Evaluating mobile applications that support Mathematics learning in the Further Education and Training Phase

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by

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DECLARATION

I hereby declare that this dissertation: **Evaluating mobile applications that support Mathematics learning in the Further Education and Training Phase**, submitted for evaluation towards the requirements for the degree **Magister Educationis**, at the University of Pretoria, is my own original work and has not previously been submitted to any other institution of higher learning or subject for evaluation. All sources used or quoted in this document are indicated and acknowledged by means of a comprehensive list of references.

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I, Therese M Bron, herewith confirm that I edited Mr HJJ Kruger's dissertation titled: Evaluating Mobile Applications that support Mathematics learning in the Further Education and Training Phase.

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28/08/2015

"The author, whose name appears on the title page of this dissertation, has obtained, for the research described in this work, the applicable research ethics approval. The author declares that he has observed the ethical standards required in terms of the University of Pretoria's Code of ethics for researchers and the Policy guidelines for responsible research"

Faculty of Education

RESEARCH ETHICS COMMITTEE

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DEGREE AND PROJECT	MEd Evaluating mobile applications that support Mathematics learning in the Further Education and Training Phase
INVESTIGATOR(S)	Hendrik Johannes Jakor Krüger
DEPARTMENT	Science, Mathematics and Technology Education
DATE CONSIDERED	12 August 2015
DECISION OF THE COMMITTEE	APPROVED

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ABSTRACT

This study explores how educators could use the Information Systems Success (ISS) model to successfully evaluate, select and use mobile educational applications. It aims to illustrate how each dimension of the ISS model could be evaluated to meaningfully contribute to mathematics learning. The increase in mobile device usage has created various opportunities for the development of learning material which can be accessed through these devices. Mobile learning is learning on the move. Mobile learning creates opportunities for learners not to be bound to a fixed location. Learners are able to work at their own pace and they are given access opportunities. *The core problem statement of this study is that mathematics educators experience challenges to evaluate, select and use applications that will support meaningful learning in their subject field and the study comments on existing applications with the aim to improve their design.* Qualitative data was collected from three mathematics subject specialists, six teachers who specialise in various subject fields, one technology and technical expert and six further education and training (FET) mathematics classes. The information gathered from the participants enabled the researcher to determine how educators evaluate and select mathematical applications and how each dimension of the ISS model could meaningfully contribute to education environments.

The analysis of the data has indicated that teachers do not use a specific methodology to evaluate and select mathematics applications. If they encounter applications they regard as useable they will evaluate the content of the application according to their curricula outcomes. The research contends that each dimension of the ISS model could be evaluated and contributes to the evaluation and selection of mobile education applications (MEAs). This provides credibility to the use of the ISS model as an evaluation tool. The conceptual framework of this study which is based on the ISS model can be regarded as a framework teachers could use to evaluate and select MEAs.

Keywords: Dimensions, evaluate, evaluation tool, framework, ISS model, mathematics, Mobile Educational Applications (MEAs), mobile learning, select, use.

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ICT4RED: This work acknowledges the TECH4RED project and more specifically the ICT4RED component, for the bursary provided for my studies, and also for the opportunity to link my research to the project. The Cofimvaba Technology for Rural Education Development (TECH4RED) project was a joint initiative between the Department of Science and Technology (DST), the Department of Basic Education (DBE) and the Eastern Cape Department of Education (ECDOE) and was aimed at contributing to the improvement of rural education through technology-led innovation. The Department of Rural Development and Land Reform (DRDLR) also joined as a key partner in the initiative in 2013. ICT4RED focused on the ICT aspects of the initiative and investigated how the application and deployment of new and existing technologies (which include e-textbooks, tablets and other supporting technologies) at schools in the Cofimvaba district of the Eastern Cape Province could assist to develop a framework, which can be replicated and scaled to other provinces and across the rural education system.

TABLE OF CONTENTS

CHAPTER 2

LITERATURE STUDY AND THEORETICAL FRAMEWORK

CHAPTER 3

RESEARCH METHODOLOGY

CHAPTER 4
RESULTS

CHAPTER 5
DISCUSSIONS AND CONCLUSIONS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

ISS	Information System Success
MEA	Mobile Educational Application
FET	Further Education and Training
ECAR	The Educause Centre for Applied Research
COP	Communities of Practise
ANA	Annual National Assessment
ICT	Information and Communication Technologies
TAM	Technology Acceptance Model
ICT4RED	Information and Communication Technologies for Rural Education Development
CSIR	Council for Scientific and Industrial Research
DRDLR	Department of Rural Development and Land Reform
TECH4RED	Technology for Rural Educational Development
TRA	Theory of reasoned actions
IS	Information System
IQ	Information Quality
SGB	School Governing Body
DBE	Department of Basic Education

LIST OF APPENDICES

CHAPTER 1

AN OVERVIEW OF THE STUDY

1.1. BACKGROUND

This study aims to investigate how educators could use the Information System Success (ISS) model created by Zaied (2012) to evaluate the usefulness of mobile educational applications (MEAs). This study specifically focused on how teachers evaluate, select and use MEAs for mathematics which could possibly contribute to meaningful learning in the subject.

Brown, Collins, and Duguid (1989) argued that education systems developed a divide between knowledge attained in formal education and the application of knowledge outside the classroom. Knowledge can be viewed as abstract, formal concepts which are theoretically independent of the context in which they are learned. Brown et al. (1989) explained that educators separate educational contexts from the subject knowledge they teach. The contexts in which learning takes place could be pedagogically useful but from a fundamental point of view, should not have a big impact on the subject knowledge that is learned. Brown et al. (1989) suggested that conceptual knowledge should rather be seen as a tool. Tools have two main characteristics: The user will only gain full understanding through using the tool and using the tool will change the user’s view of the world as the user is exposed to a new culture wherein the tool is used which will encourage the user to embrace the belief system of that culture (Brown et al., 1989). These characteristics are the most important difference between the acquisition of inert concepts and the development of useful knowledge (Whitehead, 1967). Interaction between tools and the world they are used in creates a platform for comprehensive understanding of both. The ways tools are used are determined by the world-view of communities and reflect the accumulated understanding, knowledge, experience and skills of people living and working in these communities (Brown et al., 1989 & Geertz, 1983)

The latest developments of mobile phones and devices have been introduced at a rapid speed in the last few years. The evidence of mobile penetration is unquestionable. People from all walks of life and ages are using devices such as cell phones, tablets and laptops to communicate and stay connected with each other (Jacob & Issac, 2014). The popularity of mobile devices changed the design concept of learning activities (Hwang, Wu, Zhuang, & Huang, 2013). Mobile devices create opportunities for the development of instructional materials that learners could access through them without being bound to a fixed location. Jacob and Issac (2014) emphasized that with proper facilitation, mobile learning could be of great benefit to both learners and educators. Teachers could access services to communicate and interact with learners while they are on the move (Jacob & Issac, 2014). The mobile phone has transformed to a platform where users can learn wherever they go by means of formal training or informal support and conversation (Kukulska-Hulme, Sharples, Milrad, Arnedillo-Sánchez & Vavoula, 2009).

In some parts of the world the ratio between phones and users exceeds 100%. This creates countless opportunities for the development of mobile applications (Vogel, Kennedy, & Chi-Wai Kwok, 2009). Vogel et al. (2009) rightfully claimed that there are pedagogical and technological issues regarding mobile learning but that the digital divide between learners and educators is increasing (Conole, de Laat, Dillon, & Darby, 2006). The use of mobile applications in learning may seem natural for digital “natives” but for digital “immigrants” this is viewed as a huge burden (Vogel et al., 2009).

In 2012 the Educause Center for Applied Research [ECAR] survey on Mobile IT in higher education found that “67% of the surveyed students believed that mobile devices are important to their academic success and use their devices for academic activities” (ECAR, 2012). It should increasingly be noted that learners will have access to a mobile device which could support their traditional learning activities. Subsequently, learning applications should be developed which will compliment these learning activities (Vogel et al., 2009). There are however some considerations to take into account before developing mobile applications. Vogel et al. (2009) identified the following:

- The involvement of students and instructors in the design of applications.
- Identifying content, the use of technology and how interaction will take place.
- The role of the educational institution.

Learners across the world are performing poorly in mathematics (Siyepu, 2013). Van der Walt, Maree and Ellis (2008) also found that the mathematical subject matter knowledge of South-African learners is poor. Siyepu (2013) suggested that a range of interventions should be taken which include that a learner should be able to work on their own with existing and prior knowledge, and be introduced to new knowledge with guidance. Inquiry-based learning for example, is a more student-centered way of learning and teaching, and could contribute to the goals of meaningful learning in mathematics. These goals include developing learners' critical thinking skills, encouraging learners to study, preparing learners for further learning and assisting learners to develop the skills they require to work as a scientist and inquire. These goals are closely interlinked with inquiry-based learning (Maaß & Artigue, 2013). It provides a learner with the opportunity to not only learn mathematics through mathematical and scientific ways of inquiry but equip them with strategies for further learning (Maaß & Artigue, 2013).

1.2. PROBLEM STATEMENT AND RESEARCH QUESTIONS

In Section 1.2.1 the reason for the research is explained which leads to the development of research problems identified in Section 1.2.2. The research questions are stated in Section 1.2.3 followed by the research objectives (Section 1.2.4) and the importance of this study (Section 1.2.5).

1.2.1. REASON FOR RESEARCH

The reason for the research developed from two main interest areas, namely mobile applications, mathematics and how mobile applications could complement meaningful learning. The study conducted by Vogel, Kennedy, & Chi-Wai Kwok (2009) tried to determine whether the use of mobile device applications could lead to learning or not. Their result showed that mobile applications could assist a learner in achieving better results, although their results were preliminary and not demonstrative of enhanced learning by the students. Jacob and Issac (2014) view mobile learning (m-learning) as a subset of e-learning and explain that they share commonalities in their benefits to the learners. They identified the following five benefits to learners. (1) Easy access – learners can access information wherever they are and be informed of updated information. (2) Self-study – learners can study at their own time and pace. (3) Evaluation and feedback – m-learning tools can incorporate assessment activities which provide immediate feedback to the user. (4) Access to online repository – mobile devices enables learners to access information stored online and to communicate with peers and teachers. (5) Communities of practice (COP) – a COP consists of a domain, a community and a practice. Learning takes place when learners and teachers meet online to discuss matter on a particular subject.

Taleb, Ahmadi, and Musavi (2015) emphasised that mobile devices are cheaper than personal computers and provide more people with access to information and learning opportunities. Educational applications can motivate learners. M-learning enables learners to personalise their experience and to engage with information according to the learners' needs. M-learning is interactive which is complemented by interactive interfaces and can take place in an environment which is stress free (Taleb et al., 2015).

Mathematics learners are challenged to contextualise abstract concepts on a daily basis. This converts the abstract concept into a concrete concept and enables them to understand the steps involved in the process. The main role of technology is to facilitate the thought processes of learners and to contextualise abstract concepts (Persico & Pozzi, 2011). M-learning has already increased learners' motivation to learn and the trust they have in themselves (Taleb et al., 2015). Taleb et al. (2015) research has shown that the use of mobile devices increases learners' motivation. This means that there is a direct relationship between learners' attitude towards mathematics and mobile devices. Their findings are supported by similar findings of Shin, Sutherland, Norris, and Soloway (2012) and Ciampa (2014). In a study done by Ciampa (2014) she concluded that some mobile applications create the opportunity for learners to challenge themselves against their previous best performances. This encourages indirect competition and contributes to learning. Shin et al. (2012) showed that game technology positively impacted learners' learning in arithmetic.

The rationale of this study leads to certain problem areas identified in both mathematics and mobile learning which will be discussed in the next section.

1.2.2. PROBLEM STATEMENT

Van der Walt, Maree, & Ellis (2008) found that subject matter knowledge and technical vocabulary of South-African learners are poor. Their results are supported by the Annual National Assessment (ANA) done in 2013. The results concluded that Grade 9 learners lack a wide variety of necessary skills to be successful in mathematics (DBE, 2014). Reasons for this might include the poor socio-economic background of the learners, lack of learner support material and poor quality of teachers and teaching. In a study done by Stodolsky & Grossman (1995) they found that teachers think that it is their responsibility to teach mathematics knowledge only. Therefore teachers are not taking responsibility to support learners in thinking critically and using their knowledge in real life situations. *The problem with this approach is that it is teacher centered and learners do not get the opportunity to express their discomfort with the information.* Learning motivation can be increased if a teacher has the ability to implement resources consistent with learners' interests and that can personally satisfy their career goals (Vogel, Kennedy, Kuan, Kwok, & Lai, 2007). Resources like mobile device applications have the ability to create an environment where inquiry-based learning can take place and will shift the focus from a teacher centered approach to a learner centered approach.

The development of mobile devices and applications is progressing on a daily basis. It is now possible to use the characteristics of mobile devices to develop learning platforms for educational purposes in the form of learning applications (Vogel, Kennedy, & Chi-Wai Kwok, 2009). Many learning applications are developed at rapid speed and often not by education specialists. Roschelle, DiGiano, Koutlis, Repenning, Phillips, Jackiw & Suthers (1999) explain that the development of software applications is mainly the responsibility of computer programmers. The developers of educational software lack educational experience to develop exceptional educational software and there is insufficient evidence to prove that educators will become efficient developers of educational software (Roschelle et al., 1999). *Developers are challenged to design applications that address the needs of teaching and learning. Teachers' challenge is to investigate the ease of use and usefulness of these applications in the teaching environment.* This resulted in the need for education, society and technology to develop a very close relationship (Traxler, 2007). Roschelle et al. (1999) envision a platform where educators and developers can collaborate effectively. The goal is to create educational applications which meet the standards from a technical, educational, curricular and conceptual point of view.

The core problem statement for this study is that mathematics educators experience challenges to evaluate, select and use applications that will support meaningful learning in their subject field and comments on existing applications with the aim to improve their design.

1.2.3. RESEARCH QUESTION

Primary Research Question

- How can the application of the Information Systems Success model as proposed by Zaied (2012) be used to evaluate mobile educational applications that support meaningful learning in mathematics?

Secondary Research Questions

SQ 1: How do teachers evaluate and select mathematical applications?

SQ 2: How could each dimension of the ISS model contribute meaningfully in educational environments?

1.2.4. RESEARCH OBJECTIVE

The objectives of the study are based on the primary and secondary research questions presented in Section 1.2.3 and can be articulated as follows:

- To investigate current literature on the use of mobile technologies in education;
- To investigate how MEAs could support meaningful learning in mathematics;
- To evaluate teachers evaluation, selection and use of MEAs; and
- To propose a framework which teachers could use to evaluate and select MEAs which could contribute to meaningful learning.

1.2.5. IMPORTANCE OF THE STUDY

The study will contribute to an improved understanding of the following:

- How teachers evaluate and select mathematical applications;
- The factors influencing teachers' motivation to use MEAs;
- If mathematical applications could contribute to meaningful learning;
- If the ISS model could be used to evaluate and select mathematical applications;
- An evaluation framework which teachers could use to evaluate and select mathematical applications.

1.3. LITERATURE REVIEW

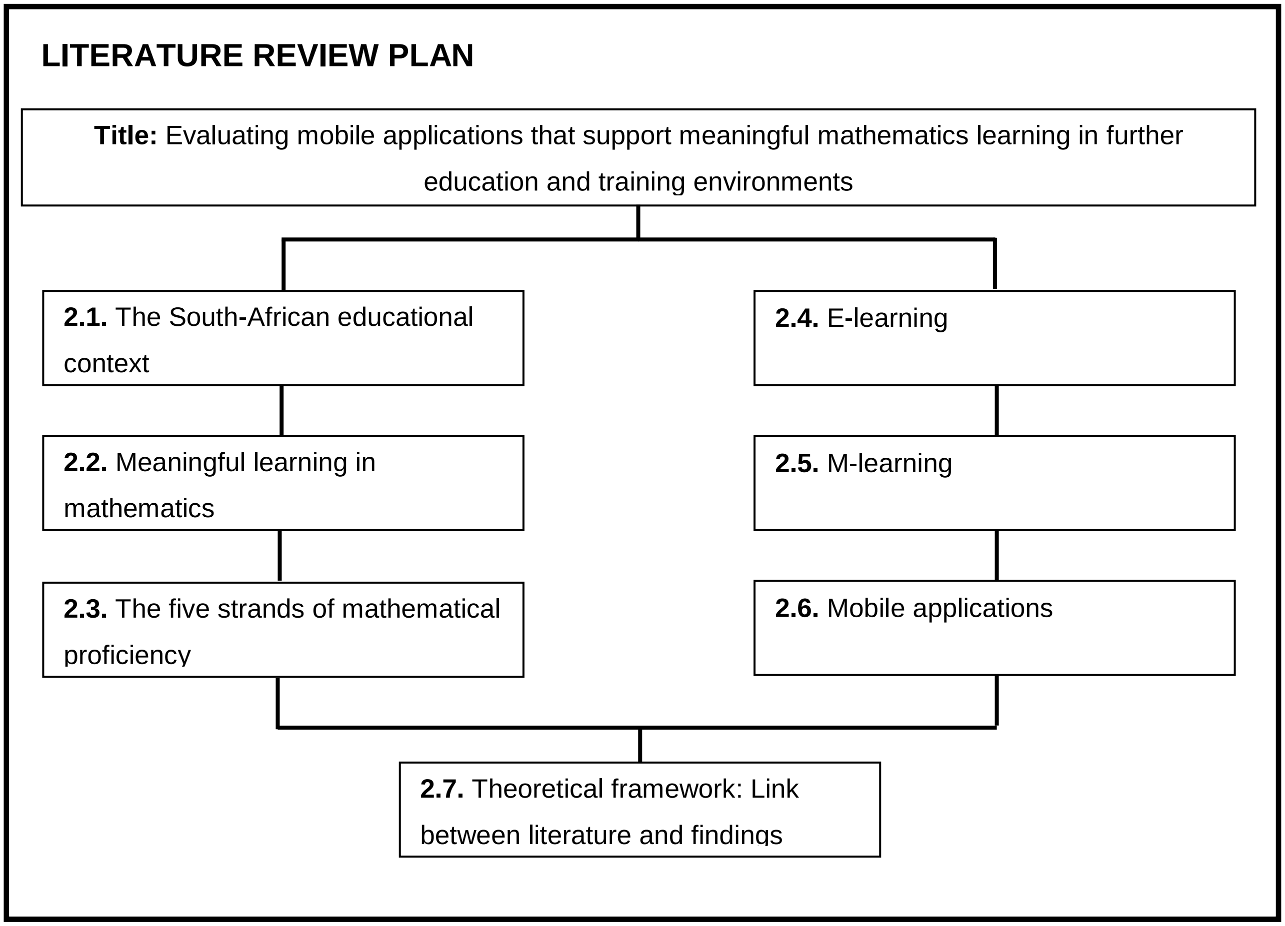


Figure 1.1: Literature review plan

The literature review as presented in Chapter two consists of two main focus areas: Mathematics and mobile technologies. These areas are specified in Figure 1.1. The focus of the review is to firstly understand the South African educational context. The context guided the study to the research problem which is: *Mathematics educators experience challenges to evaluate, select and use applications that will support meaningful learning in their subject field* and the study will *comment on existing applications with the aim to improve their design.* Meaningful learning in mathematics is addressed in Section 2.2. This section discusses challenges experienced by educators and learners in mathematics and how these challenges could possibly be overcome by implementing an inquiry-based environment. Section 2.3 specifically focuses on the proficiencies which learners should master to be successful in mathematics. Kilpatrick, Swafford, and Findell (2001) mention that productive disposition will occur when learners view mathematics as useful and worthwhile. This productive disposition could be regarded as learners' perceived usefulness of MEAs which is discussed in the conceptual framework (Section 3.4.5.). Learners' perceived usefulness was tested by administering a worksheet which they had to complete with the assistance of MEAs. The goal of this activity was to determine if MEAs could possibly promote mathematical proficiencies. The focus of the study is the evaluation and selection of MEAs which could promote meaningful learning. In order to understand the use of mobile modes of education requires a look at its predecessors which are e-learning and m-learning. Section 2.4 introduces e-learning with a brief history. This section explains how Information and Communication Technologies (ICTs) are used today. Certain barriers associated with e-learning are identified accompanied by solution strategies. Quinn (2000) describes that the only difference between e-learning and m-learning is the mobile devices used. The information and communication technologies in e-learning changed to mobile devices. Section 2.5 describes how people use mobile devices today and emphasises the importance of mobile devices in learning. The literature review concludes with Section 2.6 which is the theoretical framework. The goal of the theoretical framework is to link the research results with current literature (Ferreira, 2012). The theoretical framework discusses the Technology Acceptance Model (TAM) created by Masrom (2007) and the Information Systems Success (ISS) Model created by Zaied (2012). Zaied (2012) adapted his model from the TAM model by including six more dimensions to the TAM model. The TAM model was specifically created to test users' acceptance of technology. The ISS model was created to increase businesses' competitive advantage. Zaied (2012) specifically focussed on the utilization of each of the dimensions in the model to create this advantage and he emphasised that the model on its own does not mean much. The ISS model will act as the conceptual framework of this study. The model was tested to determine whether the model could be used as a framework to evaluate and select MEAs which could improve meaningful learning in mathematics.

1.4. RESEARCH METHODOLOGY

The research methodology as presented in Chapter three is purely qualitative, characterised by semi-structured interviews and observations. The goal of the approach was to examine a specific phenomenon which influences learning and teaching environments (Redish, 2004). The ontology of this study was developed by using two specific models: The Technology Acceptance Model (TAM) created by Masrom (2007c) and the Information Systems Success model (ISS) created by Zaied (2012). The knowledge claims in this study are supported by the literature review and will act as epistemology (Hirschheim, 1985; Siegel, 2005). Interpretivism will act as the research philosophy of this study which is rooted in both anti-positivism and constructivism (Mack, 2010). An understanding of teachers' experiences was constructed with mobile applications through the interpretation of interviews and observations and comparing the results to existing literature. Evaluation research is the core strategy for this research which will provide information that can contribute to policymaking, decision-making and future improvements (Arthur & Cox, 2014). The research focuses on how the ISS model proposed by (Zaied, 2012) could be used to evaluate MEAs to contribute to meaningful learning. Interviews and observations serve as the data collection techniques. Semi-structured interviews were used to attain detailed and in-depth data (Leech, 2002). The goal of the observation was to determine how teachers and learners interact with MEAs. The interviews and observations were analysed according to the ten dimensions of the ISS model identified in the conceptual framework. The samples were purposefully selected and consisted of three mathematics subject specialists, six teachers who specialise in various subject fields, one technology and technical expert and six Further Education and Training (FET) mathematics classes. The strategies for data collection are semi-structured interviews and classroom observations supported by digital voice-recordings. An inductive approach was followed to analyse the data (Thomas, 2006). Key concepts were derived from the raw data which were interpreted. The evaluation objectives were guided by the ten dimensions identified in the ISS model. The results of the data analysis were used to develop a framework which teachers could use to evaluate and select MEAs.

Research question		Research strategy	Data gathering methods				Data analysis methodology
Main question	How can the application of the Information Systems Success model as proposed by Zaied (2012) be used to evaluate mobile educational applications that support meaningful learning in mathematics?	**Research strategy**	**Literature review**	**Semi-structured interviews**	**Observations**	**Application evaluation**	**Data analysis methodology**
Secondary Question 1	How do teachers evaluate and select mathematical applications?	Evaluation research		✓			Qualitative
Secondary Question 2	How could each dimension of the ISS model meaningfully contribute to educational environments?	Evaluation research	✓	✓	✓	✓	Qualitative

Table 1.1: Secondary research questions by research strategy and the type of data gathering methods and data analysis methods used to answer these questions

1.5. DELINEATIONS AND LIMITATIONS

For the purpose of delineating the scope, two schools were purposefully selected. The ISS model guided the semi-structured interviews and observations in order to answer the research questions. The fact that only two schools were selected for this study will limit the generalizability of the findings across schools in South Africa but not internally within the selected schools.

1.6. ETHICAL CONSIDERATIONS

The ethical considerations are discussed in Chapter three. The study proposal and developed tools (survey instruments: interview schedule, observation schedule) were presented to the University of Pretoria's ethics committee for ethical clearance. Ethical clearance was granted. The Department of Basic Education, schools, teachers, learners and parents granted permission to conduct the research. The researcher ensured the anonymity and confidentiality of all participants at all times. Proof of the permissions can be found in Appendix C-F.

1.7. CHAPTER OUTLINE/OVERVIEW

The dissertation consists of five chapters which address the research questions (Section 1.2.3). The following table is a summary of chapters and indicates how they answered the research questions.

Research Question	Research Method	Chapter
Secondary Question 1 How do teachers evaluate and select mathematical applications?	• Evaluation research	Chapter 2 Chapter 4
Secondary question 2 How could each dimension of the ISS model contribute meaningfully in educational environments??	• Literature study • Evaluation research	Chapter 2 Chapter 3 Chapter 4 Chapter 5
Main research question How can the application of the Information Systems Success model as proposed by Zaied (2012) be used to evaluate mobile educational applications that support meaningful learning in mathematics?	• Literature study • Evaluation research	Chapter 2 Chapter 3 Chapter 4 Chapter 5

Table 1.2: Summary of research questions, methods and chapters.

Chapter 1: The aim of chapter 1 is to introduce the topic of this study. This chapter includes the reason for the research as well as the problem identified in the research. The research questions developed from the problems identified which has led to the objective and importance of this study. A brief introduction of the literature used is given as well as the research methodology used to solve the research problem. This chapter concludes with the delineations, limitations and assumptions made in this study. This chapter also emphasises that the researcher was given ethical clearance to proceed with this study and that the rules and regulations of the University of Pretoria were strictly adhered to.

Chapter 2: This chapter contains literature regarding the current educational context, the value and benefit of meaningful learning in mathematics and mathematical proficiencies which learners should be able to master. This chapter also examines how e-learning benefits learners. The transition which took place from e-learning to m-learning and the benefits m-learning provide were investigated.

Chapter 3: This chapter focuses on the evaluation of the ISS model. The researcher conducted interviews, observations and administered worksheets to determine whether the dimensions of the ISS model could be used to evaluate and select MEAs which could contribute to meaningful learning.

Chapter 4: This chapter discusses the research results. Chapter four consists of the conceptualised data gathered from Chapter three. Each dimension of the ISS model is defined by characteristics identified by the participants in this study.

Chapter 5: This chapter concludes the dissertation. The chapter includes a discussion of the research findings and how the findings addressed the research questions. The shortcomings and limitations of the study are discussed and the theoretical and practical contributions recommended. This chapter also includes suggestions for future research.

1.8. CONCLUSION

Chapter one of this study outlined the background to the research which includes problems identified in literature. The reason for the research was discussed which led to the discussion of the problem statement and the research questions. The research objectives and the importance of the study were emphasised. This chapter gives a brief introduction to the literature used in this study and explains the methodology used to address the research questions. The delineations, limitations and assumptions of this study were briefly addressed. It was also emphasised that the researcher obtained ethical clearance from the University of Pretoria to proceed with the research. Chapter two discussed the literature used in this study and the theoretical frameworks identified which links the literature and the research results.

CHAPTER 2

LITERATURE STUDY AND THEORETICAL FRAMEWORK

The aim of the literature review is to present literature which contains concepts and theories relevant to this study. This literature study starts with Section 2.1 where the educational context of South Africa is placed into the perspective of this study. Section 2.2 emphasises the importance of mathematics in our everyday lives, identifies the problems with mathematics learning and teaching and how barriers identified in the literature could possibly be overcome. Section 2.3 explains how meaningful learning in mathematics could be achieved and focuses specifically on the skills that learners should develop to be proficient in mathematics. This section also identifies five proficiencies that learners should master to become successful in mathematics. This section is important because it needs to be discovered whether mobile applications could promote these proficiencies. This study focuses on the evaluation of mobile educational applications that could possibly improve meaningful learning in mathematics in a South African context. It is imperative to investigate where mobile learning originated from and how mobile learning is approached in modern society today. This information is explained in Sections 2.4 (e-learning) and 2.5 (mobile-learning) and a brief overview of the history of mobile learning is given. The importance of Mobile Educational Applications (MEAs) is highlighted in Section 2.6. The literature then moves to the theoretical framework in Section 2.7 where the Technology Acceptance Model (TAM) and the Information Systems Success model (ISS) are explained. These models are the link between existing literature as discussed from Section 2.1 to 2.6 and the research results in Chapter 4. Section 2.8 concludes Chapter 1.

The discussion of this chapter is guided by literature review plan which is presented in Figure 2.1.

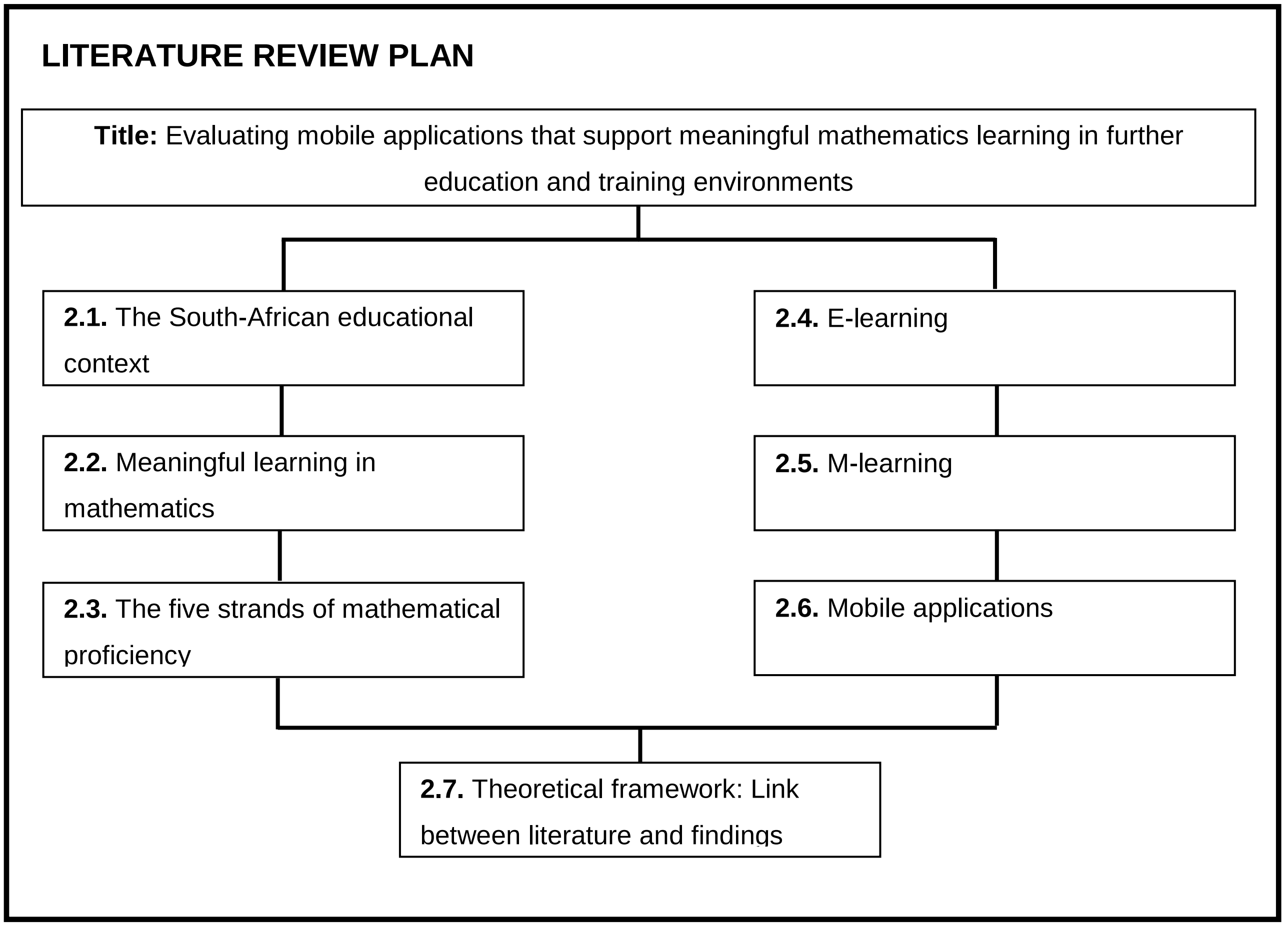
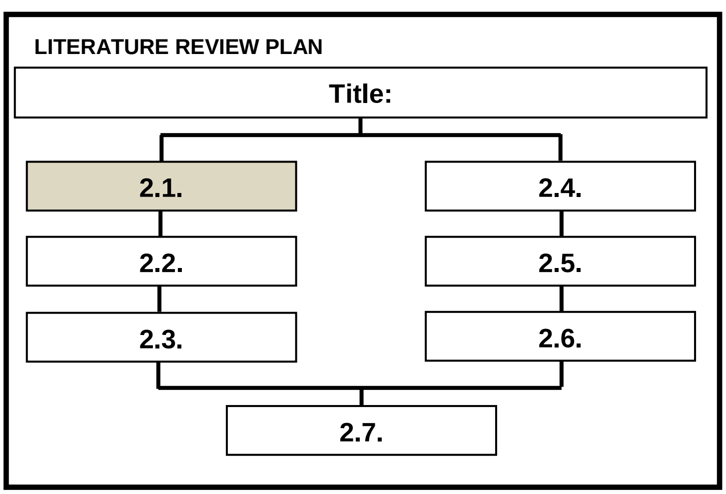


Figure 2.1: Literature review plan

2.1. INTRODUCTION TO THE SOUTH AFRICAN EDUCATIONAL CONTEXT

The following discussion addresses Section 2.1 in the literature review plan.



