RESEARCHER'S NAME AND CONTACT NUMBER:

Motlatsi Tsie tsiemj@hotmail.comtsiemj@hotmail.com Contact number

FACULTY AND DEPARTMENT:

Faculty: Education

Department of School of Mathematics, Natural Sciences and Technology

STUDY LEADER'S NAME AND CONTACT NUMBER:

Cobus van Breda

051401364005140136 40

WHAT IS THIS RESEARCH PROJECT ALL ABOUT?

Test subscription free applications housed in Google Play Store in order to test feasibility of those apps. The idea is to provide learners with apps that can assist with content acquisition as well as application of skills. These way learners have a chance to learn wherever they are since content is easily accessible and they have acquired relevant skills which will assist in learning Physical Sciences. Physical Sciences is a very demanding subject. It is important for learners to have sufficient practice and with the use of mobile applications accessible through a cell phone this can maybe be achieved. The following applications will be used in the study: Kahoot! Google Classroom, School Planner, WhatsApp, ClassDojo, Grade 11 and 10 physical sciences applications, Slack and Seesaw

WHY HAVE YOUR CHILD BEEN INVITED TO TAKE PART IN THIS RESEARCH PROJECT?

Your child is invited mainly because they are taking physical sciences as a subject. The research is based on learners taking physical sciences as a subject. The researcher would like to see how different applications can influence the way learners obtain and use information from mobile applications and use information from mobile applications. Your child is invited mainly because they are taking physical sciences as a subject. The research is based on learners taking *physical sciences as a subject. The researcher would like to see how different applications can influence the way learners obtain*

WHO IS DOING THE RESEARCH?

I am a physical science educator at Christiaan de Wet High School. I have been teaching Physical Sciences for 3 years. I also have degrees in the computer sciences. Learners take cell phones with them everywhere they go. This makes cell phones an ideal device for learning to take place because it's portable and there many applications that can be used to for learning to take place because it's portable and there many applications that can be used to, I am a physical science educator at Christiaan de wet High School. I have been teaching physical sciences for 3 years. I also have degrees in computer sciences. Learners take cell phones with them everywhere they go. This makes cell phones an ideal device

HAS THE STUDY RECEIVED ETHICAL APPROVAL?

This study has received approval from the Research Ethics Committee of UFS. A copy of the approval letter can be obtained from the researcher.

Approval number: ***UFS-HSD2020/0403/1508UFS-HSD2020/0403/1508***

WHAT WILL HAPPEN TO YOUR CHILD IN THIS STUDY?

Firstly, your child will be required to use cell phone at school. He will also be required to install certain applications which will be tested. Please note Wi-Fi access will be provided in order for learners to install there applications. The learner will then be required to interact with these applications then provide feedback by means of a questionnaire. The researcher will be making notes as the learners interact with the applications. then be required to interact with these applications then provide feedback by means of a questionnaire. The researcher will be making notes as the learners interact with the applications. Firstly, your child will be required to use cell phone at school. He will also be required to install certain applications which will be tested. Please note Wi-Fi access will be provided in order for learners to install applications. The learner will

CAN ANYTHING BAD HAPPEN TO YOUR CHILD?

No child will be victimized by the researcher or any of the participants during the research. If a child feels uncomfortable during the study they can report to the researcher and members of the school management team and assistance will be provided. However if a learner feels victimized, he can also report to you as the parent.er if a learner feels victimized, he can also report to you as the parent. No child will be victimized by the researcher or any of the participants during the research. If a child feels uncomfortable during the study, they can report to the researcher and members of the school management team and assistance will be provided.

CAN ANYTHING GOOD HAPPEN TO YOUR CHILD?

There is a lot of good that can come from your child being part of this study.

- *Discovering new applications that can be used for learning.*
- *Having access to content at any time or place thus making it easier for him to learn*
- *Learning how to test the quality of any software and the validity of the content supplied.*
- *Learning how to communicate effectively with fellow learners and educators.*
- *Making it easier for parents to monitor learners' progress in the subject.*

WILL ANYONE KNOW YOUR CHILD IS PART OF THE STUDY?

All learners will not be required to write their names on the questionnaires. This will make it easier to hide the identity of all learners involved in the study. However, only the supervisor and the researcher will get to review the content. After the completion of the study all data will be carefully destroyed in order to not risk the identity of all the learners that took part in the study. All information obtained from the videos will also be deleted without divulging the identity of the learners involved. pletion of the study all data will be carefully destroyed in order to not risk the identity of all the learners that took part in the study. All information obtained from the videos will also be deleted without divulging the identity of the learners involved. All learners will not be required to write their names on the questionnaires. This will make it easier to hide the identity of all learners involved in the study. However, only the supervisor and the researcher will get to review the content. After the com

WHO CAN YOU TALK TO ABOUT THE STUDY?

Please don't hesitate to call the administration office at Christiaan De Wet if more information about the study is required. You as the parent can also contact me directly on cell phone or WhatsApp. Face to face interactions is also welcome. Please don't hesitate to call the administration office at Christiaan De Wet if more information about the study is required. You as the parent can also contact me directly on cell phone or WhatsApp. Face to face interactions is also welcome.

