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EXPLORING THE USE OF WHATSAPP INSTANT MESSAGING AS A PLATFORM FOR PRE-SERVICE TEACHERS' LEARNING OF MATHEMATICS: A MIXED METHODS APPROACH

By

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Dedication

This work is posthumously dedicated to my late parents Mr and Mrs Kopung. No one can fill the empty space they have left in my life. This piece of work has been produced to ease the unbearable pain of losing them. ***I love you mom and dad; and I will forever miss you***.

"Pedagogics is never and was never politically indifferent, since, willingly or unwillingly, through its own work on the psyche, it has always adopted a particular social pattern, political line, in accordance with the dominant social class that has guided its interests."

(Vygotsky, 1997b:348)

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Declaration

I, Kabelo Joseph Kopung declare that:

1) The research report in this dissertation, except where otherwise indicated, is my own work.
2) This dissertation has not been submitted for any degree or examination at any other university.
3) This dissertation does not contain other person's writings, data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons. Where other written sources have been quoted, then:
   a) Their words have been re-written but the general information attributed to them has been referenced.
   b) Where their exact words have been used, their writing has been placed inside quotation marks, and referenced.

Student signature……………………………… Date……………………………………

As the candidate's supervisor, I agree to the submission of this dissertation.

Supervisor's signature………………………… Date…………………………………….

Abbreviations and acronyms

AAT	Academic Aptitude Test
ANA	Annual National Assessment
AT	Activity Theory
CBMS	Conference Board of the Mathematical Sciences
CDE	Centre for Development in Education
CHAT	Cultural-Historical Activity Theory
DBE	Department of Basic Education
DET	Department of Education and Training
FET	Further Education and Training
HPCSA	Health Profession's Council of South Africa
HT	Hyper Transcribe
KRF	Kuder-Richardson Formula
KZN	KwaZulu-Natal
LoLT	Language of Learning and Teaching
MLAP	Monitoring Learning Achievement Project
MLE	Mediated Learning Experience
MPQ	Mathematics Proficiency Questionnaire
PDS	Previously Disadvantaged Students
PIRLS	Progress in International Reading Literacy Study
SA	South Africa
SACMQS	Southern Africa Consortium for Monitoring Quality Study
SMS	Short Message Service
SSMTE	School of Science, Mathematics and Technology Education
TAM	Teaching Acceptance Model
TIMSS	Trends in International Mathematics and Science Study
UKZN	University of KwaZulu -Natal
WEF	World Economic Forum
WIM	WhatsApp Instant Messaging
ZDP	Zone of Proximal Development

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Abstract

The issue that this study addresses is pre-service teachers who enter mathematics teacher training programmes with an inadequate knowledge of mathematics. Yet, very often in teacher training institutions more emphasis is placed on pedagogical knowledge at the expense of subject matter knowledge. Consequently, pre-service mathematics teachers exit their teacher training programmes with the same subject matter knowledge as when they first entered. Arising out of this is a severe lack of competence in mathematics that results in poor attainment among South African students, as indicated by both national and international assessment reports. However, it is not clear how mathematics programmes at teacher training institutions address this dilemma.

To address this problem, the purpose of this study was to utilise a mixed methods research approach to explore the use of WhatsApp instant messaging as a platform for pre-service teachers' learning of mathematics. To gather data for the quantitative phase of the study, mathematics proficiency questionnaires were given to 93 pre-service teachers. To gather the qualitative data, observations were undertaken of mathematics interactions between pre-service teachers and the tutor through the medium of WhatsApp instant messaging. In addition to observations, semi-structured interviews were conducted with six purposefully selected pre-service teachers.

Quantitative data were analysed using statistical tests (*t*-test), measures of central tendency (means and modes only) and variability (standard deviation, and ranges). The analysis of data revealed a highly significant difference between the post-intervention Mathematics Proficiency Questionnaire (MPQ) scores of the experimental group and those of the control group. The statistical analysis also revealed that the experimental group showed statistically significant higher gains in pre-intervention MPQ as compared to post-intervention MPQ.

Observations of mathematics interactions on WhatsApp instant messaging (WIM) were analysed using Russell and Schneiderheinze's Cultural-Historical Activity Theory (CHAT) analytical framework while interview transcripts from pre-service teachers were analysed using a narrative analytic framework. These data led to the following themes: peer collaborative mathematics learning, ubiquitous mathematics learning, synchronous and asynchronous mathematics learning and anonymous mathematics learning.

CHAPTER ONE: INTRODUCTION

1.1 Background to the problem

This mixed methods study explores the use of WhatsApp instant messaging (WIM) as a platform for mathematics teaching and learning for pre-service teachers led by a tutor in the School of Science, Mathematics and Technology Education (SSMTE) at one of the universities in KwaZulu-Natal (KZN), South Africa (S.A). Tachie and Chireshe (2013) suggest that a profound understanding of mathematics is vital for applicants interested in obtaining better employment the world over. Mathematics serves as a gateway to future professions in a variety of fields and at its most basic level, it is a requirement for economics, accounting, engineering, natural, computer and medical sciences (Tella, 2008).

Similarly, Reyes and Stanic (2008) contend that a profound understanding of mathematics is essential for opening opportunities for students to participate fully in the economy and reap the benefits of unrestricted career choices in these trying times of high unemployment rate throughout the world. Furthermore, a deep knowledge of mathematics is pivotal in preparing students to be independent thinkers who are able to function appropriately and efficiently on a global platform (Barnes, 2005). However, for students to obtain a profound knowledge of mathematics, quality mathematics education is very significant (Tachie & Chireshe, 2013).