Africa as well as the Middle East has a crisis with education and teacher development systems. Dykes and Knight (2012) explain that there is a shortage of qualified teachers in these continents and that those teachers who are qualified are not motivated to use their skills to deliver quality education within the educational context. Kruger (2003) explains that teachers find it challenging to create an environment where sound teaching and learning can take place. Niemann and Kotzé (2007) found that there are several dysfunctional schools in South Africa and that the culture of teaching and learning in these schools is absent.

It has to be emphasised that the quality education the affluent population in South-Africa receives is far superior when compared to the education the poor population receives (Spaull, 2013). The results of Van der Berg (2008) have shown that students from affluent socio-economic backgrounds outperform students from poorer communities. Certain poor schools achieve great results and others fail to deliver. This can be attributed to socio-economic challenges and leadership qualities. A big contributing factor in underperformance is the lack of parental involvement and interest in their children. The children's general well-being as well as their schoolwork gets neglected (Bayat, Louw, & Rena, 2014).

Van der Berg (2008) explains that poor mathematics performance in poor schools can be attributed to childrens' unwillingness to practise mathematics and an inadequate coverage of the mathematics curriculum. Spaull (2013) emphasised that homework frequency, preschool education and the availability of reading books have a substantial impact on learner performance. Some teachers of mathematics appointed in positions do not meet the basic requirements of the profession. This means that their subject knowledge is insufficient and results in inadequate teaching. There are also many interruptions during teaching times and poor management in schools.

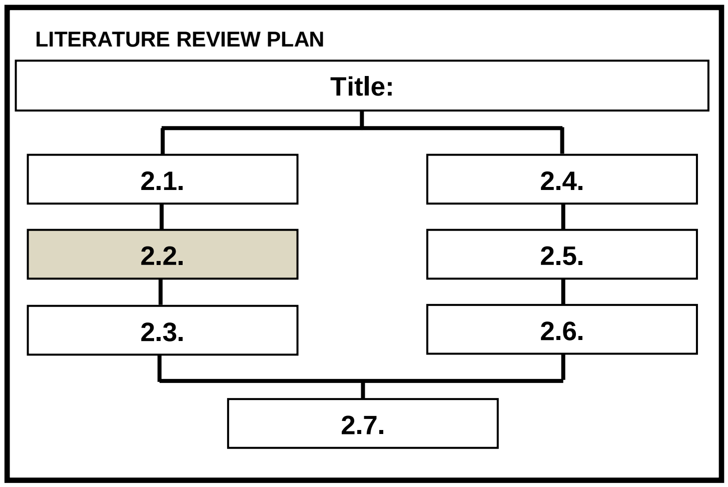
Most local African learners have minimum access to acceptable housing and basic services. The neglecting of basic services affects the hygiene of households and communities. This means that people in these communities are falling ill more often. Children stay at home more often due to sickness. The result is that children will fall behind with their school work which has a major impact on their school performance (Bayat et al., 2014). Many children are affected by violence, crime, poverty and unemployment. Peer pressure paths ways for substance abuse and underage sex. HIV/AIDS and teenage pregnancies are prevalent among these teenagers. Societies are normally seen as patriarchal, where males dominate the working class environments. “Females are more affected by unfavourable neighbourhood conditions due to their greater vulnerability” (Bayat et al., 2014).

Poor communities are characterised by violent crimes, theft, robbery and the occurrence of gangs. Most children in these communities have to walk to school and are often mugged on their way. Townships often lack infrastructure, for example street lights are not working and poor housing structures that contribute to learner experiences (Bayat et al., 2014). Sixty four (64) per cent of principals in rural schools indicated that their immediate environments are unsafe while fifty six (56) per cent of the learners shared the view of the principals (Bayat et al., 2014). Poor communities in South-Africa are associated with lack of access to good nutrition. Many schools in rural areas have feeding programmes operated by groups of local women. Some schools supply food every day of the week and some only certain days. Principals emphasise that on the days that no food is supplied, school attendance decreases significantly (Bayat et al., 2014).

Macdonald (2005) stated that South-Africa has a unique employment problem. Business and industry sectors in South-Africa are faced with a skills shortage and at the same time have high unemployment figures. San Chee (1997) emphasises that if this problem is to be addressed, a culture of learning has to be established where learners are taught to adapt to changes in this world. Van der Berg (2008) explains that parents can also have an influence on poor education if they have sufficient knowledge on what a good education is. Exceptional leadership can transform schools into successful establishments that can provide learners with excellent education. These establishments provide hope for communities and incorporate them within their mission and vision. The most important success factor in successful communities is parents who are involved with their children, both in school activities and outside of school (Bayat et al., 2014).

2.2. MEANINGFUL LEARNING IN MATHEMATICS

The following discussion addresses Section 2.2 in the literature review plan.



Mathematics forms part of everything we do every day (Kilpatrick et al., 2001). Mathematical processes and knowledge are used to build the technologies used at school, home and work. Newspapers, conversations and many jobs require a basic understanding of mathematics (Kilpatrick et al., 2001). When patrons eat at a restaurant they need to be able to interpret the bill. Farmers need mathematics to produce the correct amount of crops. Many civilisations use mathematics to build their cities and to understand nature, ultimately to bring order to human affairs. Mathematics also forms the cornerstone for deductive reasoning (Kilpatrick et al., 2001). Kilpatrick et al. (2001) emphasise that "many educational opportunities and good jobs require high levels of mathematical expertise"

(Siyepu, 2013) explains that learners across the world are performing poorly in mathematics. Van der Walt, Maree, and Ellis (2008) state that "researchers agree that the subject matter knowledge of the majority of learners in South Africa is parlous". They also emphasised that South African learners' technical vocabulary of mathematics is poor and this also causes problems. Van der Walt et al. (2008) and Ndlovu (2011) claim there are some reasons why mathematics performance in South-Africa is poor. Reasons include poor socio-economic background of learners, lack of appropriate learner support material, general poverty, poor quality of teachers and teaching, language of instruction and an inadequate study orientation.

In 2013, 40.9% of South African learners who wrote the National Senior Certificate Examination attained less than 30% for mathematics (DBE, 2015). This indicates that there are still many problems with mathematics is South Africa. Engelbrecht, Harding and Phiri (2010) mentioned that several students who attended mathematics classes in their first year at university level were under-prepared. This can be attributed to learners who performed poorly at school (Padayachee, Boshoff, Olivier, & Harding, 2011).

Studies in mathematics have shown that mathematics teachers place too much emphasis on the teaching of mathematics knowledge rather than to support students to think critically and use their knowledge in real-life situations (Cobb, Wood, Yackel, & McNeal, 1992). Stodolsky and Grossman (1995) explained that teachers think it is their responsibility to teach mathematical knowledge only. The problem with this approach is that it is teacher-centred. The learners do not get the opportunity to express their discomfort with the information and hence cannot learn meaningfully. Cuban (as cited in Wachira, Hall & Pourdavood, 2013) explains that this situation can favour teacher-talk over student-talk and disregards problems that may be revealed if the teacher worked in smaller groups or individually.

The origin of meaningful learning is rooted in constructivism. It can be described as a learning process that has the following characteristics:

- It is purpose driven
- It is self-motivated
- It is a constructive process

(Jonassen, 2006)

Jonassen (2006) explains that meaningful learning takes place when novel and unfamiliar information received, stands in contrast to what a learner already knows. Already known information is used by learners to find solutions to everyday problems and to find meaning in the complexity of the problems. If the solution and the meaning of complexity cannot be explained by learners' existing knowledge, they experience cognitive conflict. This means that the novel information must be used to find solutions and explain complexity. The process of conceptualization has now taken place where the learners experienced conceptual change, meaning and learned something new (Jonassen, 2006). Experience and reflection enable the learners to add conceptual complexity to their existing knowledge. The prior conceptions (knowledge) that the learner constructed determines how they are going to use new information. Jonassen (2006) explains that "the users are only going to use the information to the degree where the information is comprehensible, coherent and plausible to their existing conceptual models".

Meaningful learning in mathematics can be seen in students who actively engage in a classroom if there is purposeful talk on the mathematics subject. The engagement in the classroom means that the learners must observe phenomena, ask questions, carry out experiments, systematically control variables, draw diagrams, calculate, look for patterns and relationships, and make and prove conjectures. Then learners have to interpret and evaluate their solutions and effectively communicate their results through discussions, posters, presentations etc. (Maaß & Artigue, 2013).

One way to achieve meaningful learning in mathematics is to create an inquiry-based environment where learners are given the opportunity to construct their knowledge through communal problem solving and exploring. The learners have the opportunity to communicate their ideas in small groups or to the teacher. The learners have the responsibility to raise questions, explore situations and develop their own ways towards the solutions (Maaß & Artigue, 2013).

An inquiry-based environment can be described as an environment where learners have the opportunity to:

- Make observations
- Pose questions
- Examine books and other sources of information
- Plan investigations

- Use tools to gather, analyse and interpret data
- Propose answers, explanations and predictions
- Communicate the results

(Maaß & Artigue, 2013)

An inquiry-based environment is closely interlinked with an enlarged set of goals for mathematics education. The reasons are the following:

- It will enhance a learners' competencies in mathematical thinking.
- It will build a learners' motivation to learn.
- It will equip a learner with strategies for further learning.
- It will assist a learner in gaining competencies they will need to work as scientists and do inquiry.

(Maaß & Artigue, 2013)

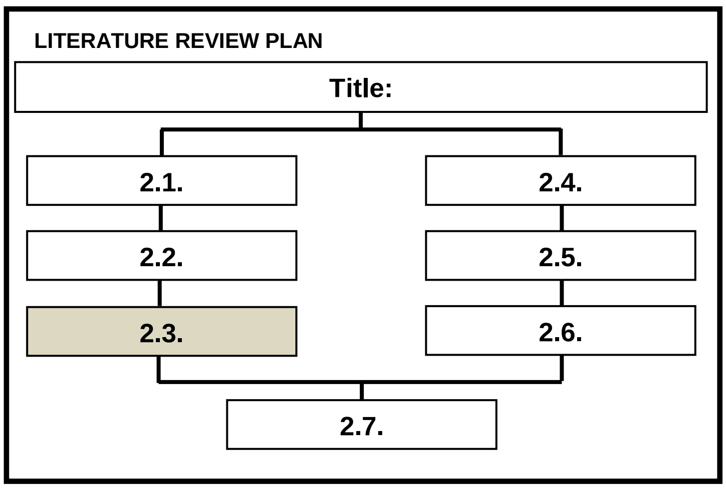
Students want to feel that they can also contribute to the subject. This can be referred to as classroom discourse. Pirie and Schwarzenberger (1988) define discourse as "purposeful talk on a mathematics subject in which there are genuine contributions and interaction". The student must be able to understand the mathematical language used in the subject to be able to complete mathematical activities. The mathematical language will help the learner to interpret and understand mathematical concepts. This forms the foundation to guide the students in their investigation to solve a mathematical problem.

Discourse gives the teacher and the learner the opportunity to make a deep analysis of the subject. This can promote development in the sense that both the teacher and the student come to more profound insight in the subject through understandings that were shared (Manouchehri, 2007; Manouchehri & St John, 2006). Siyepu (2013) explains that understanding is facilitated by means of "activities, classroom discussions and exercises that are done inside and outside the classroom"

The learning activities must be designed in such a way that learners can work independently using prior and existing knowledge. A learner should be introduced to new knowledge with guidance. As learners practice mathematical problems they will be able to solve the problems without assistance. The learners will now gain deeper understanding of the mathematical problem (Siyepu, 2013). This can also be seen as the zone of proximal development in mathematics. It is the difference between the actual development without guidance from a teacher and potential development with assistance from a teacher (Vygotsky, 1980).

2.3. THE FIVE STRANDS OF MATHEMATICAL PROFICIENCY

The following discussion addresses Section 2.3 of the literature review plan.



Kilpatrick et al. (2001) emphasise that meaningful learning in mathematics can only take place in an environment where the learner mastered the five strands of mathematical proficiency. He describes the five proficiencies as conceptual understanding, procedural fluency, strategic competence, adaptive reasoning and productive disposition. It should be understood that the proficiencies are interwoven and cannot be mastered in isolation. To be proficient in one of these strands does not mean that a student will be able to solve a mathematical problem. Each of these proficiencies will be discussed in more detail.

2.3.1. CONCEPTUAL UNDERSTANDING

Conceptual understanding occurs when learners can show that they understand mathematical ideas. Learners with conceptual understanding know that learning mathematics is not limited to learning in a classroom only, but that it occurs in our daily routines. Many newspapers and conversations contain mathematical data or ideas. A learner with conceptual understanding will be able to distinguish between ideas and connect them to information they are familiar with. A learner with conceptual understanding will have confidence in problem solving and with the handling of mathematical data outside the classroom (Kilpatrick et al., 2001).

2.3.2. PROCEDURAL FLUENCY

Procedural fluency refers to the mastering of mathematical methods. Procedural fluency supports conceptual understanding. Learners should know different mathematical procedures and be able to apply them to various problems. Without conceptual understanding the learner will only be able to recall procedures and will find it difficult to apply them. The learning of procedures should be done with understanding. If not, the learner runs the risk of learning incorrect procedures. This makes it difficult to learn the correct procedures (Kilpatrick et al., 2001).

2.3.3. STRATEGIC COMPETENCE

Strategic competence is when a learner shows the ability to formulate a mathematical problem and then use conceptual understanding and procedural fluency to solve the problem. The learner should be able to identify key components of the problem to be able to represent the problem. To be able to identify key components the learner should have the understanding and knowledge of procedures and should be able to distinguish when to use them (Kilpatrick et al., 2001).

2.3.4. ADAPTIVE REASONING

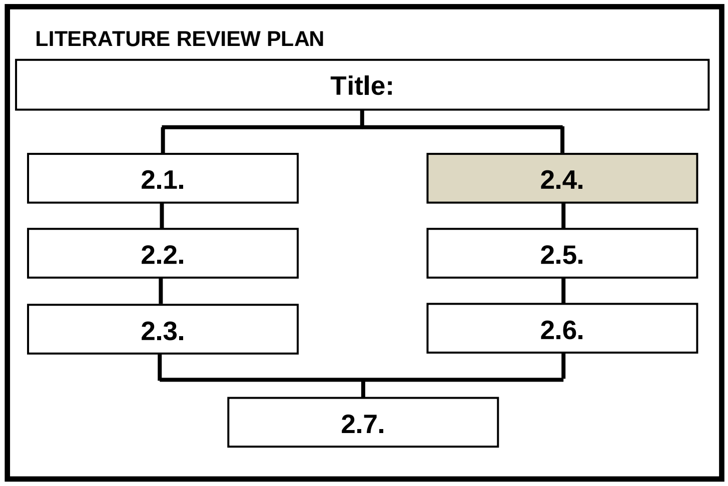
Adaptive reasoning refers to a learner's ability to think logically about problems and how to solve them. Through conceptual understanding, procedural fluency and strategic competence the learner builds a knowledge bank that consists of examples of mathematical problems, procedures and solution methods to solve simple and complex problems. The student will use deductive reasoning to consider all the possible solutions for the problem, eliminate the incorrect procedures and choose the best way to solve the problem (Kilpatrick et al., 2001).

2.3.5. PRODUCTIVE DISPOSITION

Productive disposition occurs when a learner views mathematics as useful and worthwhile. If the above mentioned "strands" were mastered then a learner must believe that there is reason in mathematics. The learner will at this stage understand that to be successful in mathematics takes effort and hard work. The learner should take on every opportunity that will test their skill in mathematics and acknowledge that with perseverance they will reap the benefits and rewards when they are successful in their problem solving (Kilpatrick et al., 2001).

2.4. E-LEARNING

The following discussion addresses Section 2.4 of the literature review plan.



E-learning can be defined as a process where information and communication tools like the Internet, audio, video, satellite broadcast, interactive TV etc. are used to facilitate education and training through the use of instructional software (Govindasamy, 2001; Holsapple & Lee-Post, 2006; Sun, Tsai, Finger, Chen, & Yeh, 2008).

Jenkins and Hanson (2003) define e-learning as learning facilitated and supported by the use of information and communication technologies (ICTs).

ICTs can be defined as Internet, computers, telephones, audio and videos etc. that can be used to facilitate and support learning. These technologies make it possible for students to receive class notes or information, take assessments, communicate with fellow students or facilitators at any time, without it being bound to a fixed location (Masrom, 2007c)

In simple terms e-learning is web-based information that learners can access without time or geographic restrictions (Sun et al., 2008). The use of ICTs in learning transformed the traditional way content was represented. The use of ITCs can now be viewed as interactive and online media can be accessed by students from anywhere at any time. The use of ICTs gives the teacher the opportunity to deliver content in different forms and from a pedagogical perspective can support learners with different learning styles (Lau, Yen, Li, & Wah, 2014).

Gráinne Conole, Maarten de Laat, Teresa Dillon and Jonathan Darby (2006) indicate that learners' approaches to traditional learning are changing. In a study done by Kennedy, Judd, Churchward, Gray, and Krause (2008) with approximately 200 first year students they came to new insight that most students were positive that technology could support their learning.

Their results showed the following:

- 94% of the students use a computer for general study purposes.
- 93% of the students use computers when searching for information.
- 84% of the students communicate via SMS.
- 75% of the students communicate through instant messaging.
- 81% of the students use a learning management system to access course materials.

(Kennedy et al., 2008)

Kennedy, Vogel, and Xu (2004) concluded that in excess of 90% of students agree that they can use technology to enhance their learning. Document creation and searching for information on the internet are their top priority.

Students acknowledged that a mobile phone is useful (in the context of university studies) to:

- Send and receive text messages (84% of students)
- Use their mobile phone as a personal organiser (60% of students)

(Kennedy et al., 2008)

The development and use of new technology resulted in a change in the way students communicate and participate and the use of e-learning is becoming more prevalent in educational institutions. Conole, de Laat, Dillon & Darby (2006) emphasized that students are aware of the impact of technologies in their learning process and are discarding technologies that do not personally benefit them.

Kennedy et al. (2008) concluded that the assumption cannot be made that students who form part of the "Net-generation" will have enough knowledge or experience to use technologies to optimise their learning experiences. In the preliminary results of the 2006 ECAR study of students and information technology, Caruso and Kvavik (2006) concluded that students use technology for the convenience and control it affords and does not contribute a lot to learning.

Sun et al. (2008) explained that learners' attitudes, which guide user satisfaction, is the most important determinant of success in an e-learning environment. This led Sun et al. (2008) to develop a framework which outlines critical dimensions ensuring the effective design, implementation and outcome of an e-learning program.

This framework consists of the following 6 dimensions:

1. **The learner dimension**

Piccoli, Ahmad, and Ives (2001) have shown that anxiety can make a significant difference to the outcome of an e-learning activity. Anxiety is referred to as an emotional state that results from fear and allows the body to detect and respond to the threat at hand (Ursache & Raver, 2014). There are two types of anxiety, namely trait and state (Cattell & Scheier, 1961). State anxiety is a temporary condition which occurs when a person feels threatened by something. Trait anxiety like state anxiety occurs following an external threat but may vary in intensity and duration. Trait anxiety may be experienced to such an intense degree that it is seen as an personality characteristic of a person (Spielberger, 1976). Ursache and Raver (2014) explain that learners' academic performances are influenced by their ability to use their executive functions. Executive functions refer to the skill to organise information and plan goal directed action and include functions such as the ability to manipulate information, attention shifting and the switching between mental frames etc. Anxiety has a negative effect on these functions. Computer anxiety is a kind of state anxiety (Heinssen, Glass, & Knight, 1987; Raub, 1981). It might be an emotional fear of potential negative outcomes that a program on a computer might produce or a fear of not knowing how to work with a computer (Barbeite & Weiss, 2004). This means the higher the level of anxiety experienced by the learner the lower the level of satisfaction and subsequently learning will be. This is the result of the negative influence anxiety has on persons' beliefs and feelings towards e-learning and this cannot be neglected (Igbaria, 1990).

2. Instructor dimension

Fulk, Schmitz, and Steinfield (1990) emphasise that individuals construct their views on reality through internalization and compliance effects of groups of individuals. Internalization happens when an individual accepts group messages, meanings and attitudes into their construction of reality process. Compliance refers to the imitation of group behaviour following group pressure. The inference drawn is that an instructor's attitudes towards e-learning can influence the outcomes of e-learning positively or negatively (Piccoli et al., 2001; Webster & Hackley, 1997). Research done by Thurmond, Wambach, Connors, and Frey (2002) has shown that a learner's satisfaction with an e-learning program is greatly influenced by the response time of instructors. The logic behind the rationale makes sense. If the learner encounters a problem with work, he needs assistance and is then unable to continue before the problem is addressed. If instructors have a negative attitude towards e-learning, they will not respond to learners problems and this will have a negative impact on their learning (Soon, Sook, Jung, & Im, 1999). Learning satisfaction will only improve with timeous response from the instructor (Arbaugh & Duray, 2002; Thurmond et al., 2002).

3. Course dimension

The University of Houston-Clear Lake embarked on e-learning in 1996. They were determined to establish a process to assure the production of quality online courses. They recognised that a variety of stakeholders should be involved in the process as each were specialists in their subject fields. Stakeholders included learners, faculties, administrators, representatives from industries and the university communities. Each of the stakeholders had their own perspectives on the meaning of quality in a course. They concluded that to define quality is an elusive process. They agreed that quality in a course would be evident if quality assurance strategies were implemented throughout the course design process (Kidney, Cummings, & Boehm, 2014)

The following table illustrates which quality attributes learners, the faculty and administrators thought should be assessed throughout the design of a course.

Group	Learners	Faculty	Administrators
Attributes of quality	• Easy accessibility • Good usability • Accurate and thorough instructions • Intuitive navigation • Well-integrated tools • Consistent behaviour • Correctly working links, materials, & media	• Easy to teach • Intuitive course management • Customizable • Consistent with information they deem important • Quick preparation for semester after semester • Easy to update and add new information	• Comparable rigor to a non-distance class • Accurate & valid information • Boosting enrolments • Free from copyright violations • Free from problems that might yield institutional liability • Uniform & reasonable efforts required to teach & maintain • Enhancing to the university's reputation

Table 2.1: Quality attributes according to learners, faculty and administrators (Kidney et al., 2014)

4. Technology dimension

This dimension consists of two distinct parts namely: Technology quality and internet quality. Sun et al. (2008) describes technology quality as software tools that have user-friendly characteristics. This means software tools that are easy to use and understand. Both Zaied (2012) and Masrom (2007) refer to this as the ease of use of technology. Software tools can complement educational environments if they are easy to use and understand. This will improve satisfaction and increase learning efficiency (Piccoli et al., 2001).

E-learning might involve learning through software tools that require internet access. The quality of the internet network might influence a learner's perceived quality and therefore its perceived ease of use of the software tool. Internet quality could refer to: network transmission speed, ease of use, universal access and search capabilities (Bhuasiri, Xaymoungkhoun, Zo, Rho, & Ciganek, 2012).

5. Design dimension

Perceived usefulness

Everyone that teaches or recently taught will agree that all students behave differently towards an educational system. There are students who really understand the meaning of attending school, there are those students who only attend school because their parents force them to go and there are learners who find school irrelevant (Prensky, 2005).

Prensky (2005) explains that all students want to be engaged in something in their life. If school or a classroom is not engaging enough they will lose interest in learning. The teacher has the responsibility to engage every student when using a mobile educational application. The student will only find the system or process of learning useful is he/she is engaged.

The following criteria can be used to measure the perceived usefulness of MEAs:

- Can the mobile educational application assist in the academic performance of learners?
- How effective is the mobile application in delivering information to the students and in the assessment of outcomes?
- Will the mobile application increase learners' productivity in mathematics? Will the mobile application increase learners' willingness to participate in the subject?
- Learners' risk and trust perception: The learner dimension (*cf.* Par 2.5)

Perceived ease of use

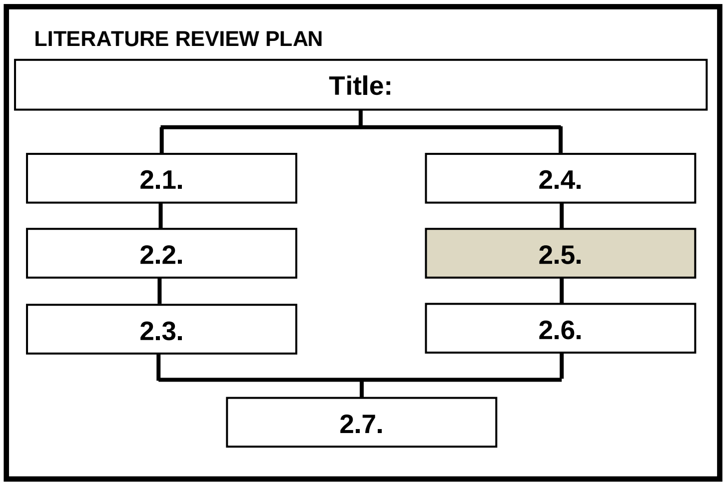
Ease of use can also refer to usability. Therefore a mathematics application can be used in such a way that it allows the user to complete an instruction efficiently and effectively. A mobile mathematics application must be easy to use. Nobody likes to use an application that has all the functionalities it requires to complete tasks but is difficult to use (Wang, 2008). Wang (2008) emphasises that if the "usability is neglected there is the risk that an educational artefact (mathematical application) is produced with many functionalities, but which cannot be handled by learners."

6. Environmental dimension

Sun et al. (2008) explain that e-learning provides learners with the opportunity to learn in many different environments. The environments are not necessarily education environments where face to face interactions take place between teachers and learners. Learners are more exposed to distractions in these environments and it is difficult for them to concentrate on the learning material (Isaacs, Morris, Rodriguez, & Tang, 1995). Arbaugh (2000) suggests that one way in which this problem can be solved is to have frequent interactions with others. These others can be described as learner interactions with peers, learning material and teachers (Moore, 1989). Piccoli et al. (2001) emphasise that these interactions can help learners solve problems and improve their progress and that is why interactive instructional design is a very important component of learning satisfaction and success (Hong, 2002). It is therefore very important to design interaction platforms which will allow interaction to take place frequently, promptly and on a platform which will stimulate quality discussions that could enhance meaningful learning.

2.5. MOBILE LEARNING

The following discussion addresses Section 2.5 of the literature review plan.



In the late 1980s a lot of questions were raised on the usefulness of computers in social environments, peoples' daily activities and their physical environment. During this time the desktop computer was viewed as a complex machine which socially constrained people to their working environments. These machines cluttered environments, isolated people due to the attention they required and did not form part of an individual's daily activities (Weiser, Gold, & Brown, 1999)

The next logical step was to envision ubiquitous computers. Computers had to become transportable to such extent that they could form part of an individual's daily activities and be readily available in many locations. These new generation computers were visualised to be small, invisible and have minimal impact on a user's daily activities. One of the most important attributes recognised then, was the ability of these devices to be connected to networks. This allowed a user to only enter information once, which would become available on these devices, irrespective of the location or time. Users would gain access to information "on-the-go" without any time or physical constraints. Learners were motivated to shift their focus and concentrate on learning activities. Less emphasis was placed on the demanding attention which computers required (Kukulska-Hulme, 2005).

Successful mobile learning could have only been enhanced if buildings and public spaces adapted and responded to the learning needs of users. Systems had to be integrated into these environments which enabled places, objects and people to have on-the-spot interactions with the users of mobile technologies (Weal, Michaelides, Thompson, & DeRoure, 2003). The use of mobile technologies is being trialled in various urban and rural educational environments in South Africa. Mobile devices have created generous opportunities for learners to connect to their surroundings, although learning through a mobile device could be individualistic in nature. Slowly but surely more and more opportunities are being created for learners to be connected and have access to collaboration around educational activities (Kukulska-Hulme, 2005).

Kukulska-Hulme (2005) emphasises that mobile devices are not specifically designed for educational purposes. Modern devices are designed to assist people to organise information, communicate via social networks and to streamline business proceedings. The communication between individuals using mobile technologies, to interact with virtual environments and to search for information, developed from educational technology research and practice and educational research on mobile technologies (Frohberg, 2002; Preece, 2000).

Gikas and Grant (2013) explain that mobile learning is still in its infancy stages in higher education. They identified three critical factors which influence mobile learning and these could be regarded as the foundations of m-learning. These foundations are briefly discussed below.

Learning delivered and supported by mobile computing devices

Mobile computers include devices such as smartphones, tablet computers, laptop computers and netbooks (Valk, Rashid, & Elder, 2010). Keegan (2005) makes it very clear that when mobile devices lose their transportability function and learners still use them for learning purposes it cannot be classified as mobile learning anymore. Mobile learning could be identified through the medium in which learning takes place. Learners should be able to access information and knowledge anywhere at any time by using mobile devices they could carry with them everywhere they go (Traxler, 2007).

Learning is formal or informal

Learning could either be regarded as formal and informal (Traxler, 2007). Formal learning is designed to have the optimal impact within an educational environment. Educational environments are usually characterised as structured environments where the learners follow a certain programme. These programmes are designed by teachers according to the learning specifications and proposed outcomes. At the end of the programme learners could be promoted to a higher grade, receive credits, a diploma or a certificate (Malcolm, Hodkinson & Colley, 2003).

Informal learning usually takes place in unstructured environments which have a specific context. Unstructured environments are characterised as non-educational environments where there is no formal program of instruction. Learning takes place intentionally at home, work or in leisure time (Halliday-Wynes & Beddie, 2009). Learners might view informal learning as the acquisition of information or knowledge without realising that learning is taking place. Informal mobile learning could take place when learners use their mobile devices to read, access the internet, browse and communicate via social media, do research and collect information (Abilene Christian University, 2010).

Billett (2002) argues that informal learning does not necessarily take place after formal learning. Mobile devices created the opportunity for informal learning to complement formal learning. As long as learning as a whole is viewed as ubiquitous, mobile devices could be used to bridge this divide.

Learning is context aware and authentic

Traxler (2010) suggests that context awareness promotes the authenticity of content. Formal educational environments are not necessarily the most suitable environments where meaningful learning could take place. Meaningful surroundings will complement meaningful learning and are environments which are familiar to a learner and where a learner could have interaction with information at their own time. This creates various challenges for developers of content. Sharples, Taylor, and Vavoula (2010) emphasise that every learner is working towards their own goals according to their skills and knowledge. Content has to provide the flexibility to the learner to access and acquire information according to their personalised needs and abilities. Tella (2003) and Traxler (2010) warn that "learning across contexts and at different times may produce fragmented knowledge and incomplete schemata".