WHAT IF YOU DO NOT WANT YOUR CHILD TO DO THIS?

The study is not compulsory for all learners taking physical sciences as a subject. If a child feels that they cannot take part in the study, they will simply be excused without any discrimination. On the last page of this document please tick no to indicate that no permission was granted for the child to be involved in the study. te that no permission was granted for the child to be involved in the study. The study is not compulsory for all learners taking physical sciences as a subject. If a child feels that they cannot take part in the study, they will simply be excused without any discrimination. On the last page of this document please tick no to indica

Thank you for taking part to read this information. If everything meets your satisfaction and you agree to give consent for your child to take part in this study, please fill in the form below.

PLEASE RETURN

Name of child:

____

Name of Parent: ____

- Do you understand the details research study, and are you willing to let your child take part in it? Yes ☐ No ☐
- Has the researcher answered all your questions? Yes ☐ No ☐
- Do you understand that you can withdraw from the study at any time? Yes ☐ No ☐
- I give the researcher permission to make use of the data gathered from my child's participation Yes ☐ No ☐

_________________________________ _________________________

Signature of Parent ***Date***

Appendix E: Participant Consent Form

RESEARCH STUDY INFORMATION LEAFLET AND CONSENT FORM

DATE

06 July 2020

TITLE OF THE RESEARCH PROJECT

Exploring the use of mobile learning applications in the Physical Sciences classroom

PRINCIPAL INVESTIGATOR AND CONTACT NUMBER(S):

Motlatsi Tsie *0710668281*

Faculty: Education

Name of Department: School of Mathematics, Natural Sciences and Technology

STUDY LEADER'S NAME AND CONTACT NUMBER:

Cobus Van Breda

0514013640

WHAT IS THE AIM OF THE STUDY?

The aim of this study is to determine how free learning mobile applications can influence Physical Sciences learning in southern Free State schools.

WHO IS DOING THE RESEARCH?

I am physical Sciences educator. I have been teaching the subject for 3 years at Christiaan de Wet Combined School. I have also taught Computer Applications and technologies for 3 years. I hold qualifications in both Information technologies and Education. I am conducting this research to investigate if mobile applications can be useful in a Physical Sciences classroom.

HAS THE STUDY RECEIVED ETHICAL APPROVAL?

This study has received approval from the Research Ethics Committee of UFS. A copy of the approval letter can be obtained from the researcher.

Approval number: ***UFS-HSD2020/0403/1508UFS-HSD2020/0403/1508***

WHY ARE YOU INVITED TO TAKE PART IN THIS RESEARCH PROJECT?

You are chosen because you are taking Physical Sciences as a subject in Grade 10 or 11. You are currently attending school Metsimapholi Secondary School or Louw Wepener Combined School. Your contact information was accessed through the school's office. I was given permission to talk to you by the school principal through your educator. A minimum of 50 participants is required.

WHAT IS THE NATURE OF YOUR PARTICIPATION IN THIS STUDY?

The study involves videotaping and answering questionnaires. At least 90 minutes will be required on a weekly basis to test the applications and completing the set tasks. You will test applications and then fill in a questionnaire afterwards, twice a week. This will be carried out *until the study is completed. The testing of applications will be conducted in a group as well as in one on-one sessions. You may utilise 90 minutes of study time per week. If you feel at any point during the study that you no longer want to continue, please feel free to inform the researcher and your parents. Your assistance is welcome, and your safety is guaranteed. If the conduct of the researcher concerns you, please feel free to report his actions to the principal or your parents.*

CAN THE PARTICIPANT WITHDRAW FROM THE STUDY?

Being in this study is voluntary and you are under no obligation to consent to participation. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a written consent form. You are free to withdraw at any time and without giving a reason. However, all submitted documents will not be withdrawn if you decide not to continue. You will not be penalised in anyway if you decide to withdraw from the study. The researcher will behave in a dignified manner at all times towards you even if you are no longer a part of the study.

WHAT ARE THE POTENTIAL BENEFITS OF TAKING PART IN THIS STUDY?

The benefits of you taking part in this study are as follows: You will be exposed to new applications, that can be beneficial in class. In addition, cell phones are portable therefore learning can take place wherever you are – it's like having a textbook in one's pocket. You will help with knowledge-creation. Your inputs can be used to recommend similar apps to other learners studying the same subject. Furthermore, this may also influence learners to find applications that can be useful in other subjects, thus making it easier to learn all subjects using a single device.

WHAT IS THE ANTICIPATED INCONVENIENCE OF TAKING PART IN THIS STUDY?

You might take a longer time compared to other learners when doing a certain task. This could be unsettling. You may possibly experience emotional bullying. In order to ensure the safety of all learners involved in the study, all forms of bullying will be reported immediately to the school management team, and the offenders' participation from the study will be terminated after censuring.

WILL WHAT I SAY BE KEPT CONFIDENTIAL?

During the data gathering process, your responses will be given a code/pseudonym and they will be referred to in this way in the data, any publications, or other research reports in conference proceedings. The researcher and the supervisor are the only persons that will have access to your data. All digital data will be encrypted, and only the two individuals mentioned above will have access to the key code and password. However, your answers may be reviewed by people responsible for ensuring that the research is done properly, including the transcriber, external coder, and members of the Research Ethics Committee. Otherwise, records that identify you will be available only to people working on the study, *unless you give permission for other people to see the records. A learner's anonymous data can also be used in a research report, journal or conference presentation. These publications will not mention you by name nor will they mention where you come from. A report of the study may be submitted for publication, but individual participants will not be identifiable in such a report. While every effort will be made by the researcher to ensure that you will not be connected to the information that they share during the study, I cannot guarantee that other participants in the class will treat information confidentially. I shall, however, encourage all participants to do so. For this reason, I advise you not to disclose personal and sensitive information to friends during the proceedings.*

HOW WILL THE INFORMATION BE STORED AND ULTIMATELY DESTROYED?

Hard copies of learners' answers will be stored by the researcher for a period of five years in a locked filing cabinet at the school office for future research or academic purposes; electronic information will be stored a password protected computer. Future use of the stored data will be subject to further Research Ethics Review and approval, if applicable. All electronic data will be deleted from all stored devices including the backup. Hard copies will be shredded. All injuries or harmful acts occurring during the study will be reported immediately to the school management team. Future use of the stored data will be subject to further Research Ethics Review and approval, if applicable. All electronic data will be deleted from all stored devices including the backup. Hard copies will be shredded, then set on fire. All injuries or harmful acts occurring during the study will be reported immediately to the school management team.

WILL I RECEIVE INCENTIVES FOR PARTICPATING IN THIS STUDY?

Your participation is voluntarily, so no form of payment will be offered. However, participants will have access to WIFI in order to download the recommended applications.

HOW WILL THE PARTICIPANT BE INFORMED OF THE FINDINGS/RESULTS OF THE STUDY?

If you would like to be informed of the final research findings, please contact Motlatsi Tsie on 0710668281 or email him at tsiemj@hotmail.com. The findings are accessible for 6 months after the completion of the study. Please do not use home telephone numbers. Departmental and/or mobile phone numbers are acceptable. Should you have concerns about the way in which the research has been conducted, you may contact Dr Cobus van Breda on 051 401 3640 or email him at vbredaj@ufs.ac.za. All findings will be submitted in a report form outlining what processes took place and how the findings arose.

Thank you for taking time to read this information sheet and for intending to participate in this study. If you agree to take part in this study, please fill in and sign this consent form below.

CONSENT/ASSENT TO PARTICIPATE IN THIS STUDY

I, _____________________________________ (participant's name), confirm that the person asking my consent to take part in this research has told me about the nature, procedure, potential benefits and anticipated inconvenience of participation.

I have read (or had it explained to me) and understood the study as explained in the information sheet. I had sufficient opportunity to ask questions and am prepared to participate in the study. I understand that my participation is voluntary, and that I am free to withdraw at any time without penalty. I am aware that the findings of this study will be anonymously processed into a research report, journal publications and/or conference proceedings.

I agree to the recording of the videotapes and questionnaires.

I have received a signed copy of the informed consent agreement.

Full Name of Participant:

____

Signature of Participant: ____________________________________ Date:

____

Parent's/Guardian's Signature for Assent: ……………………………………..

Full Name(s) of Researcher(s):

____

Signature of Researcher: ____

Date: _____________________

Appendix F: Study Covid-19 protocol.

Covid-19 guidelines for the study

The following procedures will be adopted during the sessions:

- There should be a minimum distance of 1.5m between the participants.
- There should be a minimum distance of 1.5m between the participant and researcher always.
- The researcher and the participant must always wear masks.
- The participant will be sanitised upon arrival.
- No sharing of devices will be allowed.
- All devices used will be sanitised before and directly after use.
- Participants must bring and use their own masks.

In addition to the points mentioned above, each school COVID-19 management protocol will also be adhered to.

The educator will be responsible for sanitising the classroom used before and after the session.

Appendix G: Screening tool

Learner Form	
Date	**…../……/ 2020**
Day	

Screening Tool (COVID-19)

Are you experiencing any of the following symptoms		
• Dry Cough	Yes	No
• Sore Throat	Yes	No
• Shortness of breath/ breathing difficulties	Yes	No
• Fever > **38°C** or **subjective fever**	Yes	No
• Body Aches	Yes	No
• Headache	Yes	No
• Sudden Onset of flu-like symptoms in the last 2 days (Sore throat, sneezing, runny nose, blocked nose)	Yes	No
• Diarrhoea	Yes	No
Were you in close contact with a confirmed or probable case of COVID-19?	Yes	No
Have you travelled long distances (more than 2 hours) using public transport?	Yes	No
Have you attended a funeral in the last 3 months?	Yes	No

Participant Screening Tool

Name and Surname	Cough	Fever	Temp > 38	Diarrhoe a	Body Aches	Headache s	Temp in	Temp Out	Signature

Appendix H: Request for permission to conduct research.