Clark Quinn (2000) explains that mobile learning is when mobile computing meets e-learning. When examining various definitions of m-learning it could be concluded that m-learning specifically defines the methods used to present e-learning content. Quinn (2000) defines mobile learning as "e-learning through mobile computational devices". Mobile learning compliments e-learning by creating an additional access point for mobile device users (Taleb et al., 2015)

Sharples, Arnedillo-Sánchez, Milrad, and Vavoula (2009) define mobile learning as using ICTs to stimulate conversation and using ICTs as a tool to search for new knowledge throughout multiple environments. Kukulska-Hulme et al. (2009) emphasise that mobile technology is one of different types of technologies that can support learning outside a classroom. Learners do not need the assistance of a teacher or facilitator.

Sharples, Taylor, and Vavoula (2005) explained that there is an essential difference between mobile learning and other types of learning. Mobile learning is learning on the move. This means learning taking place through the use of a medium called a mobile device.

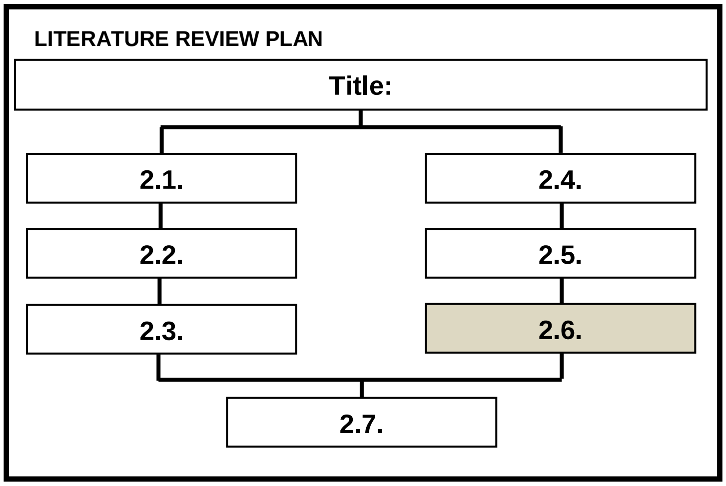
Mobile and wireless devices enable people to communicate in different ways. These technologies are easily accessible and connect learners that are geographically dispersed (Peters, 2007). The need and use of mobile devices are forming an integral part of peoples' lives today (Park, 2011). The use of mobile technology has transformed the way people communicate, how commerce takes place, the way crime is organized and the most important, the way that knowledge in the form of learning is delivered (Traxler, 2007). Peters (2007) also explains that the 21st century society is rapidly changing in a social and technological way. Technological developments enable us to communicate and process information faster. These developments are suitable for new social patterns that are emerging. People are not bound to one community based on their geographical location. New communities are developing based on peoples' interests, work patterns and opportunities (Peters, 2007)

Peters (2007) explains that mobile devices are becoming more diverse with regards to their use and offer great potential for educational purposes. The development of new technologies gives the learner the opportunity to work and study outside a fixed location or normal class setting. This enhances mobility and creates new challenges in the form of training delivery (Peters, 2007). Crowe (2007) emphasises that ubiquitous computing is able to create a virtual classroom where the teacher can still focus on his field of expertise while using technology to promote learning. Park (2011) accentuates that an environment where students have access to a variety of digital devices must be created. Such an environment will enhance ubiquitous learning. Peters (2007) emphasises that the education and training sectors must respond accordingly to the opportunities and demands of mobile learning.

Traxler (2007) emphasises that the relationship between education, society and technology is more interconnected. Learners have access to information that originates from a variety of sources. This is why the development of new information and communication technologies will be empowering to the social change experienced (Peters, 2007).

2.6. MOBILE APPLICATIONS

The following discussion addresses Section 2.6 of the literature review plan.



A mobile application is application software that is embedded in system software and that works on a mobile computer. The systems software gives the mobile computer functionality. The application software is created to assist the user to retrieve or add information from and to the application (Doering & Roblyer, 2010).

2.6.1. APPLICATIONS EXAMPLES

Table 2.2 depicts the mathematical examples used in this study to determine whether they could promote the five strands of mathematical proficiency.

<table>
<tr><td>Application 1</td><td>Math Exponents
Developer: Mathtoons Media Inc</td></tr>
<tr><td colspan="2">Math Exponents created by Mathtoons Media Inc was the first application which was used in this study. The application has a specific focus on exponents and radicals which form part of algebra. The application takes on the form of a quiz. There are 10 quizzes a learner could complete which contain a variety of questions. This application provides learners with immediate feedback if they make an incorrect choice. The feedback contains a detailed explanation of the question and the correct answer. The disadvantage of the application is that it provides the learners with three possible choices giving them a $33,\dot{3}$ chance of guessing the correct answer. Contrary to this, it could be seen that the possible answers are designed in such a way that learners should think about the application of exponential laws in order to select the correct option.</td></tr>
<tr><td>Application 2</td><td>yHomework – Math Solver
Developer:
Math Underground</td></tr>
<tr><td colspan="2">yHomework Math Solver is an application which mainly focuses on the solving of equations. The application allows the user to enter a specific equation upon which a solution for that equation is given. The application shows each step it used to solve the problem. The application is limiting in terms of only offering a certain number of credits. These credits are used to solve equations. The user can only use the application until their credits are depleted. Thereafter the users have the option to buy certain packages made available on the application before they can continue using the application.</td></tr>
</table>

<table>
<tr><td>Application 3</td><td>Mathematics
Developer: daboApps

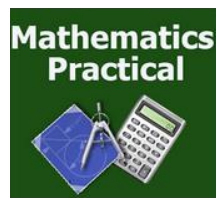
</td></tr>
<tr><td colspan="2">This application consists of various mathematical tools that can assist the user to solve various problems, such as equations, functions and factoring. It has an interactive interface that enables the user to insert information to solve problems. The functions section provides the user with a graphical representation upon which inferences can be drawn with regards to characteristics of the functions. A disadvantage of this application is the lack of a verbal explanation of the mathematic rules applied.</td></tr>
<tr><td>Application 4</td><td>Complete Mathematics
Developer: ToscanyTech

</td></tr>
<tr><td colspan="2">This application focuses on limited algebra, solid geometry, trigonometry and functions. Although the simultaneous equation section of this application is unique, it does not promote understanding through solving a quadratic equation through the quadratic formula. Some of the explanations in the tutorials promote understanding through clear and thorough examples, as opposed to other tutorials that rely heavily on a verbal explanation.</td></tr>
</table>

Table 2.2: Examples of mathematical applications (Researcher)

2.6.2. EXAMPLES OF PROJECTS

Momath in South-Africa

Nokia started this project in 2007 and aims to improve the mathematics performance of Gr.10 learners in South-Africa. The learners are given the opportunity to access mathematics content through their mobile devices and to participate in competitions and quizzes (Isaacs, 2012).

Teaching Biology project

This project commenced in 2010 in Cape Town, South Africa. This project delivers in-service teacher training workshops for Life Sciences teachers. The aim of the project is to improve teachers' knowledge of evolutionary biology and allows teachers to network with each other. This project gives the teachers the opportunity to develop resource material in collaboration with other teachers. The teachers ICT skills are developed by giving the teachers access to computer labs that can assist them in the development of lesson plans and assessment materials using ICT (Teaching Biology Project, 2013).

North-West Tablet Project

Seventy schools in the North-West province received tablets from the Department of Basic Education. Each school received 40 tablets, a server and a Wi-Fi router. All the information on the server is available offline. The tablets are loaded with teaching and learning content covering subjects like mathematics, physical science and life science. The Department of Basic Education in North-West hopes that the tablets will yield better results and improve the standard of education in South-Africa (SchoolNet SA, 2014)

Gauteng tablet project

The provincial government in Gauteng in conjunction with Huawei distributed 88 000 tablets to 2200 government schools in Gauteng early in 2014. The provincial government would also have provided connectivity. The goal of the rollout is to provide each school with 40 tablets which learners can access in the schools computer lab. This project wanted to contribute in making Pretoria the "knowledge and research capital city of South-Africa" (Huawei, 2013).

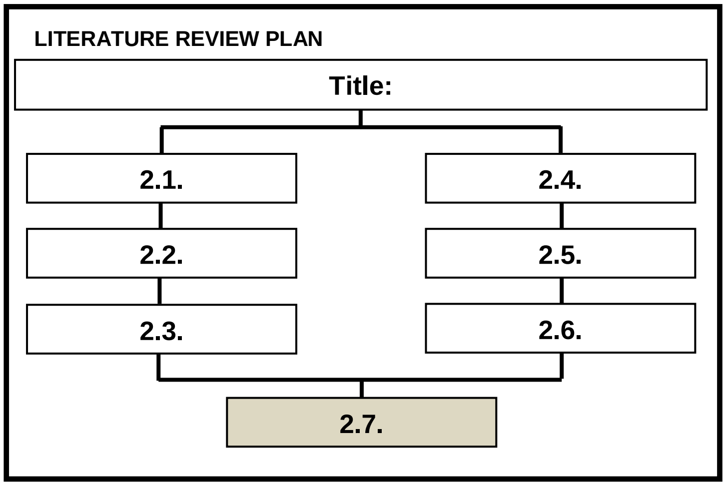
ICT4RED project

The Department of Basic Education, Science and Technology and the Eastern Cape Department of Education in conjunction with the Council for Scientific and Industrial Research (CSIR) has launched a new project where 3000 tablets were distributed to schools in Cofimvaba, Transkei (James, 2013). In 2013 the Department of Rural Development and Land Reform (DRDLR) also joined as a key partner in the initiative. The project focused on key areas which have a significant influence of the schooling system in Cofimvaba. Information and Communication Technologies for Rural Educational Development (ICT4RED) are a component of Technology for Rural Educational Development (TECH4RED) which focuses only on the use of technology in education. This project aimed to uplift rural education through the use of mobile devices. The project consisted of the implementation of certain initiatives and provided research opportunities for external researchers. This project provided the researcher with a bursary and an opportunity to link this research to the project (Herselman & Botha, 2014).

These projects illustrate the immense interest in the use of mobile devices in education in South Africa, as well as the expansion of mobile learning in recent years.

2.7. THEORETICAL FRAMEWORK

The following discussion addresses Section 2.7 of the literature review plan.



2.7.1. INTRODUCTION

The underlining theoretical vantage point of this study is rooted in constructivism. Constructivists believe that an environment must be created to provide the opportunity for practitioners to interpret events, objects and perspectives rather than to remember and comprehend an objective knowledge. The practitioners construct their own meanings from their experiences and will be able to use it in new and different situations (Jonassen, Davidson, Collins, Campbell & Haag, 1995)

The goal of the theoretical framework is to provide perspectives that can link the research results with existing literature. The goal of the conceptual framework is to explain the concepts identified in literature that can be practically applied to this study (Ferreira, 2012).

From the definitions of e- and m-learning it can be deduced that these types of learning consist of a few distinct and vital characteristics. These characteristics can be categorised as:

- Human participation
- Information
- Technology
- Information processing

The above characteristics are classical components which are also found in information systems (Zaied, 2012). There are various definitions of information systems which include the following:

Davis (2000) explains that an information system is a system that delivers information and communication. McLeod & Schell (2007) defines information systems as “virtual systems; their data represents the physical system of the firm.” The definition produced by Jessup, Valacich and Hall (2008) infers that information systems are computer-based systems that consist of hardware, software and telecommunications networks which people build to collect, create and distribute useful information. Alter (2008) describes an information system as a work system where human participants use information, technology and other resources to produce certain outcomes. These outcomes should be reached through the processing of information which includes the capturing, transmitting, storing, retrieving, manipulation and display of information.

Examples of information systems include systems devoted to create computer programs, digital products such as software and electronic games, programs which generate financial statements and perform economic analysis (Alter, 2008). An information system from an educational point of view can consequently be seen as mobile educational software or mobile applications. These software or applications can be viewed as educational artefacts which are used in educational environments. The aim of these artefacts could be to provide support and/or increase the efficiency within an educational organisation (Lupton, 2014).

The technology acceptance model created by Masrom (2007) and the Information Systems Success Model created by Zaied, (2012) can be used to evaluate information systems. Information systems research consists of two parts namely behavioural science and design science. The behavioural science part attempts to develop theories to predict and explain organisational and human behaviour when using information systems. The design part of information systems attempts to create new artefacts that can be used to improve the effective and efficient working of an organisation (Von Alan, March, Park & Ram, 2004).

A new artefact that is created with a strong mathematical basis for design allows for many types of quantitative evaluations including optimization proofs, analytical simulation and quantitative comparisons with alternative designs. The further evaluation of a new artefact in a given context allows the opportunity to evaluate the artefact empirically and qualitatively. The reason for this being that there is a new phenomenon taking place, namely the interaction between technology and people or organisations. It should be understood how these phenomena can assist in theory development and problem solving (Von Alan et al., 2004). The creation of an artefact enables researchers to understand the problem addressed by the artefact and how these artefacts can practically approach solutions.

This study will focus on the qualitative evaluation of educational artefacts which are mobile applications, with regards to the implementation of these artefacts within educational environments.

2.7.2. THE TECHNOLOGY ACCEPTANCE MODEL

The theory of reasoned actions (TRA) used in psychology research was the precursor that Davis (1989) used to develop the technology acceptance model (TAM) (Fishbein & Ajzen, 1975; Masrom, 2007c). The TRA theorises that an individual's behaviour is a product of the individual's attitude and perceptions toward the behaviour. Therefore behaviour is grounded in attitudes and beliefs.

The TAM model proposes that there are external variables that influence the perceived usefulness of technology and the ease with which technology can be used. In this model perceived usefulness refers to the degree people believe that technology can improve their work performance, and perceived ease of use refers to how effortless the people think using technology will be. These two factors will determine peoples' attitude towards technology and guide their behavioural intention to use technology.

TAM suggests that an individual will only find technology easy to use and useful if their attitude towards the technology, that is, their intentions to use the technology and the actual use of the technology are positive. A user's attitude towards technology is influenced by two distinct factors namely, the belief that the use of technology can improve their learning and the human effort needed to use the technology. The TAM is depicted in Figure 2.2.

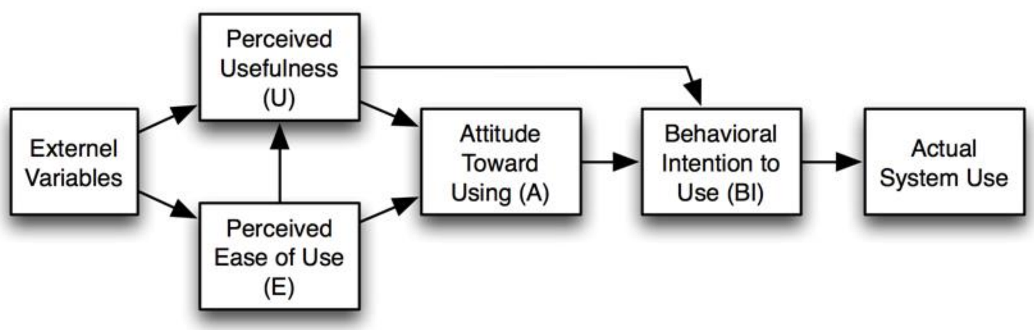


Figure 2.2: The Technology Acceptance Model (Davis, 1989).

In various studies the TAM model was used to test the user acceptance of information technology, for example, web browsers (Morris & Dillon, 1997), telemedicine (Hu, Chau, Sheng, & Tam, 1999), websites (Koufaris, 2002), e-collaboration (Dasgupta, Granger, & McGarry, 2002) and blackboard learning (Landry, Griffeth, & Hartman, 2006).

This study will focus on the evaluation of mobile applications as technology that is being used within educational environments.

2.7.3. INFORMATION SYSTEM SUCCESS MODEL

Zaied (2012) used fundamental theories and concepts of the TAM model and developed a new model with the inclusion of six new dimensions for the evaluation of information systems success. This is illustrated in Figure 2.3. This model assesses the critical factors affecting information systems in the public sector in Egypt. The proposed model demonstrates how it can assist decision makers in the evaluation and development of information systems (Zaied, 2012).

The possible utilization of an information system (IS) can increase a business's competitive advantage. It has been argued that it is not the IS itself that can create the advantage but the utilization of the IS. These systems are always advancing and therefore are very expensive. Businesses must find solutions to use the information systems in a more profitable way and have to identify key factors in the information system that can lead to success (Zaied, 2012).

The Information System Success model is illustrated by Figure 2.3.

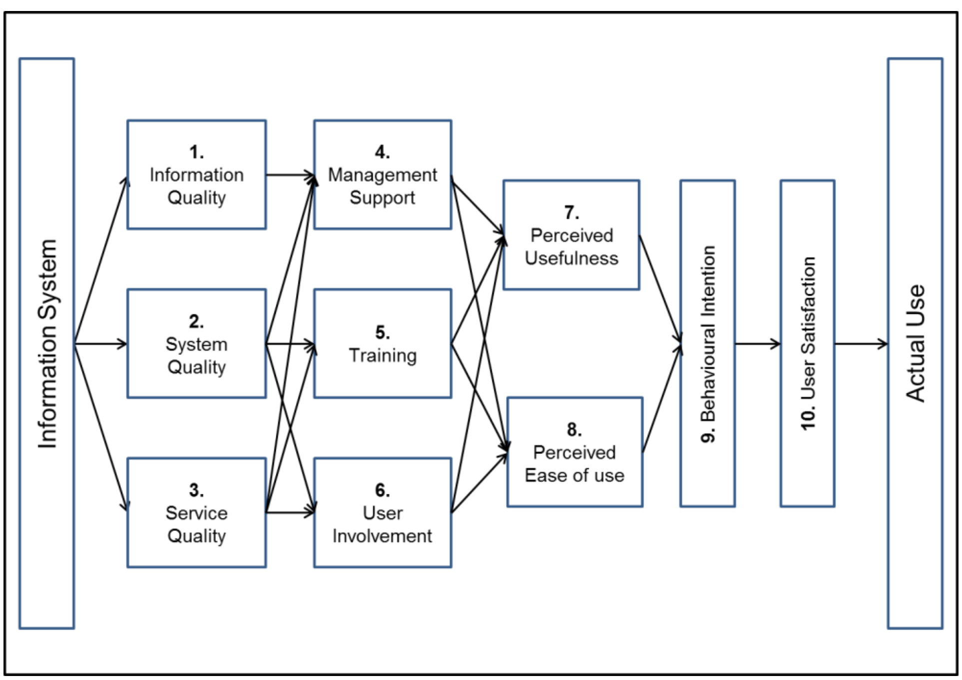


Figure 2.3: The Information System Success Model (Zaied, 2012)

The following table shows how Zaied (2012) explains the dimensions but also how other sources view the same concepts.

	Explanation	
Dimension	(Zaied, 2012)	Other sources
1. System quality	Measuring system quality usually focuses on the performance characteristics of the system under study. Measures include: Reliability, response time, aggregation of details, human factors, system trust and accuracy.	Owlia (2010) defines system quality as the "probability of a product working fault-free within a specific time period."
2. Information quality	Information quality (IQ) is an important factor for the acceptance of the system. Measures include: Completeness, Understandability, Security, Availability and Accuracy.	Is the information: • Well organised • Effectively represented • Of the right length • Clearly written • Useful • Up-to-date (Holsapple & Lee-Post, 2006).
3. Service quality	Does the service delivered match customer expectations? Measures include: Availability, reliability, integrity, functionality and efficiency.	A user of a product expects service to be delivered on a certain level through word of mouth communications, the personal needs of people and their past experiences (Pitt, Watson & Kavan, 1995).
4. Management support	Management approval and support of the information system. Measures include: Encouragement, providing resources, discussing problems, appreciating optimal use and having sufficient knowledge of the system.	Does the management of an educational institution support meaningful learning by introducing, managing and the assessing: • The equity of access to ITC's • The engagement of students in the use of ICT's • A shared vision for the use of ICT's • The use of ubiquitous networks • The professional development of teachers, learners and management (Flanagan & Jacobsen, 2003).
5. Training	Training employees on the information system. This will have a positive relationship with the success of the implementation. Measures include: Training programmes, the role of users, availability of training material and support.	The management of educational institutions should determine the knowledge and skill level of teachers and students to determine to what extent training is needed (Jung, 2005).

	Explanation	
Dimension	(Zaied, 2012)	Other sources
6. User involvement	The importance and relevance users attach to a given system. Measures include: Users involvement in input design, users involvement in output design, perceptions of service evaluations, perceived value and customer attitudes.	Users have the opportunity to add their own conceptualizations and meanings to the input design. Users will be emotionally engage and motivated (Altay, 2014).
7. Perceived usefulness	Will the use of technology improve performance? Measures include: Performance, effectiveness, productivity, risk perception and trust.	Teachers must actively equip students to become more self-directed in their learning (Grow, 1991).
8. Ease of use	The degree to which an individual believes that learning to adopt the use technology requires little effort. Measures include: Easy to learn, easy to manage, self-efficiency, simplicity and compatibility.	System, service and information quality needs to work together to determine how comfortable the user will be with the use of the application, and how the user views the perceived usefulness of the mobile application (Masrom, 2007).
9. Behavioural intention	Measures include: Personalization, interactivity, response time, uncertainty avoidance, and number of transactions executed.	The user will only be driven to learn through the mobile application if they find meaning in specific tasks in the application and be able to make that meaning their own (Jonassen, 2006).
10. User satisfaction	Satisfaction is a response to a supposed difference between prior expectations and performance after consumption. Measures include: Self-efficiency, repeat visits, personalisation, perceived risk and enjoyment.	A learner will feel satisfied when he can use novel information to explain a problem (Jonassen, 2006).

Table 2.3: The interpretations of the dimensions of the ISS model proposed by Zaied, (2012)

2.8. CONCLUSION

This chapter partially addressed the second research question: How can each dimension of the ISS model contribute meaningfully in educational environments? It investigated the South African educational context and the problems that South Africa faces in term of mathematics education. The literature suggests how meaningful learning in mathematics could be achieved and highlights the proficiencies which learners should master to be successful in mathematics. The literature proposes that meaningful learning could be achieved by implementing meaningful environments. A meaningful environment could be an environment where inquiry based learning is promoted. It should be taken in consideration that learners' approach to traditional learning is changing. Learners believe that the use of ICTs could enhance their learning. Learners want to be actively engaged in the classroom and have meaningful discussions. The literature promotes the use of ICTs in education which could enhance learning. The importance of mobile learning and the use of mobile applications are also emphasized. It is particularly important to understand how teachers evaluate, select and use mobile applications. This led to the search for a framework which could be used to evaluate how teachers evaluate, select and use mobile applications. Chapter 3 specifically describes the research paradigm, research design and methodology followed to develop a conceptual framework, evaluate the framework, gather and analyze data.

CHAPTER 3

RESEARCH METHODOLOGY

3.1. INTRODUCTION

This chapter describes the research methodology used in this study. Section 3.2 states the research questions and moves on to Section 3.3 which explains the research paradigm. The research paradigm is the theoretical framework which provides motivation and guidance. The research paradigm also describes the ontology and epistemology of this study. The ontology describes the objects and variables in the theoretical framework and the epistemology defines how we know what we know, which could be regarded as the literature study. The research design is described in Section 3.4. The research plan describes the research philosophy, namely interpretivism, the research approach which is qualitative, the research strategy, namely evaluation research, the evaluation research methodology and the conceptual framework. The data collection process is described in Section 3.5. Section 3.6 emphasises the limitations of this study and the ethical considerations are described in Section 3.7. Section 3.8 explains how the researched data could be triangulated. Section 3.9 concludes this chapter.

3.2. RESEARCH QUESTION

The primary research question is the following:

- How can the application of the Information Systems Success model as proposed by Zaied (2012) be used to evaluate mobile educational applications that support meaningful learning in mathematics?

Secondary Research Questions

SQ 1: How do teachers evaluate and select mathematical applications?

SQ 2: How could each dimension of the ISS model contribute meaningfully in educational environments?

3.3. RESEARCH PARADIGM

Personal philosophical assumptions, concepts and propositions orientate a researchers thinking and research (Bogdan & Biklen, 1998). Our thinking directs our beliefs about the nature of knowledge, methodologies and our criteria for validity (MacNaughton, Rolfe, & Siraj-Blatchford, 2010). The research paradigm as theoretical framework determines our motivation for undertaking a study, and the way knowledge is studied (Bogdan & Biklen, 1998; Mackenzie & Knipe, 2006).

There are certain tools and methods of science that can be used to study education. These utilities cannot be used outside of a theoretical framework that represents a shared language and assumptions that will guide comparisons of approaches and ways of thinking (Redish, 2004)

An example of a theoretical framework is the Technology Acceptance Model by Masrom (2007) that proposes that the perceived ease of use and perceived usefulness of applications determine their usage. Another example of a framework is a model developed by Zaied (2012) to evaluate the success of information systems in the public sector.

Both educators and scientists want to use observations, analysis and synthesis to reach their specific goals. An educator wants in depth understanding of teaching and learning to create the most suitable environment for learners to learn effectively. A scientist wants to examine phenomena that define learning and teaching environments (Redish, 2004). A collection of facts can be used to create comprehensible knowledge about phenomena and knowledge can be used to evaluate, refine and make sense of new phenomena. The difference between educational and scientific research is that the goals in educational environments often determine views of the system being investigated (Redish, 2004)

If goals and objectives in education are to be improved we need to understand how systems in education work. This could be achieved through scientific research. If the system is investigated from an educational point of view, it will only be possible to determine how teaching and learning can be improved (Redish, 2004)

The goal of a theoretical framework is to not lose sight of educational goals but at the same time to investigate the educational system from a scientific point of view. "At present research and development in education is dominated by observations and direct educational goals" (Redish, 2004). Science cannot be defined by these two factors alone. Science relies on objects and variables that will help to determine the behaviour of a system and in that way we a science could be built. This process can be referred to as mechanism. The description of the objects and variables in such a system can be referred to as the ontology of the research (Redish, 2004; Schraw, 2013).

3.3.1. ONTOLOGY

According to Gruber (1995) "An ontology is an explicit specification of a conceptualization". Ontology represents a methodological and logical summary of all the different objects and variables contained in the theoretical framework. It would be safe to say that this representation will only apply to a particular framework used at a particular time. This simple classification is acceptable when dealing with philosophical ontology but when dealing with information systems ontology this simple classification needs further clarification (Zúñiga, 2001).

Philosophical ontology created a relationship between information systems and philosophy but the roles of ontology in both of these are different. Information systems ontology language is developed to represent knowledge in a specific field of study. In efforts to computerize information the goal is to create a common language and to develop knowledge in a particular field of study not only to share with common disciplines but especially inter-disciplinary (Gruber, 1995; Zúñiga, 2001).

After the process of defining objects and variables and the collection of facts through interviews and observations, mechanisms can be created to derive new facts or check for consistency in existing theoretical frameworks. For example, in an interest in education-related knowledge, learners, teachers, learning materials, learning aids and assessments might be among the objects and variables included in the knowledge domain of the theoretical framework. These objects and variables will define the ontology for education. This ontology can be used to facilitate the development of mobile educational applications and the improvement of communication systems within the education sector (Jurisica, Mylopoulos, & Yu, 2004).

From a researcher's point of view it is very difficult to be objective about the outcome of the investigation. The outcome is often conceptualised in the knowledge that a researcher's and the participants' realities are different. The variables in the theoretical framework are unpredictable and may create unforeseen outcomes. The interviews and observations of the participants, as well as the effective use of mobile educational applications stands central in the success of this study. The outcome of this study is subjective as the researcher was involved in the process of conceptualizing the events taking place in these educational environments.

3.3.2. EPISTEMOLOGY

Epistemology defines how we know what we know, especially how knowledge is defined and the insight that the knowledge is valid (Hirschheim, 1985). Hirschheim (1985) states that this problem is quite simple: Man cannot stand independent of his language and culture and therefore man does not have the ability to have objective viewpoints. Knowledge claims have to be supported by evidence for it to be acceptable to society as truth (Hirschheim, 1985; Siegel, 2005). The search for understanding or evidence uses tools, techniques and approaches that are acceptable for a specific field of study. That is why knowledge is not infallible but conditional and subject to societal acceptance at a specific time and place.

Evidence of knowledge claims is not illogical but has throughout the years stood the test of time. Evidence at a specific point in time has through superior arguments and agreed best understanding, produced knowledge claims that are still recognised today. Nonetheless, future information about similar topics may change that status quo of knowledge claims to un-accepted (Hirschheim, 1985). The literature review in this study will act as the epistemology for this study.

3.4. RESEARCH DESIGN

A research design is a "plan or strategy which moves from the underlying philosophical assumptions to specifying the selection of respondent, the data gathering techniques to be used and the data analysis to be done" (Cohen, Manion & Morrisen, 2007).

Saunders, Lewis and Thornhill (2011) developed a model that illustrates different perspectives of the research methodologies. This model is represented as a research onion with many layers. The research onion is illustrated in Figure 3.1 below.

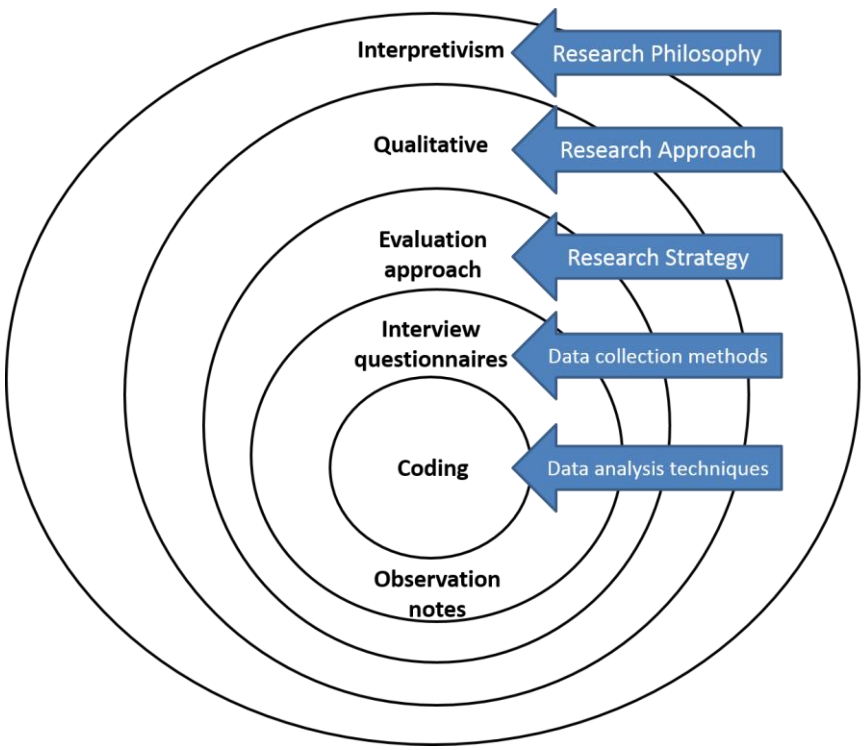


Figure 3.1: Adapted research model (Saunders, Lewis & Thornhill, 2011).

The research onion compares the research process to peeling different layers of an onion until the centre has been reached. The first layer that should be peeled is the research philosophy that underpins the study. The research approach should then be explained followed by the research strategy. Data collection methods must be chosen and lastly data analysis must be conducted. Data analysis can be seen as the result of reflection on the previous layers.

This design was influenced by the main research question: How can the application of the Information Systems Success model as proposed by Zaied (2012) be used to evaluate mobile educational applications that support meaningful learning in mathematics?

3.4.1. RESEARCH PHILOSOPHY

Interpretivism can be defined as an approach to qualitative research that assumes that truth is socially constructed. The primary goal is to investigate how respondents construct their meanings in certain phenomena (B. Kaplan & J. Maxwell, 2005).

Interpretivism's roots can be found in both anti-positivism and a constructivist paradigm (Mack, 2010). There are two distinct parts to interpretivism. Firstly, hermeneutics forms the basis for this paradigm. Hermeneutics is a theory that can be used to interpret the meaning of texts, and it is a philosophy (Bleicher & Bleicher, 1980).

Secondly, phenomenology has a strong influence as well. Phenomenology is the study of phenomena. This means a way of discovering how people interpret certain phenomena and how their world view influences their interpretations (Mack, 2010). People assign different meanings to different phenomena (Myers & Avison, 1997). The goal of interpretivism is to try and understand the complexity of the phenomena and how humans understand them (Myers & Avison, 1997).

The role of scientists using this paradigm is to rather understand or demystify the phenomena being studied than to explain them. The fact that teachers and learners share the same environments with the goal to construct meaning does not infer a causal link. There are however, correlations. To believe that there are causal links in this situation is a fallacy (Gardner, 2000; Mack, 2010). The roles of researchers include not predefining dependent and independent variables. The researcher will not be able to make an objective conclusion from outside of the phenomena. He has to make sense of world views and realities through the eyes of his participants (Mack, 2010; Taylor, 1976).

Leiviskä (2013) explains that the understanding of hermeneutics does not require an interpretation of literature or an aesthetic experience. The potential exists to derive meaning from any situation that anybody encounters that requires understanding. The meaning of an encounter can be understandable if an interpreter can use existing knowledge to give meaning to the phenomena. If existing knowledge cannot be used to give understanding to the phenomena the interpreter should engage with the object to establish meaning (Gadamer, 1976). The meaning will consist of pre-understanding of the interpreter and new knowledge of the object that needs to be compiled (Leiviskä, 2013; Schuster, 2013). The knowledge of an interpreter is bound only to encountered phenomena. The act of understanding allows these boundaries to be re-determined and will result in more insightful and sophisticated understanding (Leiviskä, 2013; Schuster, 2013). Leiviskä (2013) explains that it is difficult to determine the certainty of this knowledge, which makes hermeneutic understanding an endless task.

Hermeneutics and interpretivism will act as the general philosophical position. These philosophical standpoints will help to understand the involvement of humans and their practical choices in everyday life (Williams, South, Yanchar, Wilson, & Allen, 2011). A meaningful human phenomenon needs to be explored from a standpoint of practical human involvement.

3.4.2. RESEARCH APPROACH

Qualitative research can be defined as a detailed study of individuals in their natural settings where open-ended interviews are normally used to elicit detailed and in-depth data on the experiences and perspectives of participants on a specific phenomenon taking place (Kaplan & J. Maxwell, 2005).

The major purpose of the research is to understand the context and processes of how mathematics educators evaluate, select and use mobile educational applications. That is why qualitative research alone may be needed (Ritchie, Lewis, Nicholls & Ormston, 2013)

Ritchie et al. (2013) outlined a few factors that necessitate a single research approach and included the following:

- *Phenomena not defined or well understood:* It will be difficult to measure the subject matter if the phenomenon is not clearly defined. Qualitative research will provide the opportunity to clearly understand the nature of the problem. It is known that educators use mobile educational applications to facilitate learning processes, but it is difficult to understand how they evaluate, select and use these applications.

- *Deeply rooted:* There are limited guidelines that support educators to make informed decisions regarding mobile educational applications. Knowledge, beliefs, attitudes and experiences are factors that can facilitate educators' choices (Ritchie et al., 2013). The nature of this problem will lead the researcher to investigate the factors influencing participants thought processes.

- *Complexity:* The nature of this problem is complex because it creates a desire to rationalise thought processes into a logical structure that can be used to evaluate mobile educational applications. It needs to be investigated whether the logical framework proposed by Zaied (2012) can be used to guide the evaluation process. If not, the results will show that there are no correlations between participants thought processes and the framework used.

- *Delicacy or intangibility:* People have thought processes and choices that are intangible. The framework proposed by Zaied (2012) will enable educators to logically structure their thought processes. This will assist educators to evaluate and choose mobile educational applications that will make valuable contributions to meaningful learning. Interviews and observations will assist the uncovering of participants' perceptions and responses (Ritchie et al., 2013).

It would be difficult to address the above mentioned factors in structured surveys. Using qualitative research as a method, researchers have the opportunity to ask the questions of why or how. This will lead to a better understanding of this phenomenon's reality (Jackson, Drummond & Camara, 2007; Kaplan & Maxwell, 2005). This reality occurs in a natural environment where participants were observed and interviewed. The discovery of knowledge exhibits that there are explanations for the phenomena (Nieuwenhuis, 2011).

This study followed an inductive approach to analysing data. The aim of the analysis process was to test whether the data obtained from participants were consistent with the information in the conceptual framework (*cf.* Par 3.4.5). Through interpretations, new concepts were discovered from the raw data (*cf.* Par 3.4). The conceptual framework acted as an evaluation tool or educational artefact under investigation (Thomas, 2006). It was necessary to describe whether the ISS model created by (Zaied, 2012) could have an influence on the way teachers evaluate, select and use MEAs. The data analysis was guided by the ten dimensions in the ISS model. The findings were influenced by the questions developed by the researcher and arose from the data gathered from the participants. It was very difficult for the original ISS model to create a set of expectations about specific findings. The ISS model is created for information systems which operate within business environments and its application into educational environments is novel. The data that were attained from each dimension through interviews and observations produced key concepts which could be used to construct a framework or model (Thomas, 2006). The findings are influenced by the assumptions and experiences of the researcher. The researcher had to decide which concepts identified from each dimension of the ISS model was important enough to form part of the findings. This assisted the researcher to clearly communicate what he has found and why it matters (Williams & Morrow, 2009). The data analysis process is described in Section 3.5.3.

3.4.3. RESEARCH STRATEGY

Evaluation research is the core strategy for this research. The evaluation is concerned with how well mobile educational applications work (Ritchie et al., 2013). The purpose of evaluation is to produce information that can contribute to policymaking, decision-making and future improvements (Arthur & Cox, 2014). In order to carry out evaluation requires information on how educators evaluate, choose and use MEAs. The achievable outcomes that the MEAs propose in order to attain in-depth understanding of the dynamics of how MEAs operate also required investigation (Ritchie et al., 2013) The outcomes of the MEAs might have effects or consequences that have to be managed because of its influence on meaningful learning.

To be able to evaluate educators' evaluation methods, choices and use of MEAs requires a comparison to existing theories or models. That is why the framework proposed by Zaied (2012) as a blueprint was used. The dimensions created by Zaied (2012) should not be viewed as dependent or independent variables that need to be assessed. These dimensions are discrete entities that are viewed from an objective point of view. It needs to be determined whether the dimensions can contribute to a dynamic process that can enhance meaningful learning (Kaplan & Maxwell, 2005). The causal processes need to be investigated and not the causal relationships that exist between the dimensions. There might be correlations between the dimensions, but it does not infer causality (Gardner, 2000).

It was necessary to understand what the practical activities and challenges experienced by the educators are when engaging in the evaluation of MEAs (Williams et al., 2011). The goal is to produce generalized knowledge and to determine the merit or worth of evaluating MEAs (Shuster & Braeger, 2002). Information derived from interviews and observations might show that some of the dimensions needs refinement, are unsuitable or new dimensions must be added. This will enable the creation of a suitable and trustworthy framework that educators can use to evaluate MEAs. Educators will have peace of mind that their choices will contribute to a meaningful learning process.

(Kaplan & Maxwell, 2005) propose five main reasons why evaluation research has to be used as a strategy to evaluate computer information systems:

1. Understanding how a system's users perceive and evaluate that system and what meanings the system has for them:

Evaluation research provides the opportunity to have a detailed examination of educators' behaviours. This process will disclose the educator's behaviour towards mobile educational applications. Educators' behaviour can be regarded as successful or not towards mobile educational applications. It might be that positive behaviour towards MEAs can be regarded as success and negative behaviour as failure. Educators could evaluate, observe and give meaning to MEAs based on a positive or negative experience with MEAs. It is important to clearly define what a positive and negative experiences might be to be able to determine success or failure (Kaplan & Shaw, 2004).

2. Understanding the influence of social and organizational context on systems use:

MEAs are evaluated, implemented and used within a certain social or organisational context. The context has the ability to determine to what extend MEAs have to reform the context. The MEAs' functionality and influence are shaped by the context. This is why the context of a study cannot be seen as a separate entity when evaluating MEAs. It has to be acknowledged that the evaluation, selection and use of MEAs are unlike in different contexts (Kaplan, 2001; Rogers, 2010). The researcher has certain perspectives about the context of the study and cannot predict what the contextual influences will be.

3. Investigating causal processes:

A researcher has the ability to investigate the actual facts on how people evaluate, select and use MEAs. Evaluation research provides the opportunity to describe these events and processes of evaluation, selection and use and could lead to theory building (Miles & Huberman, 1994). Again, the aim is not to prove causality between the dimensions proposed by Zaied (2012) and the participants behaviour but correlations may be found (Markus & Robey, 1988).

4. Providing formative evaluation that is aimed at improving a program under development, rather than assessing an existing one:

Any context or system wherein people work or study, set certain goals, defines roles, provides tasks and makes assumptions on how people should think about their work. The mistake could be made that the dimensions of Zaied (2012) are used to evaluate the outcomes set by a context, or the model could be used to identify problems in the educational environment as they arise. Learning environments and MEAs that are mutually transformative enable educators, designers and implementers to change project definitions and enable learning in a spontaneous way while MEAs are implemented and used. This provides the opportunity to react proactively towards problems and improve educational systems as they develop (Kaplan & Shaw, 2004). Problems that are identified can help to give feedback to designers and implementers of MEAs. The outcomes of the evaluation process will also assist future studies of MEA practice.

5. Increasing the utilization of evaluation results:

Evaluation results have to give greater insight on how educators evaluate, select and use MEAs. The result will also support the understanding that administrators, policy makers and designers have of the environments where MEAs are used and the problems that educators encounter. The credibility of the results can only be improved if decision makers find the results useful (M.Q. Patton, 2001). The outcome of the evaluation was determined by predetermined criteria set by the researcher; these are the objectives of this study (Arthur & Cox, 2014).

The objectives of this study were:

- To investigate current literature regarding the use of mobile technologies in education;
- To investigate how MEAs could support meaningful learning in mathematics;
- To evaluate teachers' evaluation, selection and use of MEAs and
- To propose a framework which teachers could use to evaluate and select MEAs which could contribute to meaningful learning.

These objectives will help to solve the research problem: How can the application of the Information Systems Success model as proposed by Zaied (2012) be used to evaluate mobile educational applications that support meaningful learning in mathematics?

3.4.4. EVALUATION RESEARCH METHODOLOGY

A. INTRODUCTION

Evaluation is a tool used to measure and report on the results of outcomes and objectives (Suvedi & Morford, 2003). Evaluation takes place when somebody collects evidence to enable them to make a judgement about an input or part of an input. Each input should provide an output given the intention of the input. Standards are set for inputs based on the fact that the inputs fulfilled, partially fulfilled or unfulfilled the outcomes (Case, Andrews & Walter, 1988).

The purpose of evaluation should be carefully considered. The purpose of evaluation could be to:

- guide decisions
- communicate to/with administrators, policy makers, designers
- identify strengths and weaknesses of a programme
- determine whether or not to repeat or continue with a programme

The purpose of evaluation for each stakeholder in a programme could vary. It is the researcher's responsibility to clearly communicate the purpose of the evaluation to the stakeholders to avoid confusion (Suvedi & Morford, 2003).

There are three main types of evaluation:

Summative evaluation: Summative evaluation normally happens at the end of a programme to judge the extent of learning, progress and the effectiveness of a programme (Suvedi & Morford, 2003; Wiliam & Black, 1996).

Formative evaluation: Formative evaluation occurs continuously. The focus of formative evaluation is not on the programme itself but on the inputs of the programme. If the inputs of a programme are working effectively, the programme as a whole would be successful. The evidence on the success of previous inputs is able to direct the success of new inputs (Suvedi & Morford, 2003; Wiliam & Black, 1996).

Evaluation that generates knowledge: Evaluation generates new knowledge if a system or programme is evaluated and new trends, correlations and causal links are discovered (Suvedi & Morford, 2003)

MEAs are implemented into a context or system where different stakeholders are involved. It was previously explained that both the MEAs and the stakeholders influence each other and that the MEAs cannot be evaluated on their own. That is why evaluation has to provide reliable information that can be used to judge the whole programme's effectiveness (Suvedi & Morford, 2003).

Clear, specific and measurable objectives are required for evaluation to be successful. Each object or inputs within the objectives consist of characteristics. The quality of the characteristics can only be measured if we use standards and criteria objective of the object. Criteria originate from experience, previous valuations or recognition of merit. It is very difficult to define success, quality and excellence but global valuations made it possible to recognize these phenomena. Global valuations also assist in the creation of common elements that make it possible to explain criteria (Suvedi & Morford, 2003).

B. EVALUATING THE ISS MODEL DEVELOPED BY Zaied (2012)

The information systems success model developed by Zaied (2012) was used to evaluate how teachers evaluate, select and use MEAs. This model was described in the theoretical framework, Section 2.7. The ten dimensions of this model were evaluated through semi-structured interviews and/or observations. The conceptual framework identified and explained the components in the literature which could be practically applied to this study (*c.f.* Par 3.4.5). The conceptual framework provided clear, specific and measurable objectives according to the model which could be used to evaluate effectively and to provide successful feedback on the results. The information generated from the semi-structured interviews and/or observations generated new knowledge on how teachers evaluate, select and use MEAs and the results are discussed in Chapter 5. The interview questions and observation schedule can be viewed in Annexure A and B.

C. EVALUATION PROCESS

The following figure illustrates how the evaluation process was conducted.

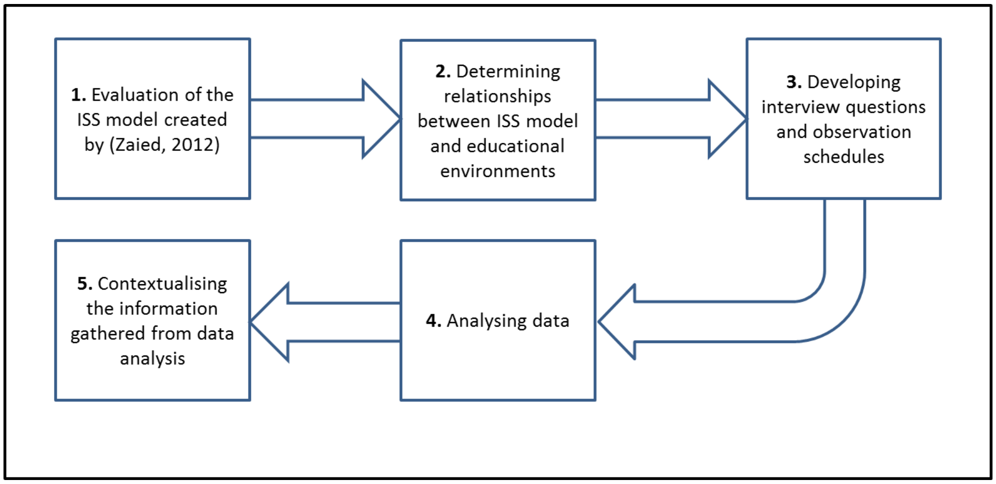


Figure 3.2: Process of evaluating the ISS model (Researcher)

1. Evaluation of the original Information System Success Model created by Zaied (2012)

When it was decided to use this model as the conceptual framework for this study it was important to consider that the model was originally developed to assist businesses. It was imperative to understand the true meaning of each dimension to be able to apply it to an educational environment.

2. Determining the relationship between the ISS model and educational environments

It was important to determine the relationship between information systems and MEAs. This relationship is discussed in the theoretical framework, Section 2.7. Table 2.3 in chapter 2 describes how Zaied (2012) and other sources understand the ten dimensions in this model. Similar meanings had to be found within educational environments to keep the authenticity of the model intact and to justify why this model could be used as an evaluation tool that could be trusted. The conceptual framework of this study was used to explain how the ten dimensions could be practically applied on educational environments (*cf*. Par 3.4.5).

3. Developing interview questions and observation schedules

The conceptual framework was used to develop interview questions and to construct an observation schedule. The interview questions were the foundation which guided conversations in the semi-structured interviews. The ten dimensions in the conceptual framework guided the creation of the observation schedule. The observation schedule guided the observations. The observation schedule and interview questions can be viewed in Annexure A and B.

4. Analysing data from interview schedules and observation notes

After the data were collected from the interviews and observations, they had to be analysed. A detailed discussion of the data analysis is described in Section 3.5.2. The aim was to find relationships between the conversations and observations that took place and the meanings of the ten dimensions in the conceptual framework. These relationships provided information to determine whether the ISS model could be used as an evaluation tool.

5. Contextualising the information gathered from data analysis

Although the ISS model could be used to evaluate any given information system, this study specifically focused on the evaluation of MEAs in mathematics. It is the responsibility of the researcher to apply the ISS model as evaluation tool in the context of a study. It could happen that different contexts might require more or even less dimensions. The model could be changed to complement the context or environment of the research.

3.4.5. CONCEPTUAL FRAMEWORK

The ISS model was used as a conceptual framework to guide the development of interview questions and an observation schedule. The aim of the questions and schedule was to gain a better understanding of how teachers evaluate and select mathematical applications. The conceptual framework was also applied to determine whether the ISS model could be used to evaluate and select mathematical applications. The first three dimensions of the model could be regarded as the factors which influence the functionality of applications. Dimensions four to six are external factors which could influence the first three dimensions. Dimensions one to six have to work together to determine the perceived ease of use and perceived usefulness of applications. These dimensions have an influence on the behavioural intention of a teacher or learner which will determine the satisfaction they will derive from an application. Each of the dimensions consists of characteristics identified by literature which are measurable and achievable. The meaningful contribution of each dimension is discussed in Chapter 5 (*c.f.* par 5.2). The interview questions and observation schedule can be viewed in Appendix A and B.

The following table illustrates how each dimension of the ISS model is addressed by the interview questions and observations.

	Dimensions of the ISS model									
Interview questions	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	Determines perceived ease of use and perceived usefulness									
	Focus on internal functioning of applications			External factors influencing Dimensions 1-3						
1.	✓									
2.	✓									
3.	✓									
4.	✓									
5.	✓									
6.		✓								
7.			✓							
8.				✓						
9.					✓					
10.						✓				
11.							✓			
12.								✓		
13.									✓	
14.									✓	
Observation notes taken?	✓			✓	✓		✓	✓	✓	

Table 3.1: Illustration of the relationship between interview questions, observations and dimensions of the ISS model

A System

A system is created when different aspects are working together as part of an interconnected whole. In the context of this study, the mathematical application is at the core of the broader mathematics educational environment. The other parts of the system can be seen as the educator, the learners, the curriculum, the school, etc.

The following discussion places each of the 10 dimensions in the ISS model created by Zaied (2012) within the educational environment investigated in this study.

1. **Information quality:**

From an educational perspective, information quality can be seen as the ability to evaluate and use information effectively (Bruce, 1999). The content of any mathematical application is compiled from various mathematical information sources. The teacher's mathematical knowledge and experience in mathematics will determine his/her choice of application. The credibility of the information of the application must be verified. This implies that if the teacher has inadequate knowledge and experience, he/she would find it difficult to choose the most suitable application to support meaningful learning.

Every teacher might experience information literacy as something else. Bruce (1999) describes six experiences that teachers might have to be able to discern between appropriate and inappropriate information:

1. Using information technology to stay informed and to communicate.
2. Finding information from appropriate sources/knowledge of information sources.
3. Using information to solve problems.
4. Internalising information to make it retrievable.
5. The acquisition of knowledge in a new area of interest.
6. Using personal knowledge and experience together with creative insight to develop new forms of knowledge and new approaches to tasks or novel solutions.

When teachers evaluate mobile educational applications the following criteria should also be taken into consideration:

- Is the information well organised?
- How the information is effectively presented.
- Is the information of the right length?
- Is the information clearly written?
- How useful is the information?
- Is the information up to date?

2. System Quality

System quality could consist of two dimensions. System in educational terms can be described as an educational institution, classroom or learning environment. The use of mathematical applications should support the tasks of the teacher and they must effectively enhance meaningful learning. The goal of the application is to provide a learning experience. The application must be effective in the process of the learning and assessment of mathematics and should support learners to achieve their mathematical learning objectives (Brink, 2010).

System quality could also refer to the quality of the mobile educational application. Quality characteristics of information systems could include the following:

- The ease of use of the MEA.
- User friendliness of the MEA.
- Stability of the MEA.
- Security features on the MEA.
- The speed at which the MEA operates.
- The responsiveness of the MEA.

(Holsapple & Lee-Post, 2006)

3. Service Quality:

The purpose of this dimension is to determine whether the mathematics application matches customer expectations. Learners expect that the mobile application might help them to learn mathematics meaningfully. Applications with content mistakes and functionality problems will not meet the expectations of learners (Holsapple & Lee-Post, 2006). This is why the teacher has the responsibility to determine the following:

- Whether there are frequent communications from the developer of the application.
- Whether a communication platform is available where a teacher can report problems to the developer.

The developer and teacher would have the opportunity to correct content errors and to add new content to existing information. This will improve customer satisfaction and support the meaningful learning of mathematics.

The following criteria can be used to evaluate the quality of service from developers and to evaluate the quality of service the user receives from the application.

Quality service received from developers	Quality service received from application
• How prompt is the feedback received from developers?	• How prompt is the feedback after completing an assessment activity on the mobile application?
• Are the developers responsive?	• How responsive is the feedback received?
• Is the service received reasonable or fair?	• Is the outcome of the assessment fair?
• Are there platforms for teachers to make knowledgeable contributions?	• Does the assessment make a knowledge contribution to the user?
• How available are developers to respond to questions?	• How available are assessment opportunities?

Table 3.2: Differences in quality service (Holsapple & Lee-Post, 2006).

4. **Management Support**

Management refers to the people and processes involved in managing an educational institution and a classroom. The management can support meaningful learning by:

- Approving and supporting the use of mobile mathematical applications.
- Encouraging teachers and learners to use mathematical applications.
- Providing resources like mobile devices to use mathematical applications.
- Providing training on how to use mathematical applications that will support professional development.
- Acknowledging the positive impact that mathematical applications might have on learning.
- Providing equal access to applications for all learners and teachers. (Jonassen, 2006)

5. **Training**

Jung (2005) created a model to demonstrate the extent to which ICTs could be used in the professional development of teachers or learners. The management of educational institutions should determine the knowledge and skill level of teachers and students to determine to what extent training is needed.

The goal of training is to equip the teachers/facilitators with specific skills that he/she can use to employ mobile educational applications effectively in the classroom. The teacher/facilitator will be able to make a meaningful contribution to learning by giving excellent training, guidance and support to students (Jung, 2005).

Training and user involvement can increase user satisfaction. There will be "first time" users of applications and ICTs and they will require training. The necessary training material must be compiled and the role of the user must be emphasised (Zaied, 2012). Users must be involved in input and output design, evaluation of applications and determine the value of the use of the applications (Zaied, 2012). This will support users' satisfaction.

6. **User involvement**

The lack of adequate information from designers may lead to products being designed that do not meet the need of specific users in a specific environment. In order to avoid this, developers decided to incorporate a user-centred approach to their design process (Altay, 2014). Altay (2014) explains that an educational artefact such as a mobile mathematical application can reach a wider audience, increase productivity and reduce errors if this approach is to be followed.

Users have the opportunity to get emotionally engaged if designers pay attention to their conceptualizations and meanings. This process can take place if designers observe, interview and shadow users, or if users take part in the design process. Other methods also include storytelling and photography (Altay, 2014).

7. **Perceived usefulness**

(*cf.* Par 2.4)

8. **Perceived ease of use**

(*cf.* Par 2.4)

9. **Behavioural intention**

The perceived usefulness and ease of use of the application will direct the user's intention to use the mobile application. The user will only be driven to learn through the mathematics application if they find meaning in specific tasks in the application and if they are able to make that meaning their own (D. H. Jonassen, 2006).

10. **User satisfaction**

The mobile application can only assist in the process of meaningful learning if the user experiences conceptual conflict. This means receiving unfamiliar information that can't be linked to anything the user already knows. If a learner is able to complete a learning objective with the support of a mathematics application, he/she will feel gratified by using the mathematical application in his learning process (Jonassen, 2006). This can be observed by administering a worksheet which learners complete with the support of a mathematics application. This will assist to determine whether the application can support meaningful learning or not.

3.5. DATA COLLECTION

The data collection process is briefly summarised as follows:

1. Different types of mathematical applications were explored. Some of these applications were pre-selected for the study (*cf.* Par 2.6).
2. Two schools were used. One school is situated in a rural community (School A) and one in an urban community (School B). Both schools are implementing mobile learning. The participants included mathematics teachers as well as other subject specialists (*cf.* Par 3.5.2)
3. Data will be collected through interviews with teachers, as well as observations of mathematics classes. The ISS model created by Zaied (2012) was used to guide his interviews with teachers and to serve as a foundation to observe teaching and learning in the classroom.

3.5.1. PARTICIPATING SCHOOLS

The study explored how teachers evaluate, select and use mobile applications in their natural setting. The sample of interviewees was purposively selected. They are fairly equal and share some similarities. The goal was to maximise the depth and the richness of the data to address the research question (DiCicco-Bloom & Crabtree, 2006).

School A:

Description

School A is situated in the rural Eastern Cape. The school lacks some basic infrastructure and makes use of borehole water and pit toilets. There are unused classrooms and a sports field is available but in disuse. The school would like to develop their school grounds for sustainable agricultural initiatives. The school wants to become a "hub" for the community where they want to develop peoples' agricultural skills. The school already integrates ICT resources for teaching and learning in their classrooms.

Why did this school form part of this study?

School A is one of the schools involved in the TECH4RED project and more specifically the ICT4RED component, led by the CSIR and the DBE. This project provided the researcher with a bursary and an opportunity to link this study to the project. ICT4RED provided school A with training opportunities which specifically focused on the integration of mobile devices (tablets) in their classroom environments. Their training specifically aimed to developed teachers' knowledge and skills to create educational environments which would reflect 21st century teaching and learning (Herselman & Botha, 2014). It was known that the school lacks basic infrastructure. There is no dedicated Internet connection which learners and teachers can access. There is a shortage of financial resources which limits the upgrade of existing technology and the procurement of new technology. The teachers have limited opportunities to learn new skills and knowledge through formal training institutions, due to a lack of physical and financial resources. Although training was provided to the teachers, the researcher was intrigued to investigate how teachers evaluate, select and use MEAs in their classrooms which could contribute to meaningful learning, regardless of their limitations.

School B:

Description

School B is situated in Pretoria East. This school is equipped with the necessary infrastructure to provide learners with the best possible education. Learners have the opportunity to take part in extracurricular activities of their choice. The school replaced the use of textbooks with tablets. The textbooks are available as an electronic source on the tablets.

Why did this school form part of this study?

School B has introduced the use of mobile devices (tablets) a few years ago. The learners had to buy their own tablets. The school systematically introduced the use of e-books and moved away from using textbooks. The school has proper infrastructure in place with an open Internet connection for both teachers and learners. Every teacher has been provided with a laptop and mobile computer (tablet). All the classrooms are equipped with projectors which could connect to their laptops and wirelessly connect to a mobile computer. There are enough financial resources to upgrade the current technology and to acquire new technology. The school welcomes innovative suggestions and ideas from teachers to promote the use of technology in their educational environment. They encourage teachers to further their education in ICTs. School B has very few constraints which could be identified in terms of infrastructure, technology and finance. The researcher was nevertheless intrigued to investigate how teachers in such an environment evaluate, select and use MEAs.

What these schools have in common is that both incorporate the use of mobile devices and mobile applications in their classrooms. The research findings (Chapter 4) produced information which clearly indicates the impact that infrastructure, technology and finances have on the ten dimensions of the ISS model which were used as an evaluation tool (educational artefact) to evaluate how teacher evaluate, select and use MEAs.

3.5.2. POPULATION AND SAMPLING

The following table summarises the characteristics of the participants who formed part of the sample of this study.

	Characteristics						
Participants	Use mobile computers and applications	Rural School (School A)	Urban School (School B)	Mathematics Teacher	Other subject specialist	Technical Specialist	Headmaster
1.	✓	✓		✓			
2.	✓		✓	✓			
3.	✓		✓	✓		✓	
4.	✓	✓			✓		✓
5.	✓	✓			✓		
6.	✓	✓			✓		
7.	✓	✓			✓		
8.	✓	✓			✓		
9.	✓	✓			✓		
10.	✓	✓			✓	✓	

Table 3.3: Characteristics of the participants in this study (Researcher)

Mathematics teachers and their use of mobile devices and applications is the central interest of this study. This focus area forms the population of this study. Ten participants in total were interviewed. Eight participants were from School A and two from School B. Three of the participants are mathematics teachers, one from School A and two from School B. Seven participants from School A are teachers in other subject fields. One of these teachers is a technical specialist and one a headmaster. One of the mathematics teachers from School B is also a technical specialist. Six classes were observed.

Taking the ISS model and conceptual framework into consideration the researcher felt that if the inquiry only focused on mathematics teachers, the information attained from the participants, on the ISS model, might be biased. Therefore, several teachers who are not subject specialists in mathematics were included as a subgroup to gain better insight in the inquiry (Ritchie et al., 2013).

The sample is a non-probability purposive sample (Nieuwenhuis & Maree, 2007). This method was selected to specifically reflect unique characteristics of the population. This sample is not statistically representative. This study focused on a small number of participants through which rich and in-depth data could be attained. The participants were specifically chosen. The key characteristic for selection was teachers who are already using mobile devices and applications in their classrooms. Some diversity is included in the characteristics. It created the opportunity to explore how mathematics teachers evaluate, select and use mobile applications and to investigate how they are supported by technical specialists (Ritchie et al., 2013). The samples are fairly homogeneous in nature. Although the two schools are located in different areas and subject to different cultures the focus of the sample is still similar. The different environments might have different influences on the populations but should not define the samples which were selected.

3.5.3. DATA COLLECTION INSTRUMENTS

Kaplan (1964) as cited in Jackson et al. (2007) regard “method” as tools, techniques or procedures to gather data. Merriam (1998) defines data as “bits and pieces of information found in the environment”.

The main purpose of selecting the most suitable data gathering techniques is to provide answers to the research questions formulated during the conceptualization phase of a study. The environment in which the data is collected is very important as the data will only be understandable within the context of the evaluation taking place (Clarke & Dawson, 1999). (Berk & Rossi, 1999) emphasise that the researcher has the responsibility to provide as truthful information as is in his practical capabilities.

The study will investigate how teachers evaluate, select and use MEAs. This should provide a better understanding of the participants' construction of knowledge and the social reality through which they view MEAs (Nieuwenhuis & Maree, 2007).

A. INTERVIEWS

The purpose of the interviews is to collect rich data from teachers and then evaluate it according to the ISS model. This interview usually takes place in the form of a two-way conversation (Nieuwenhuis & Maree, 2007). This is a "conversation with a purpose" (Dexter, 2006). Interviews were conducted with mathematics teachers, technical specialists and teachers who are not mathematics specialists.

The type of interviews which took place was semi-structured. (Leech, 2002) explains that this type of interview can provide detail and depth while the interviews responses can assist in hypothesis testing. The central focus of the study which is the conceptual framework determined the compilation of the open-ended questions set for participants (Knox & Burkard, 2009). The researcher was open to accommodate the participants' stories in greater depth (DiCicco-Bloom & Crabtree, 2006; Hill et al., 2005).

Permission was obtained from the participants to record the interviews with a voice recorder. Notes were also taken during the interviews. After the conclusion of the interview, the voice recordings were transcribed on paper. The researcher reflected on his notes in conjunction with the transcription, and identified possible gaps in the interviews. The data analysis identified no gaps which may have required follow-up interviews.