To *the principal of Louw Wepener School*

I am conducting research and would like to request permission to use Louw Wepener Combined School as a research site.

DATE

18 April 2020

TITLE OF THE RESEARCH PROJECT

Exploring the use of mobile learning applications in the Physical Sciences classroom

PRINCIPAL INVESTIGATOR'S NAME, AND CONTACT NUMBER:

Motlatsi Tsie *2011106131* Click here to enter text.

FACULTY AND DEPARTMENT:

Faculty: Education

Department: School of Mathematics, Natural Sciences and Technology.

STUDY LEADER'S NAME AND CONTACT NUMBER:

Cobus Van Breda

0514013640

WHAT IS THE AIM OF THE STUDY?

The aim of this study is to determine how free learning mobile applications can influence Physical Sciences learning in the southern Free State schools.

WHO IS DOING THE RESEARCH?

I am physical Sciences educator. I have been teaching the subject for 3 years at Christiaan De Wet Combined School. I have also taught Computer Applications and Technology for 3 years. Furthermore, I hold qualifications in both Information Technologies and Education. I am conducting this research because I would like to investigate if mobile applications can be useful in a Physical Science classroom. I would like to know if these applications can be used to help the learners perform better in a Physical Sciences classroom.

HAS THE STUDY RECEIVED ETHICAL APPROVAL?

This study has received approval from the Research Ethics Committee of UFS. A copy of the approval letter can be obtained from the researcher.

Approval number: ***UFS-HSD2020/0403/1508UFS-HSD2020/0403/1508***

WHY IS YOUR INSTITUTION INVITED TO PARTICIPATE IN THIS RESEARCH?

I chose this school for this study because it is based in the southern Free State. This will make it easier for the researcher to easily conduct research as he currently resides in Dewetsdorp. Furthermore, the school is also offering Physical Sciences as a subject. It only concerns learners in Grades 10 and 11. A maximum of 50 participants is required.

WHAT IS THE NATURE OF PARTICIPATION IN THIS STUDY?

The participants are expected to download and interact with mobile applications on a cell phone, then reflect on their experience with this application. Each participant is supposed to bring his/her own mobile devices. The researcher has purchased 10 extra cell phones in order to assist those without phones. The study involves videotaping and answering questionnaires. The learners will be given a pretest questionnaire, as well as a post-test questionnaire. The pretest questionnaire will be used to inform learner-demographics. The post-test questionnaire will investigate the feasibility of the applications in the subject. This process is expected to take between 2 to 5 months.

Click here to enter text.

Click here to enter text.

Your participation and cooperation are appreciated.

Yours sincerely

Motlatsi Tsie Motlatsi Tsie

Appendix I: School Approval letter from Louw Wepener Combined School

LOUW WEPENER COMBINED SCHOOL

PO Box 55
Wepener
9944

Tel: 051-228 0986

e-mail: louwwepenercombined@gmail.com

Dear MR TSIE

Approval to conduct research in our school Louw Wepener Combined School.

This letter serves as an acknowledgement of your request to conduct research in our school. (Mobile learning applications).

The subject concerned is Physical Sciences in Grade 10-12.

We hope and trust that everything will be done according the law and order.

Yours in Education

....

Principal (M.A Matheatau) PP

LOUW WEPENER COMBINED SCHOOL
051 228 0986
03 -08- 2020
P.O. BOX 55
WEPENER, 9944

Appendix K: Cell phone contract

Cell phone contract for duration of the study

This contract stipulates that a learner has borrowed a cell phone for the duration of the study. It is the responsibility of the learner to keep it in good condition from the moment he/she receives it until the study is completed. The phone comes with an email account already created, as well as a sim card. Both the sim card and the email account must not be changed. It is the responsibility of the learner to return the phone once the study is completed.

Learner Consent

I …………………………………………………………… have received the phone on ………… I understand that it is my responsibility to keep it safe throughout the study. I understand that any damage to the property will be paid by my parent/guardian.

Signature

…………………………………….

Date

……………………………………

Name of the phone	Phone Model	Phone condition	Charger Present?	Email Account Added?	Sim card inserted?

Parental Consent

I ………………………………………………., the guardian/parent of the person named above, agrees to the lending of the cell phone by the researcher. I understand that if it does not come back in good condition, then am liable to pay the costs.

Signature ………………………………… Date ……………………

Researcher details

Name: Motlatsi

Surname: Tsie

Cell number: 0710668281

Email address: tsiemj@hotmail.com

Occupation: Teacher

Konteraka ea mohala oa thekeng nako eohle ea thuto

Konteraka ena e tiisa hore moithuti o kalimiloe selefounu nakong eohle ea thuto. Ke boikarabello ba moithuti ho e boloka e le maemong a matle ho tloha ha ba fumana mohala ho fihlela thuto e phetheloa. Fono e tla le ak'haonte ea lengolo-tsoibila e seng e ntse e entsoe le sim. Bobeli ba likarete tsa sim le liakhaonte tsa imeile ha lia lokela ho fetoloa. Ke boikarabello ba moithuti ho khutlisa mohala hang ha thuto e phethetsoe.