Nieuwenhuis and Maree (2007) explain that it is necessary to understand how the participant is viewing this specific phenomenon under investigation, and how this phenomenon makes sense in the participants' world of reality. The study investigates how teachers evaluate, select and use MEAs which could support meaningful learning. A primary factor in an interview is gaining the trust of the participant. When the participant feels safe enough, it creates an environment in which he/she will share insightful knowledge that can't be collected in any other way (Knox & Burkard, 2009). The guiding interview questions can be viewed in Appendix A.

B. OBSERVATIONS

The main objective of the observations conducted during this study was to discern how interaction takes place in a classroom using MEAs. It was important to record how teachers interact with MEAs, how teachers interact with learners while using MEAs and how learners interact with MEAs. Five classes were observed at School A, of which four were mathematics classes and one was a non-mathematics class. Two classes were observed at School B, both were mathematics classes. Four mathematics applications which could be used to conduct the observations were pre-selected (*cf.* Par 2.6.1). It was also important to determine whether the applications could promote the five proficiencies of mathematics learning which forms an essential part of meaningful learning in mathematics (*cf.* Par 2.3). The researcher developed worksheets which the learners had to complete with the use of the pre-selected mathematics applications. The worksheets created the ideal opportunity for the researcher to conduct his observations in the classrooms. The worksheets can be viewed in Appendix G-J. When the classes commenced at School A, the mathematics teacher introduced the applications to the classes. He explained to them the reason for using the applications as well as how to use it. The teacher assisted the groups and individuals when they had questions, guiding them in their answering. It was immediately observed at school A that not all the learners had their mobile devices (tablets) ready for use in those specific periods. As a result learners spontaneously formed groups where they worked together to solve the questions posed to them on the worksheets. The researcher was actively engaged in the classroom which provided opportunities to ask questions, engage in informal discussion and record activities. The goal was to produce detailed descriptive accounts of events. The observer had the opportunity to elicit the teachers own explanations, evaluations and perspectives in the immediate context (Kaplan & Maxwell, 2005). A classroom observation protocol was drafted as well as observation notes. The classroom observation protocol can be viewed in Appendix B.

3.5.4. DATA ANALYSIS

A. HERMENEUTICS AS MEANS OF ANALYSIS

Hermeneutics is the underlying philosophy of this study but can also be used as a mode of data analysis. Hermeneutics provides the philosophical grounding for interpretivism and as a mode of analysis suggests a way of understanding contextual data (Bleicher & Bleicher, 1980). Hermeneutics recognises that shared understanding exists between individuals. These understandings become obvious through conversations. Our knowledge of phenomena occurs through these conversations or through the researcher's interpretation of text.

The objective with the use of hermeneutics is to investigate what the meaning of text or text-analogue is. This investigation is done by means of interpretation in an attempt to establish the meaning of a study or object (Radnitzky & Giorgi, 1973) (Harvey & Myers, 1995). Taylor (1976) explains that this object must be a text or text-analogue which in some way is inconsistent and indistinguishable. This interpretation intends to show that there is an underlying consistency in the investigation of the object.

B. THE HERMENEUTICS CIRCLE

The hermeneutic circle is a principle to interpret work of a hermeneutic nature. Klein and Myers (1999) emphasise that it is necessary to understand the preconceptions made about the object or study as well as the meanings of the different parts of the object and what their interrelationship is (Gadamer, 1976). The researcher has an expectation of meaning from the context of preceding events taking place. The principles of the hermeneutic circle show how the researcher moved between the small parts of the phenomena back to viewing the phenomena holistically and vice versa. This was a continuing process which enabled the interpretation of texts that could possibly lead to a better understanding of the phenomena.

The following diagram describes the different principles which form part of the hermeneutic circle. The application of the principles in this study is discussed in Chapter five.

Principles of the hermeneutic circle	
Description of principle	**Application to this study**
<u>The fundamental principle of the hermeneutic circle:</u> Gadamer (1976) explains that our movement of understanding is from understanding the concept as a whole, to the different parts it consist of and back to the whole. The synchronisation of detail in the relationships between different concepts and how they fuse into one concept is the criterion for understanding. If these concepts are not harmonious, understanding has failed. (Klein & Myers, 1999)	<u>Contextualization:</u> Gadamer (1976) explains that there are unavoidable differences between the interpreter and author and their understanding of the text. These differences were created by a time laps. The goal of contextualization is to express how the text created in the past and the present can fit together.
<u>Interaction between researcher and the subjects:</u> The researcher needs to put himself/herself and the subjects into historical perspective. Social interaction with the participants is important as facts about the object are produced as the relationship between the participant and researcher grows. (Klein & Myers, 1999, p. 74)	<u>Abstraction and generalization:</u> This entails linking the details about elements revealed in the data interpretation to "theoretical and general concepts that describe the nature of human understanding and social action" (Klein & Myers, 1999, p. 72)
<u>Dialogical reasoning:</u> The research design provides the lens through which data is documented. The researcher has preconceptions about his findings. If the researcher discovers that his findings are not aligned with his preconceptions, he will need to modify or abandon them. Hermeneutics wants to distinguish between "true" and "false" prejudices that might be a starting point for understanding (Klein & Myers, 1999, p. 76)	<u>Multiple interpretations</u> Within the social context of the study there might be elements that influenced the choices people make. The reasons for these choices must be examined from different viewpoints. There might be inherent contradictions in the different viewpoints but this will help the researcher to revise his understanding. (Klein & Myers, 1999, p. 77)

Principles of the hermeneutic circle	
Description of principle	**Application to this study**
<u>Suspicion</u> Suspicion requires sensitivity to possible preconceptions and misinterpretations in the stories collected from the participants (Klein & Myers, 1999, p. 72)	

Table 3.4: Principles of the hermeneutic circle (Klein & Myers, 1999).

C. DATA ANALYSIS PROCESS

The qualitative "raw" data were collected from interviews in the form of precise transcripts and interpreted notes from observations. The material was rich in detail, but undefined in content. Structure to the material had to be created in order to present the results and findings and to draw conclusions (Ritchie et al., 2013).

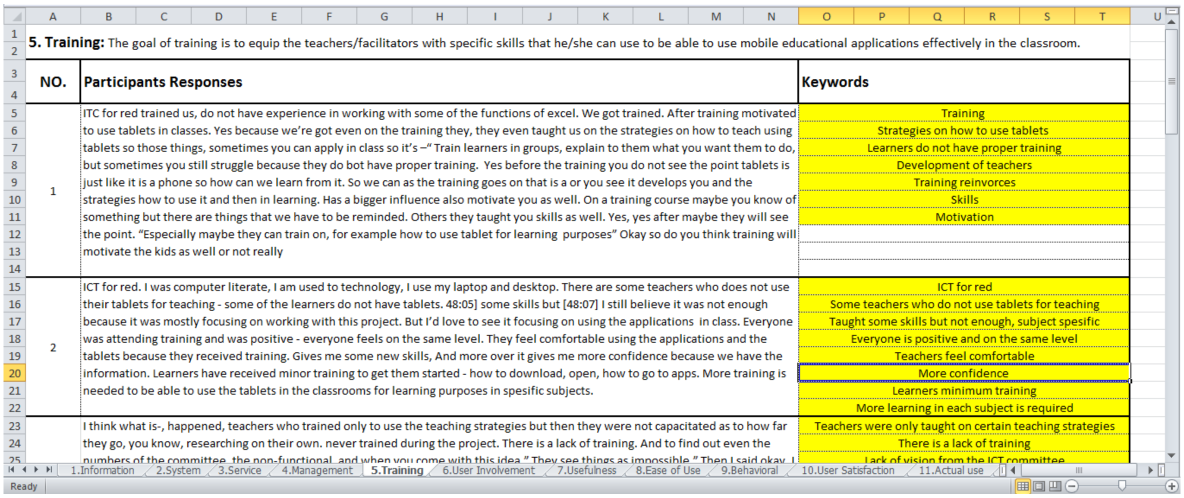
The following process outlined by Ritchie et al. (2013) was used to analyse the data:

Identifying initial themes and concepts

The ISS model and conceptual framework acted as an educational artefact in this study. The aim was to determine whether it could be employed by educators to evaluate, select and use MEAs. Before the data gathering process commenced, the ten dimensions of the ISS model were defined as the concepts which need to be evaluated in order to address the main research question in this study.

Indexing the data

The following snapshot provides an illustration of how the data in this study were indexed.



5. Training: The goal of training is to equip the teachers/facilitators with specific skills that he/she can use to be able to use mobile educational applications effectively in the classroom.

NO.	Participants Responses	Keywords
1	ITC for red trained us, do not have experience in working with some of the functions of excel. We got trained. After training motivated to use tablets in classes. Yes because we're got even on the training they, they even taught us on the strategies on how to teach using tablets so those things, sometimes you can apply in class so it's –" Train learners in groups, explain to them what you want them to do, but sometimes you still struggle because they do bot have proper training. Yes before the training you do not see the point tablets is just like it is a phone so how can we learn from it. So we can as the training goes on that is a or you see it develops you and the strategies how to use it and then in learning. Has a bigger influence also motivate you as well. On a training course maybe you know of something but there are things that we have to be reminded. Others they taught you skills as well. Yes, yes after maybe they will see the point. "Especially maybe they can train on, for example how to use tablet for learning purposes" Okay so do you think training will motivate the kids as well or not really	Training Strategies on how to use tablets Learners do not have proper training Development of teachers Training reinvorces Skills Motivation
2	ICT for red. I was computer literate, I am used to technology, I use my laptop and desktop. There are some teachers who does not use their tablets for teaching - some of the learners do not have tablets. 48:05] some skills but [48:07] I still believe it was not enough because it was mostly focusing on working with this project. But I'd love to see it focusing on using the applications in class. Everyone was attending training and was positive - everyone feels on the same level. They feel comfortable using the applications and the tablets because they received training. Gives me some new skills, And more over it gives me more confidence because we have the information. Learners have received minor training to get them started - how to download, open, how to go to apps. More training is needed to be able to use the tablets in the classrooms for learning purposes in spesific subjects.	ICT for red Some teachers who do not use tablets for teaching Taught some skills but not enough, subject spesific Everyone is positive and on the same level Teachers feel comfortable More confidence Learners minimum training More learning in each subject is required
	I think what is-, happened, teachers who trained only to use the teaching strategies but then they were not capacitated as to how far they go, you know, researching on their own. never trained during the project. There is a lack of training. And to find out even the numbers of the committee, the non-functional, and when you come with this idea." They see things as impossible." Then I said okay, I	Teachers were only taught on certain teaching strategies There is a lack of training Lack of vision from the ICT committee

Figure 3.3: Illustration of data analysis

The data in this study were indexed manually using an Excel spread sheet. The Excel spread sheet was categorised according to the dimensions of the ISS model which can be viewed at the bottom of the spreadsheet. The description for each dimension was briefly stated at the top of the sheet. Each participant was allocated a number which was recorded at the left side of the sheet. The participants' responses to each dimension were recorded next to each participant's number. The researcher read through each phrase, sentence and paragraph to determine the importance of the text. Keywords or phrases were referenced on the right hand side of the responses which were labelled "Keywords". No sorting was needed as the data were already indexed according to the ten dimensions of the ISS model.

Summarising or synthesising the data

There are two main reasons why it was needed to summarise the original data. Firstly, the amount of material was reduced to a more manageable level and secondly, to start the process of clarifying the data. Clarification of the data is needed to determine the importance of each word or phrase which was identified. The significance of each word or phrase provided in-depth meanings which were assigned to each ISS dimension. These meanings provided a holistic image of the research findings. The researcher intended to retain the key concepts identified from the clarification process which promoted the authenticity of the research findings. At this stage nothing of the text was interpreted. The text was kept in its original state to allow validation of the findings. It might seem that there are some texts which are irrelevant. As the data analysis process progressed it became clear that some of the texts which seem irrelevant could make a meaningful contribution.

3.6. LIMITATIONS

The limitations from both School A and School B are discussed below:

School A:

Communication:

Before that data gathering process started it was very difficult to get hold of the school principal. The first communication with the principal was through email but no reply was received. The principal was then telephoned and he answered and responded. After the researcher gathered data he attempted to do a follow-up enquiry with one of the teachers. This was to no avail as the teacher did not respond.

Location:

The researcher is situated in Pretoria while school A is in the rural Eastern-Cape. The researcher was provided with the opportunity to visit the school for a week. Although there was a need to conduct a follow-up interview it was difficult due to the remote location of the school and time constraints.

Finances

The researcher was allocated enough money to visit the school only once. The researcher had to make use of bed & breakfast accommodation and decided to drive to the destination by car. These expenses accrued to a large sum which made it difficult to revisit the school.

Availability of teachers

Although the researcher planned to conduct his interviews after school, most of the teachers were not available. The researcher had to adjust his planning to conduct the interviews during school hours. It was very difficult to schedule interviews and observations with all the planned interviewees within one week. The researcher planned to conduct follow up interviews while at the location but found it impossible due to the unavailability of the teachers.

School B

Time

The researcher had the opportunity to visit the school for a day. Within that day the interviews were held and but could not be concluded due to a lack of time. The researcher had to return to conduct more interviews and observations. This did not occur due to the unwillingness of teachers to cooperate.

Teachers' poor communication

When the researcher visited the school for the first time the teachers were very willing to participate in the interviews and observations. The teachers were aware that the researcher had to return to the school to conduct more interviews and observations. When the researcher attempted to contact the teachers to schedule an appointment, there was no response.

3.7. ETHICAL CONSIDERATIONS

The researcher took responsibility to ensure that the participants of this study were well informed about the following:

The purpose of the research was clearly indicated on the consent and assent forms which were signed by the headmasters, teachers, learners and their parents. It was clearly indicated on the consent and assent forms and explained to all the participants that their participation is voluntary and that they could withdraw at any time during the study. It was explained to the participants that they should not feel pressured to participate if they fear that their participation might have negative consequences to them. The researcher gave the participants assurance that the conversation which took place between the two parties is regarded as confidential. The researcher assured the participants that their names would not be associated with their conversation and that their anonymity would be guaranteed. The researcher emphasised that if he did not adhere to the ethics practices of the University of Pretoria any participant could lodge a complaint with the ethics committee of the University of Pretoria.

The only risk of this study is that the researcher could have misused the participants' identity and misrepresented the data gathered. Therefore the University of Pretoria will safeguard all the data which were gathered and could audit the researcher's work if necessary. The researcher ensured confidentiality through anonymity. The researcher did not disclose any identifiable information without the permission of the participants (Wiles, Crow, Heath & Charles, 2008). The researcher did not use any participants' names in the data analysis process. The researcher substituted the participants' names with numbers. Each number represents a participant and their responses. The benefits that will accrue to the participants are the conclusions and recommendations which were made in Chapter five of this study.

Some of the participants in this study are orphaned, separated or unaccompanied minors. These minors include any minor with no direct access to a parent or legal guardian to act in the best interests of the child and include street children, orphaned children in child-headed households and children living in a place of safety. There were participants who live in extreme poverty or who are illiterate. These include participants who are not able to meet their basic needs and who are not in a position to read documents pertaining to the research. The mathematics teachers explained the content of the consent and assent forms and assisted some learners to complete their assent forms.

There were no participants who were mentally compromised or who had physical limitations. All the participants were able to participate meaningfully. The learners who formed part of the observations in this study signed an assent form which emphasised that their participation is voluntary and that they can withdraw at any time during the study. The learners' parents or guardians completed a consent form which allowed the learners to be observed. The teachers who were interviewed completed consent forms which emphasised that they willingly chose to participate. Head of schools signed consent forms through which they provided permission for the researcher to conduct research at their school. The Department of Education in the Eastern Cape already provided permission to conduct research in their region. All the letters, as well as permission from the Department of Education, are attached to this document as Appendices.

3.8. TRUSTWORTHINESS

The concepts of reliability and validity are very important in determining the quality of the findings in this study. The reliability of a study refers to the consistency of research findings which should be attained when another researcher conducts the same research using the same or similar methods (Ritchie et al., 2013). Validity could be defined as the accuracy with which the findings in this research study represents the participants understanding of the use of MEAs in their classrooms. If the participants would have the opportunity to read through the findings of this study they should find it credible (Schwandt, 1997).

Reliability

Ritchie et al. (2013) explains that it is important for a researcher to determine which features of the data could possibly be replicated in another study. It is important to keep in mind that this study focused on the evaluation of the ISS model. The aim of the study was to determine whether the ISS model could be used as an educational artefact to evaluate and select MEAs. Therefore the ISS model and the classifications of the dimensions in educational environments could be the data features in this study which could be replicated in another study. The data analysis process clearly indicated that there are similarities but also inconsistencies in participants' approaches to the ten dimensions in the ISS model. Their approaches are significantly influenced by their worldviews which are shaped by their contexts (*cf.* Par 3.5.1.). There are some possibilities that the data and the findings might be replicated by another researcher but they are greatly influenced by the context of the sample under study, the worldview and paradigm assumptions of the researcher.

Validity

Creswell and Miller (2000) explain that a researcher's choices of validity procedures are guided by two main perspectives: the lens through which they choose to validate their studies and a researcher's paradigm assumptions. These two factors provide a rationale for the choice of procedures to validate the findings drawn from the data (Hammersley & Atkinson, 2007). The researcher in this study had a particular viewpoint which shaped the lens through which he observed the participants and their contexts. The researcher decided to investigate school A for one week and school B for a day. The data collected from school A might be saturated but not from school B. The researcher decided on the method to establish themes and categories (*cf.* 3.5.4. C). These mentioned factors influenced the narrative which the researcher compiled for this study. The researcher had the opportunity to revisit the data to validate his own interpretations and explanations (Patton, 1980). The researcher's worldview also influenced the choice of validity procedures. The researcher believes that the participants' context constructs the reality wherein the phenomenon takes place and that trustworthiness could be used to validate the data which were gathered and the findings of the researcher (Lincoln & Guba, 1985).

The following procedures were followed to ensure validity:

Triangulation of sources: This was one of the procedures used to ensure validity. The researcher conducted interviews and observations from two schools to find common concepts in the data. The narrative produced could be regarded as valid due to the fact that the researcher used multiple data sources and did not rely on only one data collection point.

Prolonged engagement in the field: The researcher conducted interviews and observation at school A for a week. During this time the researcher had the opportunity to build relationships with the participants which improved the trust of the participants towards the researcher. The participants felt more comfortable to disclose sensitive information. These credible accounts enriched the holistic image of the participants, their contexts and the phenomenon (Fetterman, 2010).

Peer reviewing: The researcher's mentor is familiar with the research and phenomenon being explored. Therefore the mentor guided the researcher methodologically and challenged the researcher's assumptions and interpretations (Lincoln & Guba, 1985). This lens which established credibility to this study was a process which occurred over the duration of this study.

3.9. CONCLUSION

Chapter 3 defines the research paradigm of this study which focussed the researcher's thinking regarding the conceptual framework used (*c.f.* par 3.3). This paradigm consists of an ontology and epistemology which could be regarded as the theoretical framework and the literature review. The research design provided this study with a plan on how to conduct research (*c.f.* par 3.4). This study followed an interpretive approach to conduct qualitative research. Evaluation research was the core strategy used to gather information from the participants. The ISS model developed by Zaied (2012) was used as the conceptual framework which guided the construction of interview questions and an observation schedule. The data collection process, population and sample, data collection instruments and data analysis process were described in Section 3.5. The limitations of the study were emphasised in Section 3.6. The ethical considerations were discussed in Section 3.7, and the trustworthiness explained in Section 3.8. Chapter 4 addresses the results attained from the data gathering process as explained in this chapter.

CHAPTER 4

RESULTS

4.1. INTRODUCTION

In Chapter 2 literature reviews on mathematics, meaningful learning, e-learning, m-learning and mobile applications were presented. The research methodology used in this study was presented in Chapter 3. This chapter presents findings from the qualitative data analysis.

4.2. THE RESEARCH PROBLEM AND QUESTION

The core problem statement for this study is that mathematics educators experience challenges to evaluate, select and use applications that will support meaningful learning in their subject field and the study comments on existing applications with the aim to improve their design. This problem was addressed by the primary research questions which state: How can the application of the Information Systems Success model as proposed by Zaied (2012) be used to evaluate mobile educational applications that support meaningful learning in mathematics? The ten dimensions which were used to construct this ISS model guided the researcher's semi-structured interviews to determine how teachers evaluate and select mathematical applications in the classrooms. Mathematics classes which were observed provided the researcher with an understanding on how teachers use mathematics applications in the classrooms. Worksheets were handed to four mathematics classes. The learners had to use certain pre-selected mathematics applications to complete the activities on the worksheets. The aim of these activities was to observe the interactions between the learners, teacher and the applications.

4.3. DISCUSSION OF RESULTS

This section provides results on the information attained from the semi-structured interviews and observations. This discussion is systematically guided by the ISS model proposed by Zaied (2012) as discussed in Section 3.4.5. The responses of participants produced characteristics in each of the dimensions of the ISS model. These characteristics define the dimensions. The researcher wished to determine whether the characteristics could be used to evaluate MEAs or contribute meaningfully towards the dimensions of the ISS model.

4.3.1. SYSTEM QUALITY

Figure 4.1 graphically represents three important concepts of information quality which were identified by participants in this study. Good system quality characteristics have the ability to improve user satisfaction.

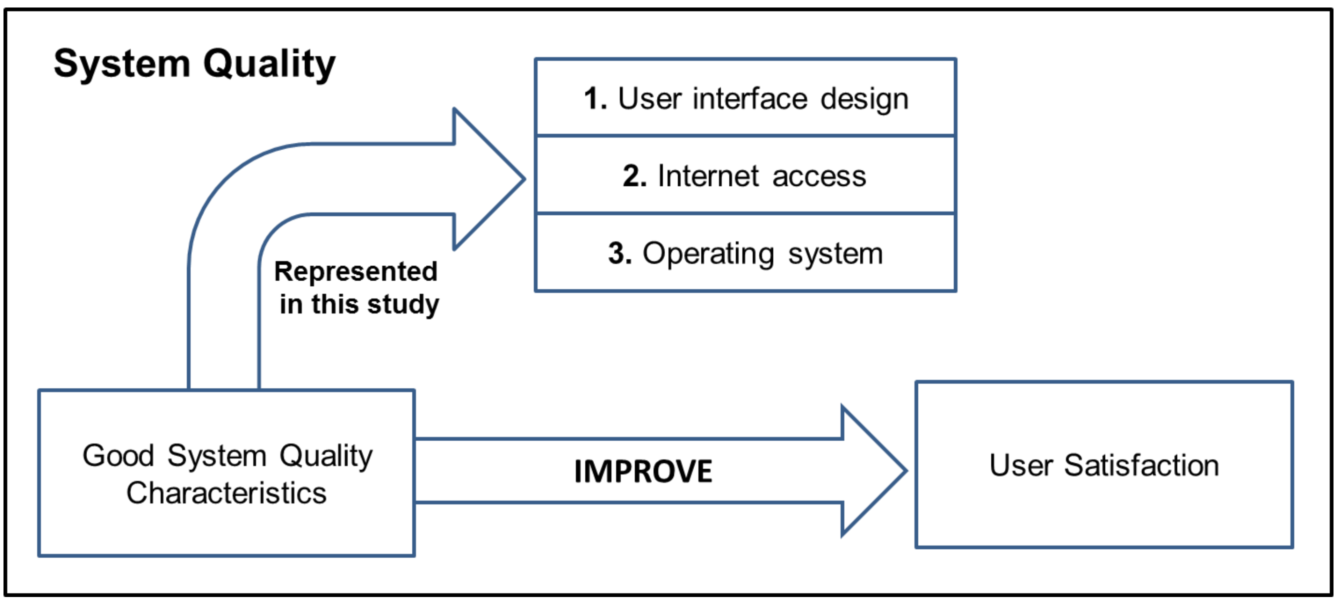


Figure 4.1: Graphical representation of system quality (Researcher)

Section 4.4.2 indicated that there are only a limited number of applications used by teachers and learners. Therefore the construction of feedback on this dimension in the ISS model is also limited. The following three topics were identified by the participants. The relationship between system quality and improved user satisfaction is discussed in Chapter 5 of this study (*cf.* Par 5.2.).

1. User interface design

The technology expert interviewed at school A said the following:

"The application is a timely process. It is not actually the content but it's just following those steps, you see. Okay so maybe it's more the interface of the applications. For instance if there's a part that is not indicated there's no way I can add that. You feel restricted. If they're simplified because really they are difficult. And also you know if some people wants, this one gives you a problem and then maybe u will lose interest. Another thing that there's a problem with, if I go onto an app you know, if the interface is difficult to understand, if the instructions is difficult to understand, if the content is hay wire or doesn't make sense or you know isn't relevant you know the teacher will be demotivated to use that app."

From the researcher's understanding the technology expert emphasised that the interface of applications should be easy to understand, the instructions should be clear and concise and the teachers should be able to relate to the content or else teachers will be demotivated to use the application.

If the application employs icons, their use should be clearly understandable or explainable. Learners should be in control of applications. They should be able to change variables. This makes them more focused, interested and improves understanding. Personal experiences of the teachers have shown that they would rather disregard ineffective applications as they find it demotivating.

2. Internet access

There are applications used by teachers which require internet access making it difficult to operate the application when internet access is restricted. The requirement of login profiles on applications could hinder the use because some learners do not have email addresses and forget passwords.

3. Operating systems

In the urban school investigated both Android and Apple tablets are used. Teachers emphasised that it is important to select applications which will operate on both platforms.

4.3.2. INFORMATION QUALITY

There are three main characteristics identified by the participants as illustrated in Figure 4.2. The shortage of mathematical applications is one of the participants' main concerns.

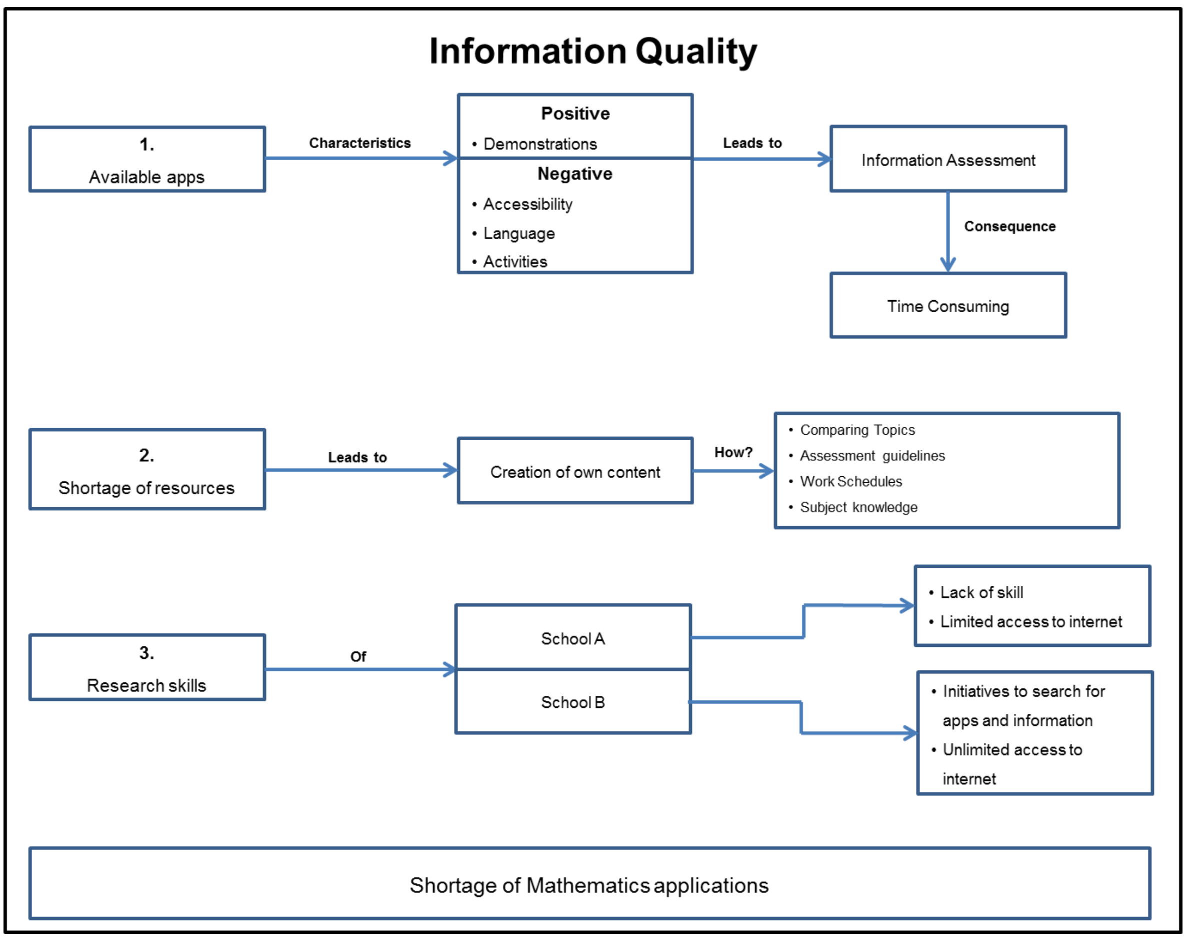


Figure 4.2: Graphical representation of information quality (Researcher).

1. Available applications

The information gathered on information quality has indicated that there is a vast shortage of mathematics applications that could be used in the South African educational context.
There are a number of curricula used by different schools and therefore teachers have indicated that it is important to assess the information which they encountered on applications although it is time consuming. The assessment of information is conducted by comparing the curriculum topics of mathematics to those mathematics topics addressed by the application. Assessment guidelines and work schedules are used to refine the comparison between curricula and applications in order to determine whether the applications could assist the teacher to reach specific outcomes addressed in the curricula used. The teachers have also indicated that it is important to determine the importance of topics in mathematics curricula and whether the information should be addressed through the use an application. Some of the applications found on different platforms are not free and are difficult for teachers to acquire without financial assistance. The use of applications has negatively impacted teachers' preparation time. The learners from school A which are part of this study are not native English speakers and find it difficult to interpret and process English educational applications. Interviewee 6 said the following about the learners' language:

"Mainly the language, you know, the communicating language we use English but most of the learners in this rural areas especially see that they are not good with the language."

Subject specific demonstrations which took place through the use of applications, created a visualisation for learners of which experiments or practical demonstrations could have been conducted in class if they did not have the constraint of physical resources.

The technology expert from school B said the following:

"If there is more applications available, more people will download applications. Let me quickly tell you this, the problem is they don't know that there's something like this until you introduce them to it. You cannot leave a learner to explore by themselves if you as a teacher do not have the knowledge. So if we can have these things injected into the system, we have a lot of activities on the tablet the learners will not have that time to take photos etc. Because if, if they are taught where to get information, then they now have the skills, when they have a question."

From the researcher's understanding the technology expert emphasised that applications need to have a wide range of activities available for learners to complete, to be able to keep them constructively busy. This expert also believes that if there were more applications available which meet the various needs of South African teachers and learners more applications would be downloaded.

2. Shortage of resources

Teachers from rural schools have indicated that there is a shortage of resources including mathematics textbooks. These teachers emphasised that they have to create their own content using their subject knowledge according to their assessment guidelines and work schedules.

3. Research skills

Teachers from the urban school investigated took the initiative to search for applications and information to assist their teaching of mathematics. It has to be emphasised that they have free and unrestricted access to the internet at school. Teachers from the rural school are unaware of mobile applications which could assist them and rely on their peers or technology experts to introduce them to subject specific applications. The technology expert interviewed at the rural school indicated that learners do not have the skill to search for information using their mobile tablets; learners on the other hand from the urban school are equipped to search for information using various sources.

4.3.3. SERVICE QUALITY

Service quality consists of two main concepts: Quality service received from developers and quality service received from applications. Figure 4.3 illustrates how these service types could improve quality and the perceived ease of use of applications.