Boitlamo ba Moithuti

Ke ……………………………………………………………… ke fumane mohala ho …………. Ke utloisisa hore ke boikarabello ba ka ho e boloka e bolokehile nakong eohle ea thuto. Kea utloisisa hore tšenyo efe kapa efe ea thepa e tla buseletsoa ke bahlokomeli ba ka.

Tekeno ………………………………………. Letsatsi …………………………………

Lebitso la mohala	Modlolo oa phone ke ofe?	Mohala o maemong a matle?	Chachara e teng?	Ak'haonte ea Imeile e Eketsehile?	Sim card e kentsoe?

Boitlamo ba Batsoali

Ke ………………………………………………………… joalo ka ha ke le mohlokomeli / motsoali oa motho ea boletsoeng kaholimo a lumela ho alima selefounu ke mofuputsi. Kea utloisisa hore haeba e sa khutle e le maemong a matle, ke ikarabella ho lefa litšenyehelo.

Tekeno ya motsoali ………………….. Letsatsi la ho saena ……………………………….

Lintlha tsa mofuputsi

Lebitso: Motlatsi

Fane: Tsie

Nomoro ea sele: 0710668281

Aterese ea lengolo-tsoibila: tsiemj@hotmail.com
Mosebetsi: Mosuwe

Selfoonkontrak vir duur van die studie

Hierdie kontrak bepaal dat 'n leerder vir die duur van die studie 'n selfoon geleen word. Dit is die leerder se verantwoordelikheid om dit in 'n goeie toestand te hou vanaf die oomblik dat hulle die foon ontvang totdat studie voltooi is. Die telefoon kom met 'n e-pos rekening reeds geskep sowel as 'n sim. Beide die simkaarte en die e-pos rekeninge moet nie verander word nie. Dit is die leerder se verantwoordelikheid om die foon terug te gee sodra die studie voltooi is.

Leerder Toestemming

Ek.. het die telefoon ontvang op .... Ek verstaan dat dit my verantwoordelikheid is om dit regdeur die studie veilig te hou. Ek verstaan dat enige skade aan die eiendom deur my voogde terugbetaal sal word.

Handtekening

....

Datum

....

Naam van die telefoon	Telefoonmodel	Telefoon toestand	Charger Teenwoordig?	E-pos rekening bygevoeg?	Sim kaart ingevoeg?

Ouerlike Toestemming

Ek... aangesien die voog/ouer van die persoon wat hierbo genoem word, instem tot die leen van die selfoon deur die navorser. Ek verstaan dat as dit nie terugkom in 'n goeie toestand dan is aanspreeklik om die koste te betaal.

Handtekening Datum

....

Navorser besonderhede

Naam: Motlatsi

Van: Tsie

Selnommer: 0710668281

E-posadres: tsiemj@hotmail.com

Beroep : Onderwyser

Appendix L: Pre-session questionnaire

Participant Code: _______

Kindly answer the following questions. Please note that there are no right or wrong answers.

Mark an X and fill in where required.

1. Are you a high school student?

☐Yes ☐ No

2. Select the appropriate gender

☐ Female ☐ Male ☐ Other

3. Choose your relevant age group

☐11 – 13 ☐14 – 16 ☐17 - 18

4. Do you take Physical Sciences as a subject?

☐Yes ☐ No

5. In what grade are you?

____

6. Do you own a cell phone?

☐Yes ☐ No

7. How often do you download apps from Google Play Store?

☐ Never ☐ Rarely ☐ Often ☐ Very Often

8. Select a relevant category of apps you download from Google Play Store?

Games ☐ Education Apps ☐ Social Networks ☐ Other ☐ _________________________

9. How often do you use the internet?

☐ Never ☐ Rarely ☐ Often ☐ Very Often

10. Indicate any application you use for learning which is installed on your phone, or leave blank if none.

i. ____________________ ii. ____________________ iii. ____________________

Thank you.

Please hand this to the administrator, and he will show you what to do next

Appendix M: SUS (System Usability Scale) Questionnaire – User Satisfaction software

Participant Code: ______

Rate the app by circling the option based on the tasks that you have performed. Please answer as honestly as possible.

		Strongly Disagree				**Strongly Agree**
1	I think that I would like to use this app frequently	1	2	3	4	5
2	I found the app unnecessarily complex	1	2	3	4	5
3	I thought the app was easy to use	1	2	3	4	5
4	I think that I would need the support of a technical person to be able to use this app	1	2	3	4	5
5	I found the various functions in this app laid out clearly and easy to understand	1	2	3	4	5
6	I thought that there was much inconsistency in using this app	1	2	3	4	5
7	I would imagine that most people would learn to use this app very quickly	1	2	3	4	5
8	I found the app very complicated to use	1	2	3	4	5
9	I felt very confident using the app	1	2	3	4	5
10	I needed to learn a lot of things before I could get used to this app	1	2	3	4	5

Thank you.

Please hand over the document to the Administrator, and he will instruct you on what to do next.

Appendix N: App Discovery Questionnaire

Participant Code: ………

Think of a topic you are struggling with in Physical Sciences. Find 3 apps that you think can help you with the chosen topic.

Write the name of the topic.

…………………………………………………….

List the name of the apps you found. Each app must be accompanied by a screenshot of it (Send the screenshots through WhatsApp to **064 154 8207**).

App 1…………………………………

App 2…………………………………

App 3…………………………………

List the steps you took to get the apps on your phone.

App 1

………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………

App 2

………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………

App 3

………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………

Appendix O: App Review Questionnaire

Participant code ………

Based on your experience, rate the app by circling the option that best describes your feelings towards the tested app.

Name of the App ……………………………………………………..

1. The content covered in the app is relevant to my chosen topic

Strongly Disagree	1	2	3	4	5	**Strongly Agree**

2. How did this app assist you? You can select more than 1 response.

- ☐ Communicate effectively at low cost with my classmates.
- ☐ Provided notes.
- ☐ Provided practice problems with answers.
- ☐ Provided videos lessons to better understand the content.
- ☐ Provided previous exams papers and memos.
- ☐ Assisted me to plan effectively.
- ☐ Presented practice problems only.
- ☐ Other ________________________________

3. After downloading, does the app require data to access it?

☐Yes ☐ No

4. Did the app contain ads?

☐Yes ☐ No

5. If you answered **yes** above, did the ads make it difficult for you to use this app?

☐Yes ☐ No ☐ Not applicable.

5. Would you recommend this app to anyone?

Strongly Disagree	1	2	3	4	5	**Strongly Agree**

6. Do you have additional comments that you would like to make about the app?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

Thank you for your input.

Please hand this questionnaire to the administrator and fill in the SUS questionnaire.

Appendix P: Task sheets

Appendix P1: Physical Sciences Mobile app task sheet

Participant ID…….

Date…./……/……

Physical Sciences Mobile app task sheet

Instructions:

- Perform the following tasks using the **physical Sciences Mobile app.**
- Connect to the WIFI **Tsie** using password: **Tsie2@20.**
- In the task completion box, write *yes* if the task was completed successfully, and *no* if it was not completed successfully.
- Make sure the app is already installed on your phone; however, if it's not installed ask the researcher for assistance.
- Write the correct answers in the spaces provided.

Task	Time allocation (minutes)	Task completion
1. How many practice problems are there in electric circuits? …………………	1 min	
2. Take a screenshot of the electricity long question from the November 2016 examination paper and **SHOW** it to the researcher.	3 minutes	
3. State the question listed as 4.1 from the 2019 exam paper 1 June exam in the space provided. ………………………………………………………… ………………………………………………………… …………………………………………………………	5 minutes	
4. Write down the correct ANSWER to question 1.4 - 2019 September Test, in the spaces below. ………………	5 minutes	

Thank you.

Please hand this sheet back to the researcher.

Appendix P2: School Planner app task sheet

Participant ID…….

Date…./……/……

School Planner app task sheet

Instructions:

- Perform the following tasks using the **school planner app.**
- Connect to the WIFI **Tsie** with password: **Tsie2@20**
- In the task completion box, write *yes* if the task was completed successfully, and *no* if it was not completed successfully.
- Make sure the app is already installed on your phone; however, if it's not installed ask the researcher for assistance.

Task	Time allocation (minutes)	Task completion
1. Set a reminder to study for the Physical Sciences informal test (pick any date that's suitable to you)	1 min	
2. Add 5 'fictitious' teachers in the app	3 minutes	
3. Add 5 school subjects. 3.6 Each subject must have only one teacher (use the teachers created in task 2) **NB: Task 4 depends on task 3. If you are unable to complete task 3, ask the researcher for assistance, then continue with task 4.**	5 minutes	
4. Create a day school timetable on the app using the subjects created in task 3.	5 minutes	

Thank you.

Please hand this back to the researcher.

Appendix Q: 2020 Free State Modified Revised ATP: Grade 11 Term 2 and 3: Physical Sciences

TERM 2 (25 days) ~~(29 days)~~	Week 1 ~~Week 3~~ (5 days)	Week 2 ~~(Week 4)~~ (5 days)	Week 3 ~~Week 5~~ (5 days)	Week 4 (5 days) ~~Week 6 (4 days)~~	Week 5 (5 days) [From term 3]
CAPS Topics	**CHEMICAL CHANGE:** • Quantitative aspects of chemical change (4 hrs)	**CHEMICAL CHANGE:** • Quantitative aspects of chemical change (4 hrs)	**CHEMICAL CHANGE:** • Quantitative aspects of chemical change (4 hrs)	**CHEMICAL CHANGE:** • Quantitative aspects of chemical change (2 hrs)	**ELECTRICITY & MAGNETISM:** • Electrostatics (4 hrs)