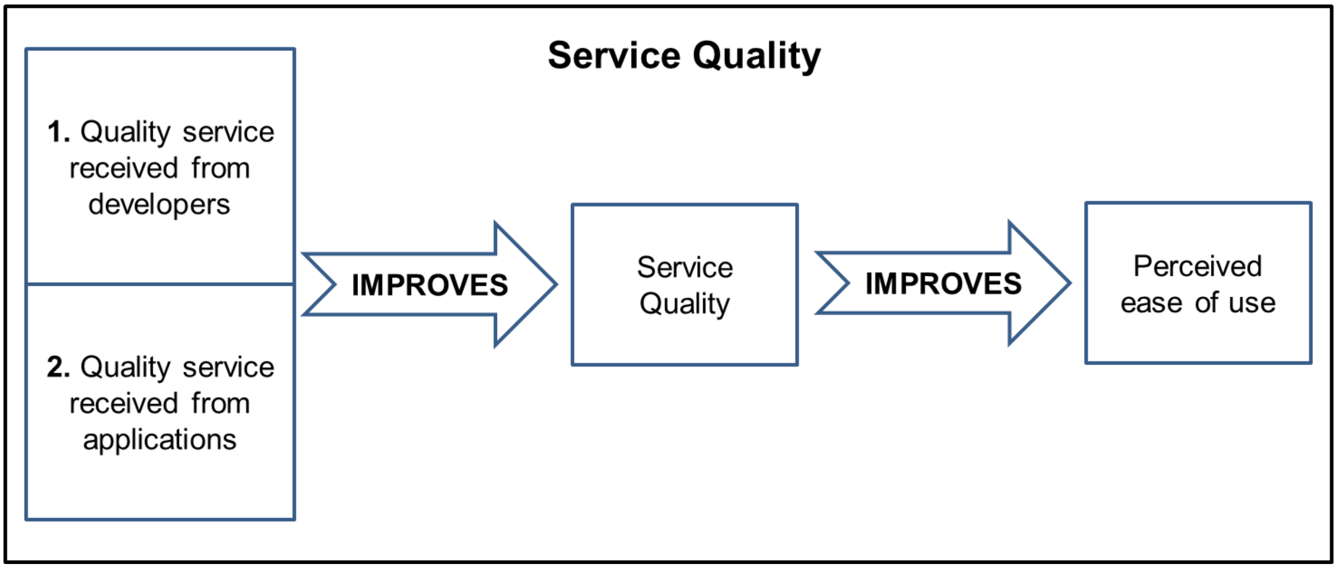


Figure 4.3: Graphical representation of service quality (Researcher).

1. Quality service received from developers

Teachers agreed that some applications provide users with a platform where they can communicate with developers. If the platform is not available on the application itself communication opportunities are provided through the supply of an email or website address. Although these opportunities to communicate with developers exist, teachers find it time consuming to provide feedback on barriers encountered or to provide constructive criticism. Teachers from the rural school usually ask for assistance from their technology expert and do not search for solutions to their problems themselves. Teachers have indicated that if there were to be an inquiry about a problem encountered on the application, the response of the developer should be prompt. The reason for this is that teachers will aim to solve the problem as quickly as possible to be able to employ the application as part of their daily activities.

2. Quality service received from applications

The observations have shown that the activities of the pre-selected mathematics applications provide limited feedback. Of the four applications used by learners to complete activities, only one application (yHomework – Math Solver) provided the learners with detailed steps on how to solve the mathematical problem. The problem with this application is that a user can only solve a limited number of problems before being asked to buy the application if they wanted to continue. The Math Exponents application only indicated to the learners when they made the correct choice or not and do not provide a detailed explanation for the correct choice or why their choice was incorrect. The Complete Mathematics application provided the students with the laws of exponents and it shows how these laws are applied by given examples. The Mathematics application provided the learners with a graphical representation of functions which was sufficient enough to answer the worksheet questions.

4.3.4. MANAGEMENT SUPPORT

Figure 4.4 indicates that management support consists of three external factors. These factors could influence the functionality of mathematical applications. These factors have the ability to improve system quality which will improve user satisfaction.

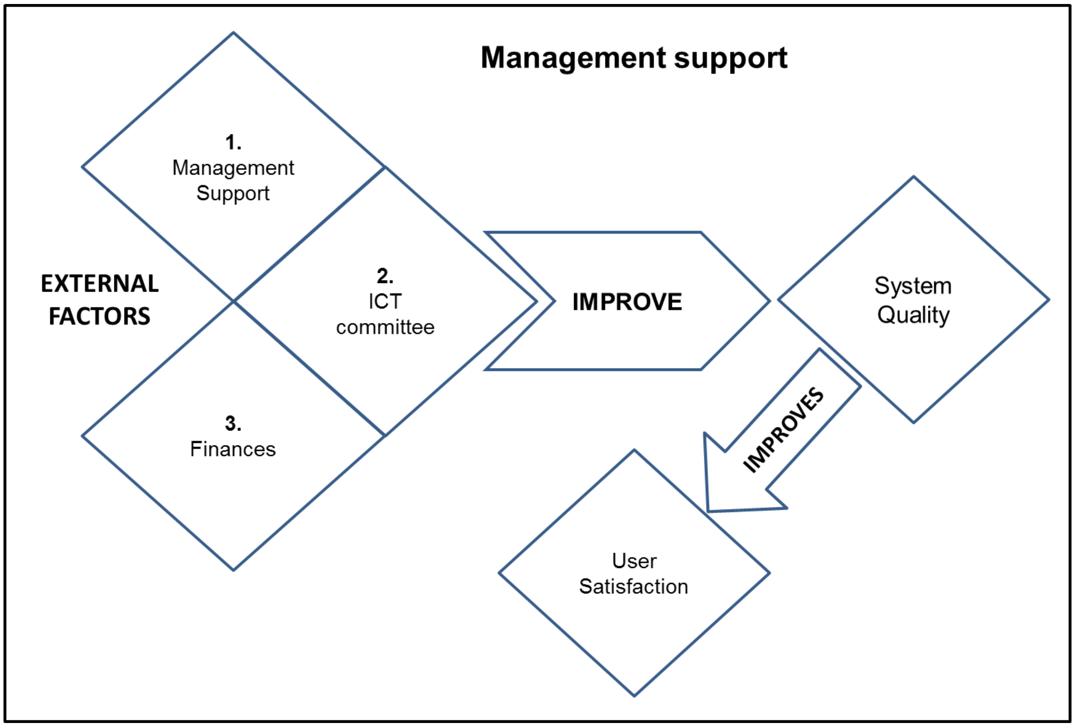


Figure 4.4: Graphical representation of management support (Researcher).

1. Headmasters

All the teachers who were interviewed agreed that their school headmasters are the driving force behind the use of tablets and applications in the classrooms. Both headmasters are accepting of technology and the change it involves. The headmasters welcome new initiatives and suggestions from teachers for the use of ICT in the classrooms

2. ICT committee

Both of the schools have ICT policies in place which stipulate rules and regulations for the use of tablets in the classrooms. Teachers agree that learners' use of tablets should be monitored as there were previous incidents of learners who accessed forbidden websites. School B has one ICT specialist which provides generic training to staff members on topics like flipped classroom and specific applications and/or software programs. The teachers of School B are divided into subjects groups. One of these teachers is identified as someone who has good technical computer skills. This teacher is responsible to guide his/her group in their use of ICT's. The group leaders have the specific responsibility to equip their groups with more ICT skills in their subject fields. The management of school A, created an ICT committee which takes responsibility for all related ICT matters. This includes the training and motivation of teachers and learners, the establishment and implementation of ICT policies and to monitor the physical condition of the tablets. The ICT committee identified specific learners (ICT champions) in each class who they provided with specific training. The aim of this training was to equip learners with skills who in turn could teach fellow learners specific skills and assist them in the class when they encounter a problem.

3. Finances

The main difference between the School B and School A investigated is the finance available to implement and develop the use of information and communication technologies. The teachers at School A receive a limited amount of support in terms of finance and ICT resources. There is only one projector available for all the teachers to use and the school encounters frequent problems with the use of the internet. The teachers agree that an ICT fund should be established to equip the school with more resources, to finance the replacement of tablets and buy anti-virus programs. The teachers also suggested that funds could also be utilised for the motivation of learners. School B has sufficient resources available to enrol the teachers on ICT courses or postgraduate degrees in education. They support the teachers in providing them with laptops and tablets at no additional cost to the teacher.

4.3.5. TRAINING

The importance of training is illustrated in Figure 4.5. If the importance is realised it could mobilise training for teachers and learners. Mathematics teachers will be provided with skills and knowledge to implement applications in their classrooms. Learners could be taught the skills to conduct educational research to expose them to information outside the school environment.

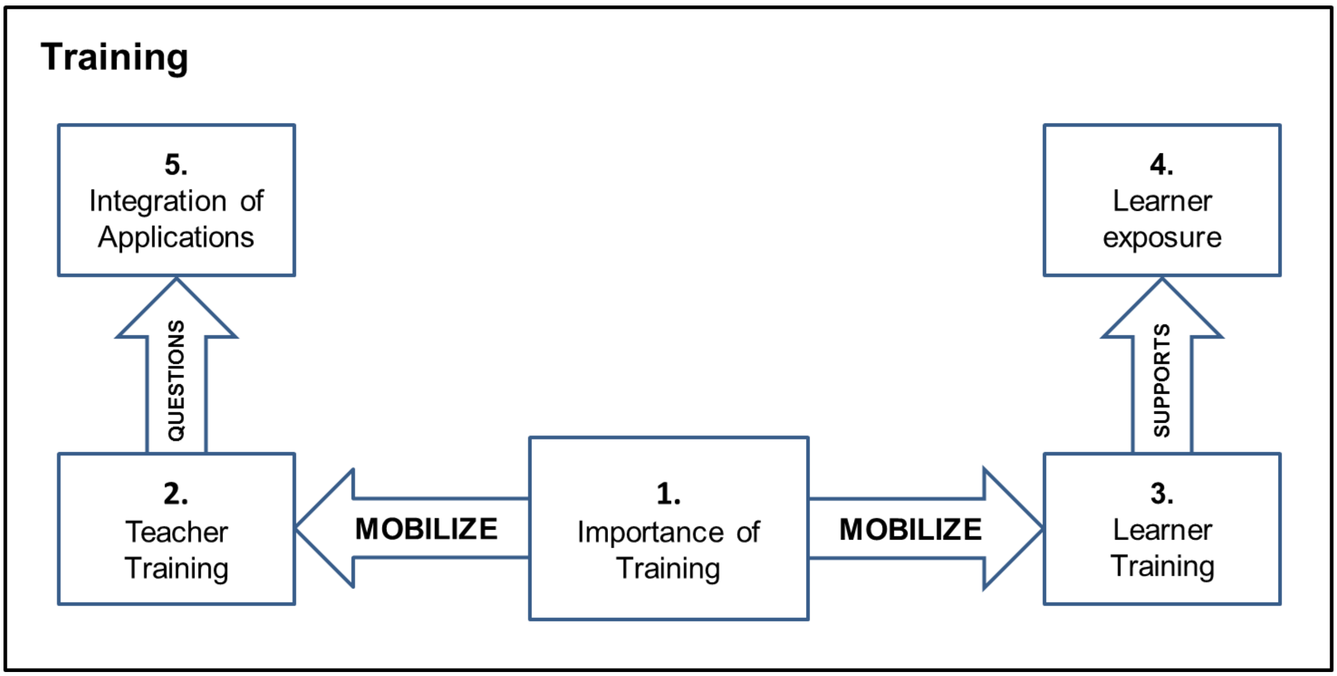


Figure 4.5: Graphical representation of training (Researcher).

1. The importance of training

Teachers agree that training could empower teachers to use mobile applications in their classrooms. Training provided the teachers with new teaching strategies, skills and motivation. Training has the ability to reinforce knowledge and skills and plays an essential role in the development of teachers.

2. Teacher training

Teachers from the rural school received training by the ICT4RED initiative (Herselman & Botha, 2014). The focus of this initiative was to introduce teachers to mobile tablets and how they could be applied in a classroom situation. Although their training was very generic it seemed that the teachers felt comfortable using their tablets and they could use them with confidence. Teachers emphasised that the training they received positioned all the teachers on the same skill level which promotes collaboration in the form of group discussions and the sharing of ideas. Teachers expressed their concerns about the lack of training in specific subjects. Teachers have the need to acquire the skills and knowledge to use their tablets and applications in their subject fields. Teachers are not aware of educational applications available for their use. Some teachers at School A are provided with opportunities to attend ICT conferences which equip them with new skills and knowledge. Teachers who attend conferences find it difficult to share their recently gained knowledge and skills because of a busy academic work schedule. Teachers from School A complained that members of the ICT committee lack vision and are cynical. Teachers have emphasised that the use of mobile tablets and applications improved their professional development. During the few opportunities teachers had to use applications in the classroom they confirmed that they could observe improved performances.

3. Learner training

All the teachers are of the opinion that the learners at both schools do not get adequate training on the use of their tablets. Training is needed to provide the learners with the basic knowledge on the working of their devices and more specific training to develop learners' skills to use their devices to improve academic efficiency.

4. Learner exposure

The principal from the rural school believes that the learners should get exposure to the world outside the school and that the introduction of tablets provides them with this opportunity. He encourages learners to use their tablets for educational purposes and views the use of mobile tablets as a tool which could provide the learners with a vision they can work towards.

5. Integration of applications

Teachers feel uncertain where in their lesson plan they should implement applications. They don’t know whether it should be used when doing homework, for revision, to teach new content or for interactive uses in class. Teachers feel that they need guidance to implement applications for the most optimal use in their classrooms. The management of the urban school decided to provide the opportunity to teachers to implement applications in their classrooms at their own pace. Management encouraged teachers to set goals for themselves and are monitored accordingly. Every teacher at this school belongs to a subject specific group (e.g. mathematics, science etc.) which is guided by a subject specialist with specific ICT skills. The aim of these groups is to guide the teachers with their use of tablets and applications in their subject and to provide them with subject specific training on the use of their tablets and applications. Teachers from the rural school have made frequent suggestions to the ICT committee on how they think technology could be incorporated in their classrooms but these have been disregarded. This demotivated teachers as well.

4.3.6. USER INVOLVEMENT

Figure 4.6 illustrates the vision of Roschelle et al. (1999) to create a platform where educators and developers can collaborate effectively (*cf*. Par 1.2.2). Subject specialists and application designers should work together to create quality applications which will meet the needs of educational institutions.

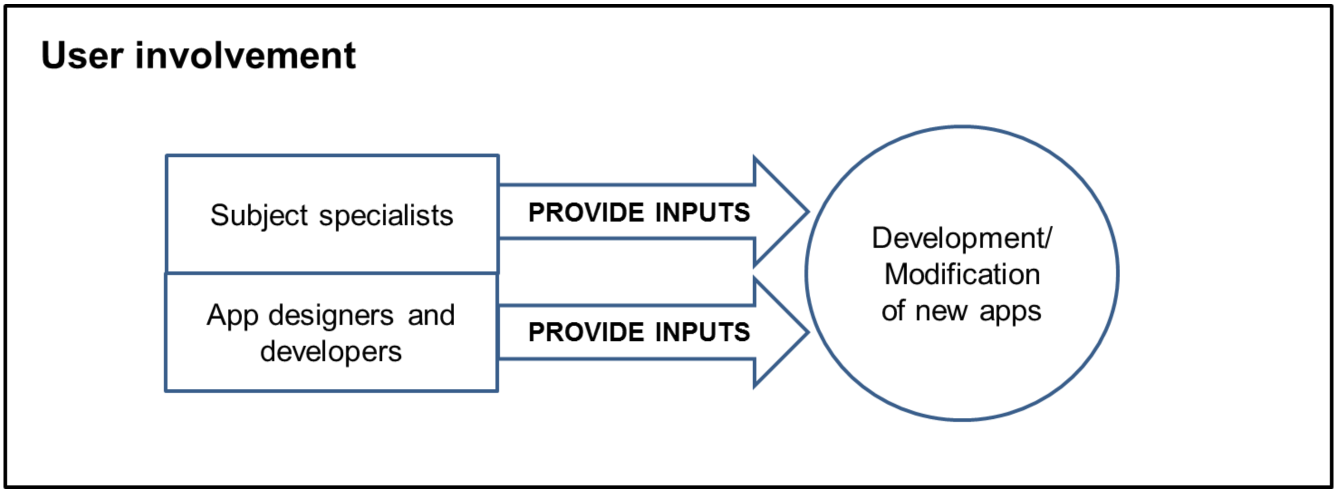


Figure 4.6: Graphical representation of user involvement (Researcher).

All of the teachers who were interviewed agreed that the developers and designers of MEAs need the input of subject specialists. The teachers indicated that most of the applications they encountered lack a wide variety of tools which they feel could assist them in their day to day activities. Only one of the mathematics teachers at School B who was interviewed indicated that developers approached her to evaluate an e-book they were creating. They observed her using the e-book in her class and interviewed her whereafter they planned to improve the e-book taking her suggestions into consideration. This teacher believes that teachers could make valuable contributions to the design and development process of MEAs.

4.3.7. PERCEIVED USEFULNESS

Figure 4.7 indicates that the five proficiencies of mathematics learning influence the functionality of applications. The functionality of applications could stimulate learners' work ethics in order for them to reach their outcomes. The functionality of applications could also create challenges for teachers and learners.

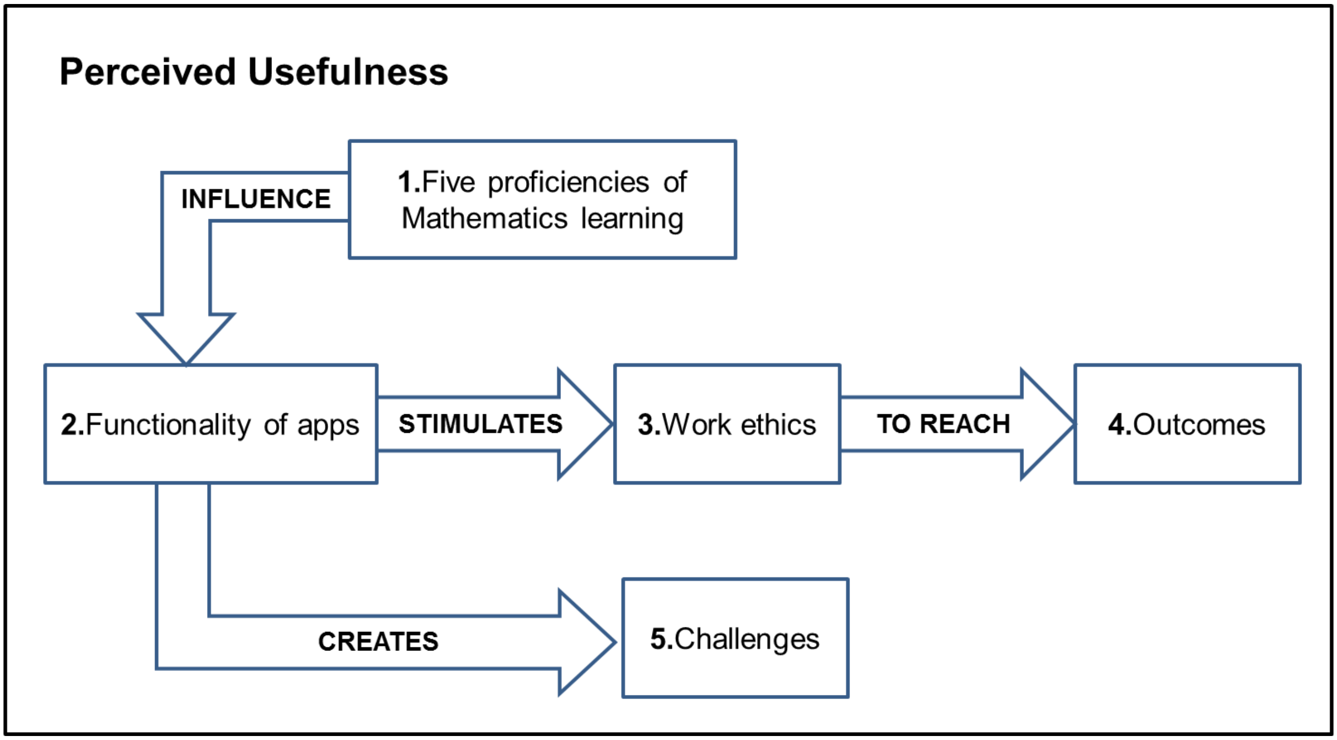


Figure 4.7: Graphical representation of perceived usefulness (Researcher).

1. The five proficiencies of mathematics learning

The literature review presented information on the five proficiencies of mathematics which learners should master to become successful learners and practitioners of Mathematics (*cf.* Par 2.3). The researcher analysed four mathematics applications to determine whether or not the applications could promote these proficiencies. The analysis process and results of the analysis can be viewed in Chapter 2 (*cf.* Par 2.6.). Chapter 5 contains a detailed discussion on the inferences made.

2. Functionality of applications

There are various reasons why teachers believe that MEAs are useful. Teachers from the rural schools emphasised that applications give them the opportunity to demonstrate to the learners how certain experiments are done or to demonstrate concepts visually. Applications provide the learners with a platform where they can investigate and do research. The learners are developing the skills to think critically and to distinguish between relevant and irrelevant information. One teacher from the rural school believes that the use of tablets assists the learners in becoming computer literate and will help them in their lives after school. One teacher commented that the more users work with applications the more comfortable they will become using them.

3. Work ethics

Teachers from the rural and urban school agreed that learners are more attentive in class and that applications make teaching easier and increase the pace at which the teachers work. These teachers also agree that applications provide the learners to do revision at home. If they struggle to understand a certain concept they have the opportunity to access the application at home and do revision. Applications like Whatsapp and Twitter encourage the learners to communicate while other MEAs encourage co-operation. The headmaster of School A confirmed that learners' results improved because of the use of applications.

4. Outcomes

Certain outcomes in subjects could be reached with the assistance of applications but not all outcomes as specified in different curricula.

5. Challenges

General problems experienced by the teachers were that their preparation time increased with the implementation of MEAs. The teaching methods intended by the application might be different from the teaching methods used by the teachers. If there are problems with the tablets or applications, it could cause delays and use up valuable teaching time. A specific problem identified in School A is that learners attach a lot of value to their tablets although the abuse and misuse of the devices are evident.

4.3.8. PERCEIVED EASE OF USE

Figure 4.8 shows that users' perceived ease of use could be influenced by the characteristics identified. Users could have a positive or negative connotation towards the characteristics which will shape their behavioural intention.

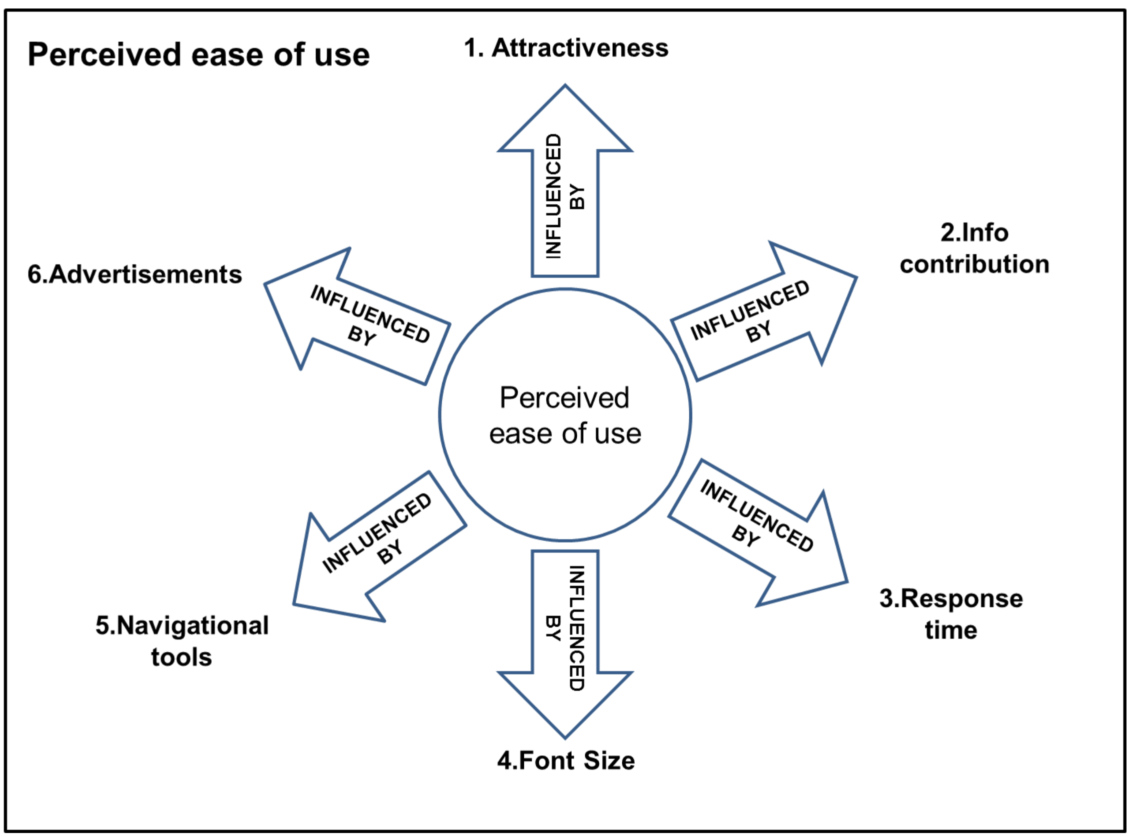


Figure 4.8: Graphical representation of perceived ease of use (Researcher).

Most of the teachers interviewed indicated that applications are easy to use if they are user friendly. The user friendliness of applications includes various concepts which consist of the following identified by these teachers: **1. Attractiveness:** The attractiveness of the application creates the impression that the application is easy to use. **2. Information contribution:** The input of information when working with the application should be effortless. Teachers from the rural school have indicated that if they could use a wireless Bluetooth keyboard to enter information it would make their tasks easier. **3. Response time:** The time the application takes to respond to an input received increases/decreases the users' expectancy of the application and could motivate/discourage them to use the application. **4. Font size:** The information displayed on the application should be readable. **5. Navigational tools:** The navigational tools on the application, for example buttons which are used to direct users from one place to another should be easy to find and apparent. **6. Advertisements:** They are hindering and discourage teachers to use applications. These factors are very important when teaching new content with the assistance of the application.

4.3.9. BEHAVIOURAL INTENTION

Figure 4.9 indicates that there are three main factors which could influence the behaviour of teachers and learners. Their behaviour could be positively or negatively influenced by these factors.

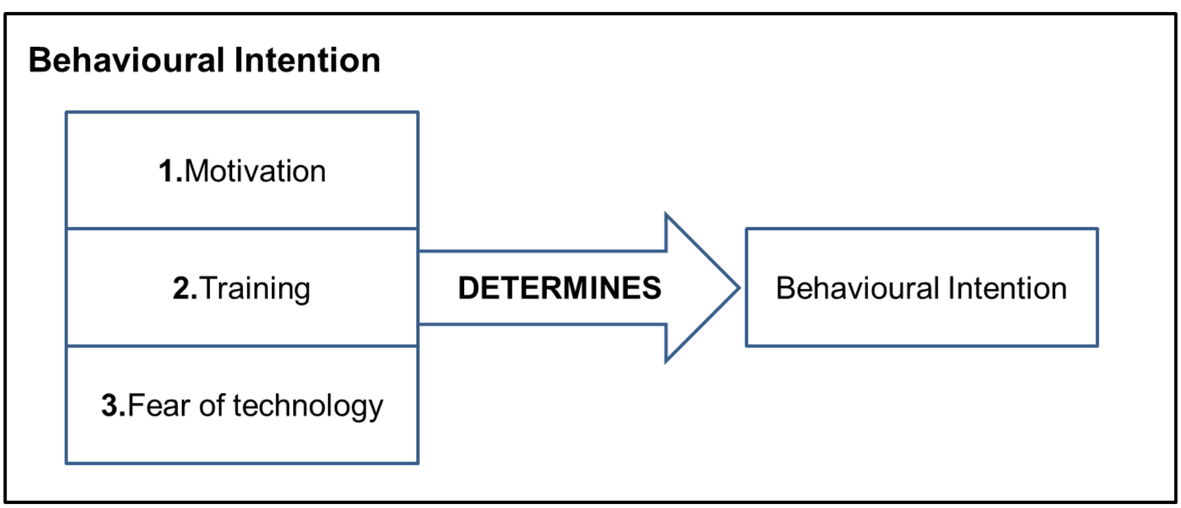


Figure 4.9: Graphical representation of behavioural intention (Researcher)

1. Motivation

Teachers experience a positive change in their behaviour towards the use of tablets and applications if they feel motivated. Motivation provides teachers with the enthusiasm to work confidently with tablets and applications and to be innovative. Teachers agree that their passion and intrinsic motivation to teach with their tablets became visible to the learners and motivated the learners to use their devices for learning. The improvement of learners' results due to the use of applications should also motivate and act as proof to the teachers that applications could benefit both them and the learners. Teachers believe that if tablets and applications are used on a regular basis, the users will become more comfortable using them. If the benefit of applications is realised together with proper training, both teachers and learners could enjoy using applications for educational purposes.

2. Training

Teachers at School A received generic training on how to use tablets in their classroom. Their training equipped them to incorporate different teaching strategies in their teaching approach. It became clear through the interviews that they feel they need specific training in their subject fields. The lack of subject specific applications demotivates teachers to use their devices in the classroom. Teachers agree that sufficient training will change the attitude of teachers. New motivation is needed to demonstrate to teachers how mobile tablets could be used in their classrooms. Teachers believe that new motivation could encourage them and the learners to use tablets and applications more frequently as an educational tool. They also should be taught the skills to search for subject specific information and applications.

3. Teachers fear of technology

Interviewee 5 said the following:

"Most of the people are technophobic after the training."

Interviewee 6 said the following:

"It is very difficult, in fact they're a bit scared of, you see, maybe they make mistakes and people who laugh at them or something."

It is clear that some teachers have a fear for using technology. Their fear combined with a lack of applications creates an environment where the use of mobile tablets is perceived as complicated. There are two factors which contribute to teachers' fear or dislike of these complex devices. The first factor is a result of under exposure and the second is that senior teachers find it difficult to adapt to change. These teachers are labelled with an unfavourable attitude and an uneasiness to explore. Teachers expressed their anxiety of being humiliated by their colleagues when they experience difficulties with technology.

4.3.10. USER SATISFACTION

User satisfaction will result from the successful outcomes of the previous nine dimensions as discussed. Information, system and service quality which are regarded as the internal factors affecting the operation of an application are influenced and/or supported by the other dimensions. Chapter 5 contains a detailed discussion on the inferences on user satisfaction.

4.4. THE EVALUATION OF MATHEMATICAL APPLICATIONS

The previously discussed applications were evaluated to determine whether they can promote the five proficiencies of mathematics learning.

The following diagram illustrates how the evaluation was conducted.

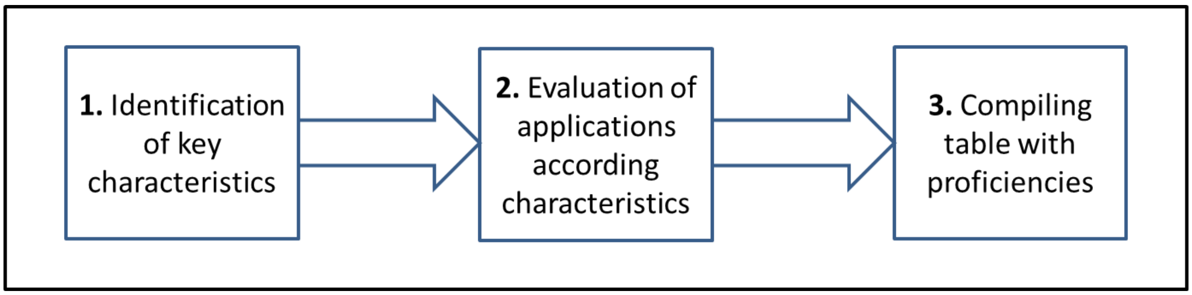


Figure 4.10: Application evaluation process (Researcher)

The following method was used to evaluate the applications:

1. Identifying key characteristics in proficiencies

The proficiencies of mathematics learning contain characteristics which should promote meaningful learning. These characteristics were identified to assist with the evaluation of each application. The following table summarises the key characteristics of the proficiencies according to Kilpatrick et al. (2001):

Proficiency	Characteristics
1. Conceptual understanding	• Promotion of facts and methods • The contexts in which facts and methods are useful • Organization of knowledge into a coherent whole • Retention of knowledge
2. Procedural fluency	• Knowledge of procedures • Knowledge of when and how to use procedures • Analysis of similarities • Differences between methods of calculating
3. Strategic competence	• Formulation of mathematical problems • Representation of mathematical problems • Solving of mathematical problems
4. Adaptive reasoning	• Logical thinking about relationships among concepts and situations • Consideration of alternatives • Justification of conclusions • Navigation through facts, procedures, concepts and solution methods • Deductive reasoning
5. Productive disposition	• Frequent opportunities to make sense of mathematics • Productive disposition develops when other strands develop • Opportunities to learn

Table 4.1: Key characteristics of the proficiencies according to Kilpatrick et al. (2001)

2. Evaluation of applications according to characteristics

Each application was examined according to the characteristics of the proficiencies to determine whether the application could promote the proficiencies.