TERM 3 (31 days) ~~(37 days)~~	Week 1 (3 days) ~~Week 2 (5 days)~~	Week 2 (5 days)	Week 3 ~~Week 4~~ (5 days)	Week 4 ~~Week 5~~ (5 days)	Week 5 ~~Week 6~~ (5 days)	Week 6 ~~Week 7~~ (5 days)
CAPS Topics	**ELECTRICITY & MAGNETISM:** • Electrostatics (4 hrs)	**ELECTRICITY & MAGNETISM:** • Electromagnetism (4 hrs)	**ELECTRICITY & MAG- NETISM:** • Electromagnetism (3 hrs) • Electric circuits (1 hr)	**ELECTRICITY & MAGNETISM:** • Electric circuits (4 hrs)	**ELECTRICITY & MAGNETISM:** • Electric circuits (4 hrs)	**ELECTRICITY & MAGNETISM:** • Electric circuits (1 hr) **CONSOLIDATION & REVISION** • (3 hrs)

Appendix R: 2020 Free State Modified Revised ATP: Grade 10 Term 3: Physical Sciences

TERM 2 (15 days) ~~(19 days)~~	Week 1 (5 days)	Week 2 (5 days)	Week 3 (5 days)
CAPS Topics	**MARCH CONTROL TEST** • Discussion (2 hrs) **ELECTRICITY AND MAGNETISM:** • Electrostatics (2 hrs)	**ELECTRICITY AND MAGNETISM:** • Electrostatics (2 hrs) • Electric circuits (2 hrs)	**ELECTRICITY AND MAGNETISM:** • Electric circuits (4 hrs)
Topics / Concepts, Skills, and Values	• Discussion and corrections of March Control Test • Two kinds of charge • Forces exerted by charges on each other (descriptive). • Attraction by charged and uncharged objects (polarisation)	• Charge conservation • Charge quantisation • Emf, potential difference (pd) • Current	• Measurement of voltage (pd) and current • Resistance • Resistors in series

TERM 3 (31 days) ~~(37 days)~~	Week 1 (3 days) [From term 2]	Week 2 (5 days) [From term 2]	Week 3 ~~Week 2~~ (5 days)	Week 4 ~~Week 3~~ (5 days)	Week 5 ~~Week 5~~ (5 days)	Week 6 ~~Week 6~~ (5 days)
CAPS Topics	**ELECTRICITY AND MAGNETISM:** • Electric circuits (3 hrs)	**CHEMICAL CHANGE:** • Physical and chemical change (4 hrs)	**CHEMICAL CHANGE:** • Representing chemical change (4 hrs)	**CHEMICAL CHANGE:** • Quantitative as- pects of chemi- cal change (4 hrs)	~~**CHEMICAL CHANGE:**~~ ~~• Quantitative aspects~~ ~~• of chemical~~ ~~• change (2 hrs)~~ **MECHANICS:** • Vectors and scalars (2 hrs)	**MECHANICS:** • Vectors and scalars (2 hrs) **MECHANICS:** • Motion in one dimen- sion (2 hrs)

Appendix S: 2020 school calendar

January 2020

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

February 2020

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29

March 2020

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

April 2020

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

May2020

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

June 2020

S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

July 2020

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

August 2020

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

September 2020

S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

October 2020

S	M	T	W	T	F	S
				1	2	3
64	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

November 2020

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

December 2020

S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

KEY

	Weekends
	Days for administration
	School days
	Public holidays
	Revised School holidays

Public and School Holidays 2020	
01 January	New Year's Day
21 March	Human Rights Day
10 April	Good Friday
13 April	Family Day
27 April	Freedom Day
01 May	Workers' Day
16 June	Youth Day
09 August	National Women's Day
10 August	Public Holiday
24 September	Heritage Day
16 December	Day of Reconciliation
25 December	Christmas Day
26 December	Day of Goodwill

TERM	Duration	No. of weeks	No. of days	No. of public holidays	Actual no. of school days
1	(13) 15 Jan – 18 March	10	(48) 46	00	(48) 46
2	(01 June) 08 June – 24 July	(08) 07	(40) 35	01	(39) 34
3	24 August – 23 October	09	45	01	44
4	02 November – 15 December	07	32	00	32
	Total	(34) 33	(165) 158	02	(163) 156

Appendix T: Participant reflection

Participant code…….

Name of an app …………………………………

1. What do you like about the app? (Colour, font, interface, etc.)

……………………………………………………………………………………………
……………………………………………………………………………………………

2. What do you like least about the app?

……………………………………………………………………………………………
……………………………………………………………………………………………

3. Which feature of the app did you use the most?

……………………………………………………………………………………………

4. Are there any features of the app that you needed, but were missing?

……………………………………………………………………………………………
……………………………………………………………………………………………

5. Were you able to get easily to the desired tabs (pages)? Explain.

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

6. Did this app help you understand Physical Sciences content better? Explain.

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

7. Did this app increase your interest for the subject? Explain.

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

8. Any additional comments regarding your use of this app?

……………………………………………………………………………………………
……………………………………………………………………………………………

Thank you (please hand this back to the researcher)

Appendix U: Observation sheet

Participant code ………

Researcher ID…………

Date …… /…./20…… Time ….: …….

Name of the app ………………………………………

Situation	Actions observed	Reflections on actions observed

Appendix V: SUS score physical sciences

Participant code	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	SUS SCORE
MSS01	5	1	5	2	5	2	4	1	5	2	90
MSS02	5	1	4	1	5	1	5	1	3	1	92.5
MSS03	4	2	3	1	4	3	3	1	4	3	70
MSS04	5	2	4	1	4	1	4	3	4	1	82.5
MSS05	2	2	3	2	4	3	2	4	3	3	50
MSS06	5	1	5	1	5	1	5	1	5	1	100
MSS07	4	3	4	2	2	2	5	1	4	1	75
MSS08	4	3	3	1	5	3	4	1	5	1	80
MSS09	5	1	5	1	5	1	5	5	3	5	75
MSS10	1	3	4	4	5	3	4	3	5	4	55
MSS11	5	3	3	2	2	3	5	1	3	5	60
MSS12	5	1	5	1	5	1	5	1	5	1	100
MSS13	5	1	5	1	5	1	5	1	5	1	100
MSS14	2	3	4	3	4	4	2	1	4	2	57.5
MSS15	4	4	2	5	5	3	2	5	5	1	50
MSS16	5	2	2	5	1	3	3	1	5	5	50
MSS17	3	2	2	3	3	4	3	1	5	2	60
MSS18	2	2	5	2	3	2	2	5	3	1	57.5
MSS19	3	4	4	4	4	4	2	4	5	4	45
MSS20	3	4	5	2	2	4	4	2	5	1	65
MSS21	5	4	5	2	3	2	1	4	3	1	60
MSS22	4	3	1	1	5	3	5	1	4	2	72.5
MSS23	3	2	4	3	2	5	2	2	5	3	52.5
MSS24	3	2	4	4	1	4	5	3	5	5	50
MSS25	4	4	5	2	1	4	5	2	5	1	67.5
MSS26	4	1	4	1	5	2	3	3	5	1	82.5
MSS27	5	1	4	2	5	5	1	5	3	1	60
MSS28	5	1	3	1	5	1	5	5	5	1	85
MSS29	5	3	4	2	4	1	4	4	4	1	75
MSS30	3	4	4	5	1	4	4	1	3	1	50
MSS33	5	4	5	1	5	1	2	5	3	5	60
MSS41	2	2	2	2	2	4	4	1	4	1	60
MSS42	5	1	5	1	5	3	5	2	5	2	90
MSS43	5	4	5	5	5	3	5	1	5	3	72.5
MSS44	5	3	5	3	5	1	4	1	4	3	80
MSS45	4	2	5	1	5	2	5	1	5	1	92.5
MSS46	5	3	2	2	2	1	1	4	4	2	55

MSS47	4	3	5	1	5	2	1	3	5	1	75
MSS48	5	3	5	5	3	3	5	1	5	4	67.5
MSS49	4	3	1	5	3	2	4	5	4	1	50
MSS50	3	3	4	4	4	5	5	4	3	4	47.5
MSS51	3	4	4	1	4	1	4	1	4	1	77.5
MSS52	1	5	1	1	1	4	1	5	3	1	27.5
MSS53	5	1	5	1	5	1	5	1	5	1	100
MSS54	5	1	5	2	3	1	4	2	5	3	82.5
MSS55	3	5	3	4	1	4	5	1	5	1	55
MSS56	5	1	5	1	5	2	5	1	5	1	97.5
MSS57	5	1	3	5	1	4	5	1	5	3	62.5
MSS59	5	2	4	1	4	2	4	4	5	2	77.5
MSS61	4	4	3	1	5	3	5	5	5	1	70
MSS68	5	1	5	1	5	1	1	1	4	1	87.5
MSS69	4	1	4	4	1	3	1	2	5	2	57.5
MSS70	4	2	4	3	4	2	5	3	3	4	65
MSS71	5	1	5	1	5	1	5	1	5	1	100
MSS72	4	1	4	1	5	1	4	2	5	3	85
MSS73	3	1	5	1	4	1	4	1	4	1	87.5
MSS74	5	2	4	4	4	5	3	1	3	1	65
MSS76	3	2	3	1	3	1	1	3	3	1	62.5
MSS77	5	3	5	1	5	3	5	5	5	1	80
MSS78	5	5	2	4	2	1	5	1	5	2	65
MSS80	3	2	3	2	4	2	4	2	4	2	70
MSS83	4	1	3	4	2	2	3	1	5	2	67.5
MSS84	2	5	1	3	1	5	4	2	5	3	37.5
MSS85	5	5	4	2	4	4	1	2	4	1	60
MSS86	5	2	4	4	4	2	2	3	5	3	65
MSS87	4	1	2	1	1	5	3	3	3	5	45
MSS88	5	2	3	1	5	1	5	1	5	2	90
MSS89	5	3	5	5	5	3	3	2	5	3	67.5
MSS91	5	5	5	1	4	1	3	2	4	3	72.5
MSS92	5	1	5	1	5	2	5	1	5	1	97.5
MSS93	5	1	4	2	4	2	5	1	5	2	87.5
MSS95	5	1	4	1	5	1	4	2	5	4	85
										Average SUS score	**70.42**