3. Compilation of table with proficiencies

The following table summarises the results of the investigation and indicates the proficiencies each application promotes.

Applications	Characteristics				
	Conceptual understanding	Procedural fluency	Strategic competence	Adaptive reasoning	Productive disposition
1. Math Exponents	✓	✓		✓	
2. yHomework – Math Solver		✓		✓	
3. Mathematics	✓	✓			
4. Complete Mathematics	✓	✓			

Table 4.2: Proficiencies of mathematics applications (Researcher)

Mobile applications provide opportunities to develop educational learning applications on mobile devices which could complement and/or support traditional learning activities. This will give learners the opportunity to learn beyond a normal class setting.

To address the challenges mentioned in this literature review require a range of interventions. This could include the integration of information and communication technologies (Isaacs, 2012). Isaacs (2012) explains that more recently the growth of mobile phone subscriptions has generated interest in how mobile devices could assist a teacher in his professional development and support their teaching and administrative duties. There are several projects that support the use of mobile devices and mass communication in educational institutions in

South Africa (Mostert, 2010). The following are examples of projects that took place or are currently taking place.

4.5. CONCLUSION

This chapter addressed secondary research question 1: How do teachers evaluate and select mathematical applications? (*cf*. Par 4.3.1) And question 2: How could each dimension of the ISS model contribute meaningfully in educational environments? The researcher used the ISS model proposed by Zaied (2012) to guide the questions asked in the semi-structured interviews and to guide the notes made in the observations. The participants' responses produced characteristics which defines the dimensions of the ISS model. These characteristics should be measurable and attainable to determine whether they could be used to evaluate MEAs and how they contribute meaningfully to the dimensions of the model. Chapter 5 demonstrates how each of the characteristics in the dimensions, identified by the participants, could be evaluated and/or contribute meaningfully in order to promote learning in mathematics.

CHAPTER 5

DISCUSSIONS AND CONCLUSIONS

5.1. INTRODUCTION

The primary goal of this research study was to determine whether the ISS model developed by Zaied (2012) could be used to evaluate MEAs in support of meaningful learning in mathematics. The two secondary questions assisted in answering the main research question (*cf.* Par 1.2.3.). This Chapter presents the findings and conclusions of this study and are guided by ISS model of Zaied (2012) as illustrated in Figure 5.1.

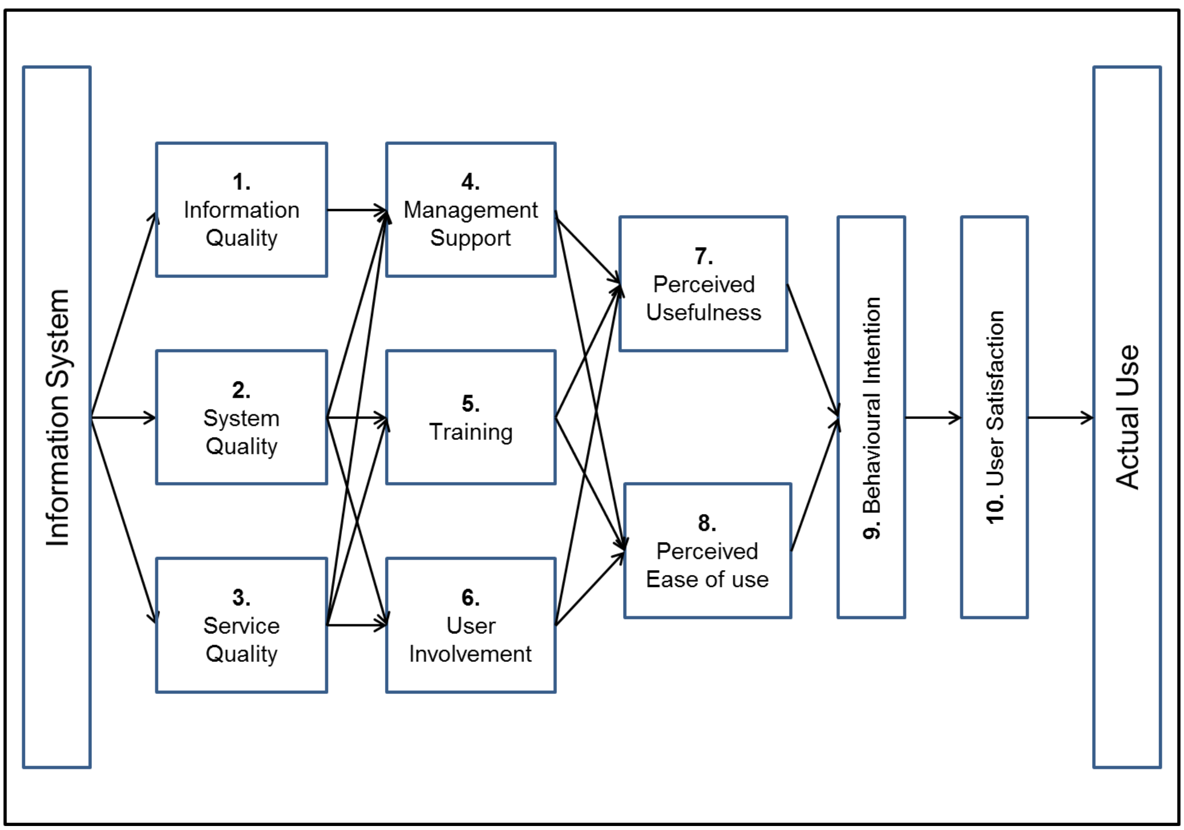


Figure 5.1: The ISS model created by Zaied (2012).

5.2. FINDINGS

The application of the ISS model in school A and B presented new understanding on how teachers evaluate and select MEAs. In the original ISS model Zaied (2012) define the roles of the dimensions as important influences which could contribute to the actual use of an information system. For this study the researcher showed how the dimensions of the model could contribute to the meaningful learning of mathematics. The dimensions of the ISS model could be regarded as important focus areas which could form part of an evaluation process to lead to the meaningful selection and use of MEAs.

It could be deduced from Chapter 4 that each dimension can be viewed as an independent unit which could make meaningful contributions and be assessed on its own. Nonetheless, the original ISS model created by Zaied (2012) infers that there are relationships between some of the dimensions which affect one another. Therefore this study concludes that all the dimensions in the ISS model form a coherent whole which have a significant impact on the actual use of MEAs. Each dimension could make meaningful contributions which will support the meaningful learning of mathematics.

The following discussion addresses both secondary questions 1: How do teachers evaluate and select mathematical applications? And question 2: How could each dimension in the ISS model contribute meaningfully in educational environments? (*cf.* Par 1.2.3.). The discussion was guided by the ten dimensions of the ISS model. The first three dimensions contribute to the internal functioning of an application. The conclusions indicate how teachers and learners could incorporate evaluation strategies to measure the quality that each of these dimensions delivers. Dimensions four to six are external factors which could influence the first three dimensions. These dimensions could be evaluated by determining their meaningful contribution to the ISS model. Dimensions one to six have to be seen together to determine the perceived ease of use and perceived usefulness of applications. They have an influence on the behavioural intention of a teacher or learner which will determine the satisfaction they will derive from an application.

Each of the dimensions consists of characteristics identified by the participants. These characteristics define each dimension and are regarded as important factors which could influence the evaluation or meaningful contribution of the dimensions. The characteristics should be measurable and attainable to determine their influence. Therefore the following conclusions made of the ten dimensions of the ISS model illustrate how the characteristics of the dimensions could be evaluated or contribute meaningfully.

5.2.1. SYSTEM QUALITY

Definition according to conceptual framework:

System quality refers to the quality of a MEA which consists of certain quality characteristics (*cf.* par 3.4.5).

Section 4.3.1 explained that there is a lack of MEAs which focus on the South African curricula. The researcher concluded from the results that when a teacher encounters an application they would rather focus to ensure that the information on the application is useable. They will spend less time evaluating the system quality of the application.

Zaied (2012) found that there is a strong relationship between system quality and user satisfaction. Therefore applications should enhance user friendliness which will increase the ease of use. They should promote stability which will limit technical difficulties experienced and decrease security features but still protect the identity and personal information of users. The application should operate with speed and precision and act responsively to users' input (Holsapple & Lee-Post, 2006).

Conclusions made from data analysis:

1. User interface design

Teachers evaluate system quality mostly through the user interface. The user interface should be easy to understand and easy to navigate.

Influence on evaluation: MEAs could make a meaningful contribution when the application allows users to change variables, add information and change basic interface settings. These factors will motivate teachers and users to use the applications.

2. Internet access

Internet access is very important if a teacher or learner wants to do research. Learners' and teachers' research skills cannot improve if there is no searching platform. Internet access will also allow teachers to search for suitable mathematical applications and information which will enable school A to bridge the divide between textbooks and mobile devices. Internet access will enable teachers and learners to download and use mathematics applications which require login information.

Influence on evaluation: Some mathematical applications will be of no use if the mobile computer does not have access to the internet. If internet access is restricted the teacher or learner should assess whether the application requires an internet connection and choose applications accordingly.

3. Operating system

School B allows the learners to use mobile devices which operate on both Apple and Android platforms. School A only use mobile devices which operates on android platforms. Some learners will be excluded from the use of certain MEAs if the MEA is designed for only one operating system.

Influence on evaluation: Mathematics teachers need to verify that applications and information selected for the learners will work on both operating systems.

5.2.2. INFORMATION QUALITY

Definition according to conceptual framework:

From an educational perspective, information quality can be seen as the ability to evaluate and use information effectively (Bruce, 1999).

In the study done by Zaied (2012) to validate the usability of the ISS model, he found a strong relationship between information quality and perceived usefulness. This means that if teachers find the mathematical information on the application useable and if they can incorporate the information in their lesson planning they will have a strong inclination to view the application as useful. It must be emphasized that it is very difficult to employ a process of evaluation if very few applications are available which focus on the South African curricula.

Conclusions made from data analysis:

1. Available applications

The shortage of MEAs which could be used to complement the curricula creates various challenges for teachers (*cf*. Par 4.3.2). Most applications available only support the South African curricula to some agree. Most teachers have to dissect applications in order to search for functional activities or information which will support their curricula. They then have to adapt their work content and schedule to incorporate the mathematics information on these applications. This becomes a time consuming process. Most applications are displayed in English. Accommodating learners with non-English mother tongues is only possible when options in language preference are available. The deduction that can be made is that certain learners and teachers are excluded from using applications. This perspective is also supported from a financial point of view. Not all the applications are free to use. This excludes even more teachers and learners. Applications could however contribute meaningfully.

Influence on evaluation: When searching for applications the teacher or learners should verify whether the application could accommodate their teaching or learning needs. Their assessment process should determine whether the information and/or activities could assist them to reach the outcomes set in the curricula they use. Because of the shortage of MEAs and their limited use, teachers should also be aware that their preparation time will increase. Teachers will possibly have to use multiple applications to reach some of their curricula outcomes but might not reach all outcomes using MEAs.

2. Shortage of resources

From the investigation done at School A, it was observed that there are vast deficiencies of resources including insufficient textbooks to distribute to all the learners.

Influence on evaluation: If teachers wish to supplement their curricula with MEAs they should implement the assessment process explained above. The MEAs might not cover all the related mathematics topics in the curricula used. The teachers then need to find alternative ways to teach those topics. If the assessment of mathematics information and activities on an application is not properly conducted, the MEAs which are used might impair effective and appropriate learning and/or teaching.

3. Research skills

Research skills could assist teachers and learners to distinguish between appropriate and inappropriate mathematics applications and information. It is evident from the data analysis that there is a big skills gap between school A and school B. School B has the required resources to provide training to their learners and teachers. School A lacks resources in this regard.

Influence on evaluation: The management of a school should provide training to teachers and learners. Training could provide them with skills and knowledge to make better choices with regard to MEAs. Training could result in the acquisition of skills and knowledge to assess an application according to the five strands of mathematical proficiencies. It could also provide teachers with skills to assess applications according to curricula information and outcomes. The activities contained in applications could be assessed to determine whether they could assist a teacher or learner to reach the outcomes in the curricula they are using.

5.2.3. SERVICE QUALITY

Definition according to conceptual framework:

The purpose of this dimension is to determine whether mathematics applications match teachers' and learners' expectations.

It was explained in Section 3.4.5 that service quality has two main focus areas. The first focus area concentrates on the service a user receives from the developers of applications and the second focus area concentrates on the service the users receive from the application. Zaied (2012) explains that there is a strong relationship between service quality and perceived ease of use. The importance of this relationship is emphasized in the interpretations made.

Conclusions made from data analysis:

1. Quality service received from developers

Teachers expect the service they receive from developers to be of outstanding quality, but they are not willing to make meaningful contributions towards the improvement of applications. Zaied (2012) emphasized that there is a strong relationship between service quality and perceived ease of use. The perceived ease of use of applications consists of a few characteristics which were identified by the participants in this study (*cf.* Par 4.3.8). This means that each of these characteristics should be of exceptional quality for teachers and learners to regard the application as a good quality application. If teachers and learners regard the characteristics as easy to use or of good quality, they will regard the service provided by the application as good quality service.

Influence on evaluation: Teachers and learners should verify that the application they use has a platform where they can communicate with developers. The communication could occur through the application or through other methods like email. Users of the application could report on shortcomings which will provide the opportunity for developers to improve their application. This will improve a user's perception on the quality of service they receive from developers.

2. Quality service received from applications

The qualities of service applications provide to users are imperative to a user's perceived ease of use. An application could have many functionalities but whether they can contribute to a meaningful learning process, is the question that should be asked.

Influence on evaluation: If a mathematics application provides the learner with assessment opportunities, the feedback from the activity should be prompt which should provide the learner with a result. The feedback from the activity should be reliable. It should be determined whether the outcome of the activity is fair. A mathematics subject specialist should determine whether the application probes appropriate questions which the learners will be able to answer. This specialist should also determine whether the activities contribute to conceptual understanding. It will not be worthwhile to complete activities which have no meaning. Assessment opportunities should be readily and frequently available (Holsapple & Lee-Post, 2006). This will improve a learner's conceptual understanding and procedural fluency abilities.

5.2.4. MANAGEMENT SUPPORT

Definition according to conceptual framework:

Management refers to the people and processes involved in managing an educational institution and a classroom.

Zaied (2012) found that management support will increase system quality which improves user satisfaction.

Conclusions made from data analysis:

1. Headmasters

The management of a school which includes the headmaster and the school governing body (SGB) has the ability to implement the meaningful use of application into their educational environments. The management of a school could employ three main functions which will clarify their responsibility. The **first function** is to manage ICTs within their educational environment. The management of ICTs entails providing sufficient financial resources to acquire new and replace old technology. Management could also implement policies and procedures to ensure the safe use of mobile devices and applications. The **second function** which management could fulfil is to support teachers psychologically. Teachers expect that if management advocate the use of mobile devices and applications, they should lead by example. The **third function** which managers could perform is to provide teachers and learners with equal access to mobile devices and to provide them with training. This role could be delegated to the ICT committee.

Meaningful contribution: Teachers and learners could assess the management of a school according to their functions explained above. It might seem difficult for teachers to keep management accountable for these functions. Respectable and transparent relationships could promote understanding between these parties and will ensure that open communication takes place.

2. ICT committee

An ICT committee could be one of a school management's supporting functions. The ICT committee could take responsibility for the implementation of m-learning programs which consist of various roles. Their responsibilities could include the training of staff and learners on how to use mobile devices and more specifically how teachers could implement the use of mobile devices in their classrooms. It is important to recognize that teachers have the need to implement mobile applications in their subject fields. Therefore subject specific research has to be conducted to search for methods and innovative ideas on how such implementation could take place. The ICT committee could also take on the responsibility to develop policies and procedures regarding the use of ICTs in educational environments.

Meaningful contribution: As discussed above the ICT committee could make meaningful contributions with regards to implementation of m-learning programs, training, research and developing policies and procedures.

3. Finances

Although this point was briefly described above it is discussed as a separate point which emphasises how important this point is to teachers. It would be an assumption to state that schools have the necessary resources to support ICT initiatives. School A has shown that they do not have enough financial and technological resources to support various teacher initiatives for the use of ICTs. There are some teachers who have the initiative and the motivation to implement the use of ICTs to its fullest extent. A lack of finances could discourage these teachers. If school A is compared to school B the difference between the functionalities of ICTs could clearly be recognized.

Meaningful contribution: Schools with limited financial resources that wish to implement ICTs that will work efficiently and effectively, need to find additional financial support to supplement their financial shortage.

5.2.5. TRAINING

Definition according to conceptual framework:

The goal of training is to equip the teachers/facilitators with specific skills to enable him/her to use mobile educational applications effectively in the classroom.

Zaied (2012) explains that training might lead to increased service quality which will improve perceived ease of use. These correlations will be discussed in the following paragraphs.

Conclusions made from data analysis:

1. The importance of training

The importance of training has been recognized in School A and School B. Although training equipped the teachers at both schools there still exists a divide between generic training and subject specific training.

Meaningful contribution: Training is not a once off event. Ongoing training is needed to support teachers in mathematics.

2. Teacher training

Teachers emphasized that they feel uncertain on how to implement the use of MEAs in their classrooms. Although it was mentioned earlier that there is a vast shortage of applications that could be applied to South African curricula, this specific dilemma emerged from teachers using available mathematics applications. Teachers' concerns are from a methodology perspective and they have the need to be guided in this regard. Teachers are not willing to share their ideas on the implementation of ICTs in their subject fields with each other. This impedes the acquisition of knowledge. A conclusion could be reached that only certain teachers at School A have opportunities to attend conferences which discourages non-privileged teachers to the extent where they feel de-motivated to use their mobile tablets for teaching. No real effort was made by both School A and School B to find solutions and ideas to incorporate MEAs in daily mathematics activities. There are individual teachers who work innovatively with MEAs which did not result from initiatives of management or ICT committees. Neither school made an effort to conduct a skills audit to provide specific training to teachers and learners.

Meaningful contribution: A skills audit could be conducted to determine in which areas teachers need training. Specific training is needed to assess information as discussed under "Information Quality – Research skills". After these skills have been acquired by teachers they have to be taught how to incorporate mathematics applications in their daily lesson planning.

3. Learner training

Some teachers believe that today's learners are "born" with the skills to operate mobile devices. Although there might be some truth in this assumption it cannot be assumed that they have specific skills to conduct research or work with applications.

Meaningful contribution: An ongoing training process could be implemented to provide learners with the skills to conduct appropriate investigations through the use of mobile devices. Their training could focus on research skills and the useful operation of mobile devices. The learners' skills could be recorded to determine their future training needs.

4. Learner exposure

The use of mobile devices and applications could provide opportunities to learners to expand their current world view. It provides opportunities for learners to conduct research on concepts and topics they encounter in class which will assist them to choose a career. Learners are provided with new learning opportunities and could structure their thoughts to create goals and objectives for the future.

Meaningful contribution: Training provides learners with knowledge and skills which can assist lifelong learning. These skills will particularly become useable when learners are provided with job opportunities or when they attend tertiary institutions.

5. Integration of applications

The integration of MEAs in South African curricula is implemented at a very slow rate. This could be due to the unavailability of mathematics applications which could supplement South African curricula needs, or a shortage of skills and knowledge in educational environments. The shortage of skills and knowledge could impede the development of applications aimed at the South African curricula.

Meaningful contribution: The integration of applications into curricula consists of two aspects namely, the assessment of applications, information and training. Both of these aspects were discussed previously under "Training – Teacher training and Information Quality – Research skills". Schools which formed part of the population of this study have a collective voice which could be used to emphasize the importance of the development of applications which will support their needs. These schools could also cooperate with each other to determine how they could contribute to the development or improvement of mathematics applications. Mathematics teachers could collaborate with each other to provide practical advice and tips on how to integrate existing applications into their daily activities.

5.2.6. USER INVOLVEMENT

Definition according to conceptual framework:

The definition of "user involvement" in this study is seen as the involvement of teachers in the designing and development of MEAs

Conclusions made from data analysis:

Roschelle et al. (1999) explain that a divide exists between the developers of MEAs and teachers. Developers of MEAs are not subject specialists and teachers do not have the skill to develop MEAs. Teachers are regarded as subject specialists. They have the required knowledge and skills to teach their subject.

Meaningful contribution: Some teachers have enough experience to be able to discern between appropriate and inappropriate information in such a way that they will be able to support developers in their creation of applications. This creates opportunities for teachers to devote their extra-curricular time in conjunction with developers to produce MEAs. The assistance of educational specialists in the development of MEAs could create alternative employment opportunities.

5.2.7. PERCEIVED USEFULNESS

Definition according to conceptual framework:
This dimension attempted to determine how MEAs could contribute to learners' mathematics performance and how teachers could apply it to assist in their teaching of mathematics.

Conclusions made from data analysis:

1. The five proficiencies of mathematics learning

Kilpatrick et al. (2001) specifically emphasised that all the proficiencies in mathematics are interwoven and form a coherent whole for the mastering of mathematics. Therefore each of the competencies should be regarded as equally important. This discussion is a result of the analysis of applications which was addressed in Chapter 2.

Conceptual understanding

Mathematics applications should assist learners to use their current knowledge to draw inferences in order to make deductions. Applications should contain exercises to promote mathematical problem solving to enhance conceptual understanding. The application should provide feedback to incorrect answers. The learner should get the opportunity to reflect on, memorise and internalise the feedback given by the application. The emphasis should be on the practise of mathematical problems where the feedback would be applied. The application should promote retention by providing the learners with various practice questions.

Procedural fluency

An application should provide the learner with sufficient practice questions which will assist the learner to memorise and practice mathematical laws of a particular topic. The knowledge and skills that learners acquire through practice should help them to discern between a correct and incorrect method. According to Kilpatrick et al. (2001) if learners know when to use certain procedures they should apply them accurately and efficiently. Therefore applications should create opportunities to promote the skills of procedural fluency.

Strategic competence

Strategic competence is a very complex concept to represent within an application. There might be some applications which ask questions in the form of word sums. The learner then has the responsibility to formulate an equation to solve the problem. Not one of the applications used for this study aided a learner to create an equation after a real-life problem has been encountered. Learners need practice in problem formulation and solving. The developers of applications need to devote more time to the development of this competency in mathematics and should find innovative ways to represent them in applications.

Adaptive reasoning

Any mathematical application should provide the opportunity for a learner to check whether their reasoning is valid. Validity in mathematics is normally conducted through formal proof and deductive thinking. Mathematical applications could promote adaptive reasoning by providing in-depth explanations of steps. It will also assist the application to incorporate theoretical examples as additional information. All the facts, procedures and solution methods in mathematics fit together. Adaptive reasoning will assist a learner to understand this thinking process.

Productive disposition

All of the above mentioned proficiencies play a role to develop a learner's productive disposition towards mathematics. Learners who have a productive disposition towards mathematics view the subject as useful and worthwhile. They will recognise that there is no quick way to become proficient in the subject and have confidence in their mathematical ability. Learners' need frequent opportunities to practice the above mentioned proficiencies to be able to develop each strand. Many learners study mathematics by memorising. The problem with this approach is that as soon as a learner is confronted with a similar problem with changed variables they will not be able to solve the problem. The sense making of the problem has not been emphasised, and therefore learners will lose confidence in their abilities.

Meaningful contribution: These proficiencies could be used by mathematics teachers to assess the information of an application. If applications could promote these proficiencies it will positively contribute towards the information quality of the applications which will enhance its perceived usefulness.

2. Functionality of applications

The use of applications has provided teachers and learners with various learning opportunities which were not available before the use of mobile devices were introduced. Teachers and learners have opportunities to conduct investigations and do research while they are on the move not bound to a fixed location (Masrom, 2007c).

Meaningful contribution: The use of mobile devices and applications could assist in the development of critical thinking skills which could improve learners' and teachers' decision making ability.

3. Work ethics

The use of applications supports learners to focus on their educational progress. Mathematics applications provide opportunities to learners to do revision at home especially those learners who do not own textbooks. Learners have the opportunity to communicate with each other outside the school to assist each other to solve mathematical problems. This improves co-operative learning.

Meaningful contribution: The use of applications could provide learners with enough resources regardless of the shortage of textbooks. The availability of resources should motivate learners to work diligently and to the best of their ability.

4. Outcomes

One of the objectives of mathematics is to reach the outcomes as stipulated in the curricula. Teachers have the need for the support of applications in reaching their teaching goals.

Meaningful contribution: Mathematics teachers need to assess the information and activities on applications as discussed under "Information Quality".

5. Challenges

Teachers in South Africa should comprehend that challenges form an influential part of the development and improvement of mathematical applications. Teachers have to search for and select appropriate applications for mathematics. Unfortunately, this will form part of their daily activities until effective and efficient applications have been developed for the South African contexts.

Meaningful contribution: Teachers should convert this challenge into an opportunity. Although searching for appropriate applications is time consuming, teachers have the opportunity to explore and experiment and this should also contribute to their professional development

5.2.8. PERCEIVED EASE OF USE

Definition according to conceptual framework:
Ease of use can also refer to usability. A mathematics application could therefore be used in such a way that it allows the user to complete an instruction efficiently and effectively.

Conclusions made from data analysis:

The ease of use of applications is a very subjective concept. Teachers who are frequently working with applications and mobile devices might find difficult applications easy to work with and teachers who are unfamiliar with applications and mobile devices might find it very difficult. Individuals might identify different elements in applications which are challenging for them to work with.

Meaningful contribution: The data analysis identified six elements which teachers perceive as advantages or disadvantages of the ease of use of applications. Each of these elements influence the satisfaction they derive from the application and their interpretation of quality.

5.2.9. BEHAVIORAL INTENTION

Definition according to conceptual framework:
The perceived usefulness and ease of use of the application will direct the users' intention to use the mobile application.

Conclusions made from data analysis:

1. Motivation

The management of schools and ICT committees have a big responsibility to find innovative ways to develop and increase the motivation of teachers and learners. Although it is very difficult to find applications suitable for the South African context, motivation should be aimed at promoting the usefulness and ease of use of applications.

Meaningful contribution: If teachers and learners feels motivated and confident to use applications there will be a change in their behaviour towards the use of applications.

2. Training

The management of a school has to provide sufficient and effective training to their teachers and learners if they wish that their behaviour towards the use of applications changes. Generic training will provide teachers with basic knowledge and skills which can be used to incorporate new teaching and learning strategies. Although this might seem sufficient, teachers have the desire to incorporate subject specific applications into their lessons which will provide them with an extra tool through which learning could take place. Training is needed in this regard.

Meaningful contribution: There should be a balance between generic training and subject specific training. Subject specific training should focus on how teachers could implement applications in their mathematics lessons and how to evaluate and select mathematical applications. A combination of generic and subject specific training could improve a teacher's behaviour to become more favourable towards the use of mathematics applications.

3. Teachers' fear of technology

The introduction and dissemination of mobile devices and applications should be conducted at a very steady and measured pace. This will ensure that all teachers involve feel comfortable using the devices and applications. Teachers' fear of technology creates the impression that they have a dislike towards technology which creates tension among teachers. Their fear results from a lack of knowledge and an inability to recognize the benefits, and a lack of skill to be able to work effectively with technology.

Meaningful contribution: The management of a school should respect a teacher's fear of technology and embrace it as a teaching opportunity. Teachers should challenge their fear by attending training courses and attempting to gain more knowledge and acquire more skills in their use of mobile devices and applications.

5.2.10. USER SATISFACTION

Definition according to conceptual framework:

The definition of user satisfaction to be used in this study is when a learner is able to complete his learning objective with the support of a mathematics application and the feelings of satisfaction when using the mathematical application in his learning process (D. H. Jonassen, 2006).

Conclusions made from data analysis:

It could be deduced from the discussions of the previous 9 dimensions that each dimension on its own could make a valuable contribution to the meaningful learning of mathematics. Each of the dimensions consists of characteristics which defines each dimension. These characteristics should ensure that each dimension achieves the outcomes which were set for their intended use. To determine the meaningful contribution of each of the dimensions could be extremely subjective. A teacher or learner could find one or more characteristics useful within a dimension and still attach value to the application. This means that a teacher or learner could achieve a learning objective through the use of that application. For this study the researcher followed a holistic approach to evaluate applications using the ISS model. The researcher believes that each dimension contributes to the meaningful learning of mathematics, even if it is on a very small scale. There are certain relationships that exist between the dimensions that cannot be ignored. These relationships are found in the original ISS model due to the natural influence they had on one another (Zaied, 2012). It could also be deduced that each dimension should form a coherent whole where it plays a significant role in the evaluation of applications. User satisfaction could be reached in each dimension on their own but their efficiency and effectiveness could be determined through the influence of the other dimensions. Therefore teachers and learners might not achieve all the intended learning outcomes due to the shortcomings of the dimensions caused by their incoherent working.

5.3. CONCLUSION OF FINDINGS

How did the findings answer secondary question one: How do teachers evaluate and select mathematical applications?

All the inferences made on the ten dimensions of the ISS model indicated that teachers do not use a specific method to evaluate MEAs. Most teachers evaluate and select MEAs by comparing the content of the applications with the content they encounter in their curricula. The use of applications increases their preparation time due to the fact that they have to adjust their lesson planning to incorporate the content encountered in applications or they have to search for appropriate applications to fit their lesson plans. Most applications cannot be used in their totality due to their inability to address all the topics in the South African curricula.

There are certain factors which influence teachers' choices of applications that they are unaware of. This research proposed that information, system and service quality could be used to assess the functionality of applications. Management support, training and user involvement influence the functionality of applications which teachers are unaware of. These factors could shape teachers' perspectives on the applications' perceived ease of use and perceived usefulness. A teacher's behavioural intentions are influenced by these factors which will lead to user satisfaction and the actual use of applications.

How did the findings answer secondary question two: How could each dimension in the ISS model contribute meaningfully in educational environments?

The inferences made on each dimension of the ISS model addressed their meaningful contribution. The researcher has shown that each characteristic in the dimensions could be evaluated or contributes meaningfully. These characteristics create aims and objectives which should be measured by educational institutions. This will assist teachers in their evaluation and selection of mathematics applications. The researcher believes that all the dimensions form a coherent whole which should work together in order to shape learners' and teachers' behavioural intention which could lead to user satisfaction and actual use.

How did the findings answer the main research question: How can the application of the information systems success model as proposed by Zaied (2012) be used to evaluate mobile educational applications that support meaningful learning in mathematics?

Both secondary questions assisted the researcher to answer the main research question. The findings concluded that no methodology exists that teachers could use for the evaluation and selection of MEAs. The ISS model could be incorporated as an evaluation tool if all the dimensions function as a coherent whole. Each dimension in the ISS model should be evaluated according to the dimensions' characteristics. The characteristics should be measurable and attainable. This will assist teachers to determine whether applications could contribute meaningfully to reach mathematics outcomes. Teachers and learners from different schools might assign different meanings to the characteristics. Each dimension's meaningful contribution could promote meaningful learning in mathematics. The neglecting of one of the dimensions could impede the meaningful learning of mathematics.

5.4. THE HERMENEUTIC CIRCLE

The following diagram shows how the researcher applied the principles of the hermeneutic circle to this study. These principles assisted the researcher to conduct a continued analysis of the data in Chapter 4 to be able to derive meaning from it. The application of the principles shows how the researcher considered each principle when conducting data analysis and the reporting of findings.

Principles of the hermeneutic circle	
Description of principle	**Application to this study**
The fundamental principle of the hermeneutic circle:	The main focus of this study was to investigate how teachers, evaluate, select and use MEAs which could support meaningful learning in mathematics. The primary research question was answered through the interactions which took place between the researcher and the participants. The conceptual framework guided the development of the research questions and observation schedule that was used in this study. Through these interactions shared meanings were discovered which formed a holistic image for this study.
Contextualization:	The researcher understands that people, technology and organisations (schools) are subject to constant change. The research that took place at each school in this study was a unique historical occurrence but was influenced by the total history of the school. This research could become part of the schools' futures. The researcher recognised that the participants who formed part of this study are the producers and not products of history.

Principles of the hermeneutic circle	
Description of principle	**Application to this study**
Interaction between researcher and the subjects:	The researcher recognised that the interpretation of the phenomenon is a time-consuming process of construction. The researcher took time to build good relationships with the participants which assisted the researcher to understand the contexts wherein MEAs are used. The participants are viewed as interpreters and analysts. Their viewpoints of the phenomenon could be altered as they are constantly influenced by stakeholder groups with the same interests as the researcher.
Abstraction and generalization:	The results attained from the data analysis were linked with the theoretical and conceptual frameworks. The theoretical framework acted as an undeveloped model for this study which the conceptual framework is based on. The conceptual framework aimed to describe how the concepts (dimensions) in the theoretical framework could be applied to educational environments.
Dialogical reasoning:	Interpretivism which acts as the philosophy of this study assumes that truth is socially constructed. The researcher engaged with the phenomenon to establish meaning using pre-understanding of the researcher and new knowledge attained from the participants. The data analysis provided the researcher with information which was used to draw correlations between pre-understandings and new knowledge. The researcher disregarded information from the data analysis which delivered differences between pre-understandings and new knowledge.

Principles of the hermeneutic circle	
Description of principle	**Application to this study**
Multiple interpretations	The results from the interviews have shown that the teachers have different viewpoints on the research questions which reflect the conceptual framework of this study. This might be a result of each participant's viewpoint on power, economics, values and technology. These differences assisted the researcher to form a true understanding of the phenomenon, taking the social context into consideration.
Suspicion	The data acknowledged that certain participants have prejudices towards the research questions which were posed to them. There are correlations as well as disassociations which were made towards the conceptual framework through the interviews and observations. This could be a result of the participants multiple interpretations and their interaction with other stakeholder groups. The researcher questioned the surface meaning of the conceptual framework which assisted him to discern between (more or less) true beliefs, (more or less) appropriate consent, (more or less) deserved trust and (more or less aptly focused) attention.

Table 5.1: The application of the hermeneutic circle to this study (Klein & Myers, 1999)

5.5. EXCEPTIONS

Although enough evidence were gathered to show that the ISS model of Zaied (2012) could be used to evaluate and select MEAs there could be exceptions to this study. Some educational institutions might find the need to add or remove dimensions to and from the ISS model to adapt to their educational needs. The characteristics of the dimensions of the ISS model might change according to the contexts of educational institutions.

5.6. SHORTCOMINGS AND LIMITATIONS

Only participants from two schools were used to conduct this study. Therefore it would be very difficult to generalise the findings. Only three mathematics teachers participated which limited the amount of information gathered on mathematics. The researcher will consider including more participants who are subject specialists for future studies. Some of the individuals in the sample gave notice that they are willing to partake, but when the researcher required an interview they were unwilling. The researcher felt uncomfortable pursuing these individuals which led to a loss of information on the subject field. The researcher did not have the time or resources to return to the participants to conduct follow-up interviews which could have assisted in the trustworthiness of the data gathered. Different researchers might draw different inferences from the data gathered due to differences in perspectives. Due to this fact the findings of this study are influenced by the researcher's objectivity.

5.7. RECOMMENDATIONS

Researchers

The researcher will recommend the following for future studies based on the evaluation of applications using the ISS framework:

- To investigate whether the dimensions in the ISS framework could be adapted according to the needs and contexts of educational institutions.
- To investigate how applications could be developed or modified to promote the five proficiencies of mathematics learning.
- To investigate whether all content in mathematics should or could be represented using mobile applications.
- To investigate how the ISS model could be implemented and assessed from a quantitative perspective to test whether it could be generalised.

Participants

Based on the inferences, the researcher recommends the following to the participants of this study:

- *School A faces a challenge with a shortage of resources:* A possible solution for this problem is to involve local businesses and other enterprises which have the capacity to assist this school in their need for resources. Most of these businesses contribute to their societies which form part of their social objective policies.
- *Training:* Schools' main training focus should be to equip teachers to use applications in their specific subject areas. The benefits and disadvantages of mobile devices and applications should be clearly defined and explained to create a sense of expectation with teachers and learners. This will ease the implementation processes. Teachers and learners could develop a negative attitude towards mobile devices and applications if they are unfamiliar and uncomfortable using technology.
- *ICT committee:* The ICT committee should have regular feedback sessions to the management of the school. The management of the school should be aware of the aims and objectives of the committee and how they plan to reach them. This enhances a process of accountability to ensure that the ICT committee achieve their goals.

Education Industry

Based on the inferences the researcher recommends the following to the individuals or organizations involved in the educational industry:

- Although developers might be aware of problem areas regarding their applications, they should regard the users' feedback as very important as they are a key stakeholder group.
- Users can expect developers to be available for feedback and should be prompt in their replies.

- There should be a proper platform available on applications to make communication effortless between the users and the developers.
- Developers of MEAs in South Africa should devote more time to create specific applications which will complement the curricula of the country. This will enable teachers to work more efficiently and become more proficient in the use of MEAs.
- A new relationship should develop between teachers and developers. Developers could use teachers' contributions to create MEA's which will satisfy the needs of educational institutions from an information, system and service quality perspective.

5.8. RESEARCH CONTRIBUTIONS

This research made theoretical and practical contributions to the field of study.

5.8.1. THEORETICAL

The researcher developed an evaluation process in order to evaluate the ISS model developed by Zaied (2012) (*c.f.* Par 3.4.4). The researcher is unaware and could not find a specific process which could have provided guidance to conduct an evaluation of this model. Therefore this process could be used by researchers in future to evaluate similar models. The five proficiencies of mathematics learning could enhance the usefulness of mathematics applications. These proficiencies could also be used to assess the content of mathematics applications. The literature does not specifically classify MEAs as information systems. The theoretical framework of this study describes the correlation made between MEAs and IS (*c.f.* Par 3.7). This created the opportunity for the researcher to use the ISS model created by Zaied (2012) in order to evaluate MEAs.

5.8.2. PRACTICAL

The data analysis has shown that the participants could define each dimension of the ISS model which reflects their contexts and their perspectives regarding MEAs. Their definitions consist of key characteristics which they think is important in each dimension. This provides uniqueness to the ISS model in this study. The findings of this study have proven that teachers find it difficult to discern between appropriate and inappropriate mathematics applications. Teachers do not unambiguously use evaluation and selection strategies which could lead to poor application decisions. This research has indicated how all the dimensions of the ISS model should function together to achieve meaningful learning in mathematics through the use of MEAs. There are internal components and external factors which influence the functionality of applications that should be taken into consideration. It would be very difficult for MEAs alone to achieve meaningful learning in mathematics. All ten dimensions of the ISS model should contribute meaningfully to achieve meaningful learning.

5.9. REFLECTION

To be able to answer the main research question of this study it was essential to design this research appropriately. The researcher has chosen to use interpretivism as the philosophy of this study which enabled determining how the participants constructed their meanings of this phenomena (B. Kaplan & J. Maxwell, 2005). Qualitative research provided opportunities to ask personal and in-depth questions which assisted the researcher to understand the participants' viewpoint on the phenomena. The true complexity and reality of the phenomena were illuminated through this approach. To be able to understand whether mathematics applications could contribute to meaningful learning, the researcher had to determine how educators evaluate, select and use mathematics applications. The researcher decided to use evaluation research as a strategy through which the ISS model by Zaied (2012) could be used to conduct the evaluation. The ten dimensions of the ISS model were the focus points of the evaluation process. The original model was evaluated to determine the true meaning of each of the dimensions. The relationship between the ISS model and educational environments was determined to form the conceptual framework of this study. The conceptual framework could be regarded as an evaluation framework which teachers could use to evaluate and select MEAs.

The infrequent use of applications by the participants resulted in their inability to comprehensively answer questions relating to the ten dimensions. The purpose of this study was to determine whether the ISS model could be used to successfully evaluate, select and use MEAs which would improve mathematics learning. This purpose was realised through the creation of a conceptual framework which defined how each dimension could be utilised and evaluated in educational environments. The research results and findings confirmed that the ISS model could be used as an educational tool to evaluate and select mathematical applications.

Reflecting back on the reasons why evaluation research was chosen as a strategy to evaluate MEAs, the researcher drew the following conclusions:

When an educational institution has the need to conduct an evaluation of MEAs, the purpose of the evaluation should be clearly defined. The evaluation of MEAs could be time consuming and establishing a goal could provide direction for evaluators. Some evaluation purposes are specified in Section 3.4.4. If the participants in this study engaged more with MEAs before this study was conducted, the characteristics they identified could have been different. The frequent use of MEAs would enable participants to allocate more value to its use and therefore their viewpoint on MEAs would probably change. Although MEAs could influence the context where they are used, educational environments shape the way in which MEAs are used. For this reason the external dimensions (four to six) of the ISS model cannot be ignored. The differences mentioned between school A and B in this study indicate that the external factors play a significant role (*c.f*. Par 3.5.1). The use of the ISS model should not be viewed as a tool to identify problems. The ISS model should rather be regarded as a tool which allows educational institutions to respond proactively. Learning could take place while MEAs are implemented in different contexts.

5.10. FINAL CONCLUSION

This study aimed to investigate how the ISS model created by Zaied (2012) could be used by educators to evaluate and select MEAs to support mathematics learning in the FET phase.

The literature emphasised that learners' general mathematical results in South Africa are poor (DBE, 2014). Chapter 2 highlights possible factors which could affect this problem and indicates that there are a vast shortage of teachers in South Africa that contributes to the current dysfunctional educational environment (Dykes & Knight, 2012; Niemann & Kotzé, 2007). A unique mathematical problem was identified through the literature which indicates that teachers place too much emphasis on the teaching of mathematical knowledge (Stodolsky & Grossman, 1995). When this approach is followed meaningful learning becomes impaired because learners are not provided with opportunities to actively engage in educational environments to make sense of mathematics. The literature indicates that meaningful learning could be achieved through enquiry-based environments. Learners are provided opportunities to explore and develop their critical thinking skills (Maaß & Artigue, 2013). This research acknowledged that the five proficiencies of mathematics learning are essential to master mathematics and consequently should be incorporated into MEAs (Kilpatrick et al., 2001)

The increased usage of mobile devices has created opportunities for educational institutions to incorporate them in their inquiry-based environments. Consequently, the development of mobile computer applications which could support learning in these environments have commenced (Vogel et al., 2009). This exciting development amazed the educational environment across the world, but caused another challenge. The developers of MEAs are not educational specialists and educators do not have enough skills and knowledge to become developers (Roschelle et al., 1999). The researcher identified that mathematics educators will find it challenging to evaluate and select MEAs that will support meaningful learning in mathematics. No proposed methodology exists which educators could use to conduct evaluations. These statements are supported by the research results from Chapter 4.

The researcher proposed that the ISS model created by Zaied (2012) could be utilised to support teachers in their evaluation and selection processes. The researcher found a correlation between IS and MEAs which supported the researcher to interpret the ISS model as an educational artefact which could be used to conduct evaluations (*c.f.* Par 2.7.1). The conceptual framework of this study aimed to conceptualize the ISS model to discover meaning in educational environments (*c.f.* Par 3.4.5). This conceptualisation process involved searching for characteristics in each dimension of the ISS model which could be applied in educational environments. Each of the characteristics of the dimensions is measurable and attainable. The researcher developed interview questions and an observation schedule according to the conceptual framework. This assisted determining how teachers evaluate and select MEAs and how each of the dimensions of the ISS framework could contribute meaningfully in educational environments (*c.f.* Par 3.2). The participants of this study indicated which characteristics from each dimension they regard as important. This provided the researcher with a greater understanding of their evaluation and selection criteria and on the meaningful contribution of each characteristic. The researcher has shown that each dimension could be evaluated and contributes meaningfully in the evaluation and selection of MEAs (*c.f.* Par 5.2). This provides credibility to the use of the ISS model as an evaluation tool.

The researcher believes and has shown that each of the dimensions should work as a holistic unit. The neglecting of one of the dimensions could lead to the dysfunctional working of other dimensions which could impede the meaningful learning of mathematics. The conceptual framework of this study which is based on the ISS model could be regarded as a framework which teachers could use to evaluate and select MEAs (c.f. Par 3.4.5). The researcher acknowledges that different educational environments could assign different meanings to the dimensions of the ISS model. Therefore the findings in this study are unique to the sample which was selected. New research should be conducted to determine whether the dimensions of the ISS model could be adapted to address the different educational needs of educational institutions.

Nihal Mehta from Eniac Ventures said the following: “The mobile device has become our communications hub, our diary, our entertainment portal, our primary source of media consumption, our wallet and our gateway to real-time information tailored to our needs. The revolution is now!” (Business2community, 2016). Therefore it is very important to assess information and applications thoroughly to determine their learning and teaching use. Teachers and learners should take care in the way they operate applications. They should acknowledge that a mathematics application could provide them with excellent teaching and learning opportunities given that it went through a rigorous evaluation process which could assists them to achieve their outcomes in meaningful learning.

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APPENDIX A: TEACHER INTERVIEW PROTOCOL

Time of interview: ________________ Duration: ______________________

Date: ____

Place: ____

Interviewer: ____

Interviewee: _________________________Pseudonym: _______________________

Male / Female: ____

Interview Questions

1. System Quality

1. What would be the characteristics that define a good quality application?

2. Information Quality

2. How is the information of the application organised?
3. How can the information on the application effectively be represented?
4. How can you determine if the information is of the right length?
5. How can the information be clearly written?
6. How can you determine if the information is up to date?

3. Service Quality

7. Describe how the applications provide you with a support platform where you effectively can communicate with the developers of the applications?

4. Management Support

8. Explain how management introduced, manage and assess the use of ICT's in your school.
   - Commitment of management
   - Financial Support
   - Resources
   - Psychological and behavioural support
   - Resistance from staff

5. Training

9. How were you and the learners trained on using mobile devices and mathematical applications?
   - How did the training increased teachers ability to use and feel comfortable with tablets
   - What does the training of teachers and learners mean to you?

6. User involvement

10. If you were to have inputs on the development of applications, how do you think can you contribute?
    - How important is the use of applications to u?
    - What personal relevance do applications have to u?

7. Perceived usefulness

11. How should applications contribute to your daily activities in order to be useful?

8. Perceived Ease of use

12. What makes applications easy to use?

9. Behavioural intention

13. Which factors encourages or discourages you to use applications in your classroom?
14. How do the mathematical applications support the learners in achieving their learning objectives?

10. User satisfaction

(*cf*. Par 4.3.10, Par 5.2.10)

APPENDIX B: CLASSROOM OBSERVATION PROTOCOL

Part 1: Background Information			
OBSERVERS:			
OBSERVATION DATE:		OBSERVATION START TIME:	
LENGTH OF OBSERVATION:		OBSERVATION END TIME:	
SCHOOL NAME:		DISTRICT/LOCAL AUTHORITY/REGION:	
TEACHER NAME/ PSEUDONYM		SUBJECT:	
NUMBER OF STUDENTS	NUMBER OF BOYS	NUMBER OF GIRLS	TOTAL AVERAGE STUDENT AGE
Teacher's stated goals for the lesson			
Physical Arrangement of the classroom			
How is Technology used in the classroom			

Part 2: Observation Notes	
In this section, detailed notes will be taken as classroom activities are viewed	
Structure of the lesson: How do the learners interact with the mobile applications?	
What you see	**What you think**

Interactions between Teacher and students	
What type of questions does the teacher ask about the mathematical application, and how do the learners respond? What type of questions do the students ask about the mathematical application? In which other way do the teacher and the learners interact with the mathematical application?	
What you see	**What you think**

Interactions among students	
Do the students have the opportunity to interact with one another while using the mathematical application? If so how do they interact? Do they use the mathematical application in groups to complete a task? Do they provide feedback to one another?	
What you see	**What you think**

Use of technology Is the Mathematics applications being used part of the activity? If so, how and for what purpose? Are teachers or students experiencing difficulties in their use of the mathematical application? Are they able to troubleshoot?	
What you see	**What you think**

Use of other resources What other resources does the teacher use? (Chart paper, black boards, visual aids, computers etc.). What, if any, other technologies are being used in the lesson?	
What you see	**What you think**

APPENDIX C:

LETTER OF INFORMED CONCENT

HEADMASTER

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

Department Science, Mathematics and Technology Education

Letter of Informed Consent for participation in the study investigating: Evaluating mobile applications that support Mathematics learning in the Further Education and Training Phase

Dear Headmaster,

This investigation focuses how teachers evaluate, select and use of mobile educational applications in the classroom that could possibly support meaningful learning in mathematics. Data will be collected through interviews that will be audio taped and observations that will be audio and video taped

We are asking your consent to observe your learners and interview teachers in a research project investigating the impact that mobile applications have. The researcher guarantees that in this study, non-disclosure, no betrayal, informed consent and confidentiality agreements will be prioritized. The respondents, school and institutions will not be identified by names and where pseudonyms are used they shall not link or identify the real and actual.

Should you allow your learners and teachers to participate in this research; the following will be required of you:

1. Completion of this consent form to observe the learners.
2. To interview your teachers and audio record them.
3. To observe your teachers and learners in their classrooms. A video and audio recording will be taken from the back of the class. The learners' faces will not be recorded.

I hereby request your consent in this study. I guarantee that I will abide by the University of Pretoria's research ethics regulations and will use the information for the purposes of this study only. Ethical procedures will be followed in that the observations made in the classroom and the information obtained from teachers will be regarded as confidential.

Your teacher's participation is voluntary and he/she may withdraw his/her participation at any stage during the research process, prior to the reporting of the findings for the project. The learners will not take part in the research but will be in attendance of the class together with the researcher. The learners and parents or guardians will receive a letter to inform them about the research that will be conducted. It is important to note that your name and your learners and teachers names' and identities of offices, institutions will be withheld in the reporting of the data. No information that you share will be disclosed to other individuals in a way that will allow them to identify contributions that your teachers may make to the research.

As such, confidentiality and anonymity will be guaranteed. If you are willing to give us your consent for your learners and teachers to participate in this research, please sign below in the space provided by this letter as a declaration of your consent i.e. that your learners and teachers will participate willingly and that you understand that your learners and teachers may withdraw from the study at any time prior to publication of findings.

Researcher's Signature	**Name:** HJJ Kruger	**Tel:** 0824525251
Supervisor's Signature	**Name:** Dr Ronel Callaghan	**Tel:** 0834454918

Headmaster's Signature	**Name:**	**Date Signed:**

APPENDIX D:

LETTER OF INFORMED CONCENT

TEACHER

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

Department Science, Mathematics and Technology Education

Letter of Informed Consent for participation in the study investigating: Evaluating mobile applications that support Mathematics learning in the Further Education and Training Phase

Dear Teacher,

This investigation focuses how teachers evaluate, select and use of mobile educational applications in the classroom that could possibly support meaningful learning in mathematics. Data will be collected through interviews that will be audio taped and observations that will be audio and video taped.

We are asking your consent to interview you in this research project. The researcher guarantees that in this study, non-disclosure, no betrayal, informed consent and confidentiality agreements will be prioritized. The respondents, school and institutions will not be identified by names and where pseudonyms are used they shall not link or identify the real and actual.

Should you free willingly choose to participate in this research; the following will be required of you:

1. Completion of this consent form.
2. Interview with the researcher for +- 30-60 minutes that will be audio recorded.
3. Observation of teachers in their classroom for +-30-40 minutes that will be audio and video recorded from the back of the class. None of the learners' faces will be recorded.

I hereby request your consent in this study. I guarantee that I will abide by the University of Pretoria's research ethics regulations and will use the information for the purposes of this study only. Ethical procedures will be followed in that the observations made in the classroom will be regarded as confidential. Your participation is voluntary and you may withdraw your participation at any stage during the research process, prior to the reporting of the findings for the project.

It is important to note that your name and identities of offices, institutions will be withheld in the reporting of the data. No information that you share will be disclosed to other individuals in a way that will allow them to identify contributions that you may make to the research. As such, confidentiality and anonymity will be guaranteed. If you are willing to give us your consent for your participation in this research, please sign below in the space provided by this letter as a declaration of your consent i.e. that you will participate willingly and that you understand that you may withdraw from the study at any time prior to publication of findings.

Researcher's Signature	**Name:** HJJ Kruger	**Tel:** 0824525251
Supervisor's Signature	**Name:** Dr Ronel Callaghan	**Tel:** 0834454918

Respondent's Signature	**Name:**	**Date Signed:**

APPENDIX E:

LETTER OF INFORMED CONCENT

PARENT

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

Department Science, Mathematics and Technology Education

Letter of Informed Consent for participation in the study investigating:
Evaluating mobile applications that support Mathematics learning in the Further Education and Training Phase

Dear Parent,

This investigation focuses how teachers evaluate, select and use of mobile educational applications in the classroom that could possibly support meaningful learning in mathematics. Data will be collected through interviews that will be audio taped and observations that will be audio and video taped

We are asking your consent to observe a class where your child is a learner. The researcher guarantees that in this study, non-disclosure, no betrayal, informed consent and confidentiality agreements will be prioritized. The respondents, school and institutions will not be identified by names and where pseudonyms are used they shall not link or identify the real and actual. A video recording will be taken from the back of the class. None of the faces of the children will be recorded. The focus of the video is on the teacher and his/her interactions with the learners.

Should you allow your child to participate in this research; the following will be required of you:

1. Completion of this consent form.

I hereby request your consent in this study. I guarantee that I will abide by the University of Pretoria's research ethics regulations and will use the information for the purposes of this study only. Ethical procedures will be followed in that the observations made in the classroom will be regarded as confidential. Your child's participation is voluntary and he/she may withdraw his/her participation at any stage during the research process, prior to the reporting of the findings for the project. It is important to note that your name and your child's name and identities of offices, institutions will be withheld in the reporting of the data.

No information that you share will be disclosed to other individuals in a way that will allow them to identify contributions that your child may make to the research. As such, confidentiality and anonymity will be guaranteed.

If you decide not to give permission for your child to be observed I will take the following measures to accommodate your child:
The learners without permission to be observed cannot be visible in the recording of the video. I will create a separate space at the back of the classroom where they can be seated and take part in the activity. The space created will be behind the camera recording the observation. I will make sure that the video being taken will not cover that part of the class.
The activities that will take place will be revision on academic work that was already taught and purely for the learners' academic benefit.

If you are willing to give us your consent for your child to participate in this research, please sign below in the space provided as a declaration of your consent i.e. that your child will participate willingly and that you understand that your child may withdraw from the study at any time prior to publication of findings.

Researcher's Signature	**Name:** HJJ Kruger	**Tel:** 0824525251
Supervisor's Signature	**Name:** Dr Ronel Callaghan	**Tel:** 0834454918

Respondent's Signature	**Name:**	**Date Signed:**

APPENDIX F:

LETTER OF INFORMED ASSENT

LEARNER

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

Department Science, Mathematics and Technology Education

Letter of Informed Assent for participation in the study investigating: Evaluating mobile applications that support Mathematics learning in the Further Education and Training Phase

Dear Learner,

This investigation focuses how teachers evaluate, select and use mobile educational applications in the classroom that could possibly support meaningful learning in mathematics. Data will be collected through interviews that will be audio taped and observations that will be audio and video taped

We are asking you to take part in this research study. The researcher guarantees that in this study, he will not use your name and ensures you that confidentiality is his top priority.

Should you be willing to participate in this research; the following will be required of you:

1. Completion of this assent form.
2. Learners will form part of an observation that will be video recorded in a classroom for about 30 to 40 minutes. (The video will be taken from the back of the class, no faces will be recorded)

I hereby request your approval in this study. I guarantee that I will abide by the University of Pretoria's research ethics regulations and will use the information for the purpose of this study only. Ethical procedures will be followed in that the observations made in the classroom will be regarded as confidential.

Your participation is voluntary and you may withdraw your participation at any stage during the research process, prior to the reporting of the findings for the project. It is important to note that your name will be withheld in the reporting of the data. No information that you share will be disclosed to other individuals in a way that will allow them to identify contributions that you made to the research.

If you are willing to give us your approval to participate in this research, please sign below in the space provided. This will serve as a declaration of your approval, that is, that you will participate willingly and that you understand that you may withdraw from the study at any time prior to publication of findings.

Researcher's Signature	**Name:** HJJ Kruger	**Tel:** 0824525251
Supervisor's Signature	**Name:** Dr Ronel Callaghan	**Tel:** 0834454918

Respondent's Signature	**Name:**	**Date Signed:**

APPENDIX G: MATHTOONS MEDIA APPLICATION - WORKSHEET

Name of Mathematics application:

Mathtoons media

Instructions:

- Choose the green "Exponents" option.
- Choose the first quiz.
- Confirm by pressing the "take the quiz" option in the bottom right corner.
- Choose the correct answer on your device and press on the green "next" button at the bottom of the page.
- Also write your answer on this worksheet in the space provided.

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Name: ……………………………………………

Quiz 1: Questions

1/10: 2^3 and 3^3 are ………………………………………………………………………….

2/10: 125 is the same as ……………………………………………………………………...

3/10: Any natural number raised to the zero power is …………………………………………

4/10: 3^2 and 4^2 are ………………………………………………………………………….

5/10: Which is NOT a list of perfect squares? ………………………………………………..

6/10: 2^4 and 3^4 are ………………………………………………………………………….

7/10: 144 is the same as ……………………………………………………………………...

8/10: 1^{1001} equals ……………………………………………………………………………

9/10: 1^5 and 2^5 are ………………………………………………………………………….

10/10: What is zero raised to zero (0^0)? ……………………………………………………..

What is your score displayed on your device? ……. / 10.

Quiz 2: Questions

1/10: Evaluate $(-3)^2$ …………………………………………………………………………

2/10: $(-1)^{100}$ ……………………………………………………………………………..

3/10: $-(3)^2$ is ………………………………………………………………………………

4/10: $(-5)^0$ is ………………………………………………………………………………

5/10: $-(5^0)$ ………………………………………………………………………………

6/10: $-(-2)^3$ is the same as ……………………………………………………………………

7/10: Which expression evaluates to a positive number? ………………………………………...

8/10: Which expression evaluates to a negative number? ………………………………………..

9/10: $-(-1)^{100} =$ ………………………………………………………………………

10/10: Which is true $(-3)^2 = -(3)^2$ or $(-2)^3 = -(2)^3$?

What is your score displayed on your device? ………… / 10.

APPENDIX H: PRACTICAL MATHEMATICS APPLICATION - WORKSHEET

Name of Mathematics application:

Practical Mathematics

Instructions:

- Choose the "Tutorial" option. (Top of the list).
- Choose the "Indices" option. (4th from the top). Indices are also called **exponents**.
- Scroll down to the rules displayed in green.

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Name: ……………………………………………

Question 1

1.1 Write down in words what the first rule states. $a^m \times a^n = a^{m+n}$

……

……

1.2 Simplify the following by applying the first rule. If needed, refer to the examples given in the application to help you apply the first rule.

1.2.1 $a^2 \times a^6$ = ……………………………………………………..

1.2.2 $3^4 \times 3^{-2}$ = ……………………………………………………

1.2.3 $2x^4y \times 3x^2y^8$ = ……………………………………………

1.2.4 $3 \times 3^{3t} \times 3^2$ = ………………………………………………….

Question 2

2.1 Write down in words what the second rule states. $(a^n)^m = a^{nm}$

……….

……….

2.2 Simplify the following by applying the second rule. If needed, refer to the examples given in the application to help you apply the second rule.

2.2.1 $(a^2)^6$ = …………………………………………………………..

2.2.2 $(x^3 . x^{1/3} . x)^3$ = ………………………………………………

2.2.3 $(3^{n-2})^3$ = ………………………………………………………..

2.2.4 $[(2^3)^4]^2$ = ……………………………………………………….

APPENDIX I: MATHEMATICS APPLICATION - WORKSHEET

Name of Mathematics application:

Mathematics

Instructions:

- Open the list of options by pressing on the three white stripes in the top left corner of your screen.
- Choose the functions option (3rd from the top).

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Name: ………………………………………….

The standard form of a quadratic function is

$f(x) = ax^2 + c$ (grade 10)

$f(x) = ax^2 + bx + c$ (grade 11)

Question 1

Type the quadratic function of $f(x) = 2x^2 + 4$ in the space provided to display the parabola. Then answer the following questions by writing your answer in the space provided.

1.1 By using the graphical representation given by the application, where does the parabola pass through the y-axis? …………………………………………………………...

1.2 What is the c value in the given equation $f(x) = 2x^2 + 4$? ……………………………….

1.2 Does this parabola have a minimum or a maximum value? In other words, is it a "smiley" or a "frowny" parabola? …………………………………………………………...

1.4 In the given equation, is the value of 'a' positive or negative? …………………………….

Question 2

Type the quadratic function of $f(x) = -2x^2 + 4$ in the space provided to display the parabola. Then answer the following questions by writing your answer in the space provided.

2.1 By using the graphical representation given by the application, where does the parabola pass through the y-axis? ....

2.2 What is the c value in the given equation $f(x) = -2x^2 + 4$? ....

2.3 Does this parabola have a minimum or a maximum value? In other words, is it a "smiley" or a "frowny" parabola? ....

2.4 In the given equation, is the value of 'a' positive or negative? ....

Question 3

Type the quadratic function of $f(x) = -2x^2 - 4$ in the space provided to display the parabola. Then answer the following questions by writing your answer in the space provided.

3.1 By using the graphical representation given by the application, where does the parabola pass through the y-axis? ....

3.2 What is the c value in the given equation $f(x) = -2x^2 - 4$? ....

3.3 Does this parabola have a minimum or a maximum value? In other words, is it a "smiley" or a "frowny" parabola? ....

3.4 In the given equation, is the value of 'a' positive or negative? ....

Question 4

4.1 In the equation $f(x) = ax^2 + c$, what does the a value always represent?

....

....

4.2 In the equation $f(x) = ax^2 + c$, what does the c value always represent?

....

....

APPENDIX J: YHOMEWORK SOLVER APPLICATION - WORKSHEET

Name of Mathematics application:

Yhomework solver

Instructions:

- Open the yhomework solver application
- Enter the equation using the keypad
- Press solve

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Name: ……………………………………

Question 1

1.1 Solve for x.

$2x = 144$

……………………………………………………………………………………………

……………………………………………………………………………………………

1.2 Describe in words the rule applied to solve the equation given in question 1.1.

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

Question 2

2.1 Solve for x.

$\frac{x}{2} = 36$

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

2.2 Describe in words the rule applied to solve the equation given in question 2.1.

……

Question 3

3.1 Solve for x.

$2x + 1 = 3x + 2$

……

……

……

3.2 Describe the steps in words in order to solve a linear equation like question 3.

……

……

Question 4

4.1 Solve for x.

$(2x - 5)(3x + 2) = 2(3x^2 - 4x + 1)$

……

……

……

……

4.2 What is the process called that should be applied on the left-hand side?

……

……

4.3 What is the process called that should be applied on the right-hand side?

……

……