According to Putnam and Borko (2010), quality mathematics education presupposes quality mathematics teachers who possess a rich and flexible knowledge of mathematics. These are teachers who understand the central facts and concepts of mathematics, how they are connected, and the process used to establish new knowledge and to determine the validity of the claims made (ibid). In addition, quality mathematics teachers are able to actively involve students in meaningful mathematics problems that build upon their experiences, focus on broad mathematical themes, and build connections within branches of mathematics as well as between mathematics and other disciplines, so that students can perceive mathematics as a connected whole relevant to their lives (Barnes, 2005).

Unfortunately, the legacy of apartheid in S.A education system continues to affect the quality of mathematics education negatively (Biyela, 2012). Most of the teachers who currently teach mathematics were trained poorly in under-resourced colleges of education, while they had already been exposed to very low levels of mathematics content at school (Department of Basic Education [DBE], 2012). Lott and Souhrada (2008) postulate that under apartheid education system, black students were not taught enough mathematics in high school. Even those who took three years of teacher college preparatory mathematics programme did not learn mathematics in a deeper way (ibid). Furthermore, no significant improvement has been observed from the transfer of the three year teacher preparatory programme from colleges of education to a four year degree at university (Biyela, 2012).

The high infiltration of smartphones into the market has initiated the growing use of instant messaging techniques such as Mxit, Facebook and WhatsApp instant messaging (WIM) as communication platforms for various student groups, and more recently, for groups of teachers and their students (Tzuk, 2013; Amry, 2014). Motiwalla (2014) suggests that this popularity of instant messaging techniques within student and teacher population is so great that, ‘‘it would be foolish to ignore them in any teaching and learning environment’’ (p. 584); and therefore suggests that researchers begin investigating how they can be best utilised in academic activities. While the current researcher acknowledges the popularity and potential of instant messaging techniques such as Facebook and Mxit to be used in academic environments, the current study focuses exclusively on the use of WIM in mathematics learning by pre-service teachers at one of the universities in KwaZulu-Natal, South Africa.

WhatsApp instant messaging is a cross-platform smartphone messenger that employs users' existing internet data plan to assist them network socially in real time (WhatsApp, 2010). Since its introduction in 2009, WIM has reached 500 million users worldwide, sharing 700 million photos and 100 million videos daily (Acton & Koum, 2014) and it is rated the most downloaded application in 127 countries worldwide (Cohavi, 2013). Everyday an average of 31 billion messages are sent via WIM (Tzuk, 2013). Built as an alternative to short messaging service (SMS), WIM offers real-time texting or communication, including the ease of sharing information. As a means of sending and receiving messages to and from individuals or groups, WIM includes a variety of functions such as text messages, attached images, audio files, video files, calls and links to web addresses (Eric, 2012; Tzuk, 2013; Amry, 2014).

In recent years, while a growing body of literature has investigated the use of WIM (Church & Oliveria, 2013; Soliman & Salem, 2014; O'Hara, Massimi, Harper, Rubens & Moriis, 2014; Devi & Tevera, 2014), there is little research on the effects of WIM use in students' mathematics learning and performance (Bere, 2014; Yeboah & Ewur, 2014). Thus, the current study aims to extend the current body of knowledge on the use and effects of WIM in mathematics learning, highlighting the challenges and successes. The purpose of this study is to explore the use of WIM in mathematics learning between pre-service teachers and the tutor. This study seeks to contribute to and expand the limited knowledge in this area. The findings of study would be of interest to policy makers, lecturers, educators, marketers, parents and even pre-service teachers themselves.

1.2 Defining the problem

The current study is intended to investigate the influence of using WIM as a platform for mathematics learning on pre-service teachers' knowledge of mathematics. The study is also intended to investigate how pre-service teachers experienced the learning of mathematics using WIM and why they experienced it in that way. In South Africa (SA), it is undoubtedly true that most pre-service teachers enter mathematics teacher training programmes with parochial conceptions of mathematics as a set of rules and conventions (Biyela, 2012). This is due to the fact that the knowledge they have acquired during their high school days is based mainly on their scanty experiences as students.

Additionally, given the vicissitude of recruiting mathematically competent students into mathematics education programmes, it is inevitable that the bulk of those who eventually enter, are those who would not have been accepted into mathematically rigorous programmes of study due to their low matric mathematics marks (Pournara, 2005). Yet, very often in teacher training institutions more emphasis is placed on pedagogical content knowledge at the expense of subject matter knowledge (Benken & Brown, 2008; Seaman, Szydlik, Szydlik & Beam, 2006). Consequently, pre-service mathematics teachers exit their teacher training programmes with the same subject matter knowledge as when they first entered.

Further, in S.A, the current mathematics teachers, particularly those who have recently graduated from teacher training institutions, often evince practices that are consistent with Hristovitch and Mitcheltree's (2008) judgement that novice teachers' instructional activities do not encourage attainment of conceptual understanding and strategic competence of mathematical ideas. Very often they (novice teachers) fail to arrange mathematical topics coherently and as a result rely very much on the textbook's suggested sequence of topics (Hristovitch & Mitcheltree, 2008; Turnuklu & Yesildere, 2007). Presumably, the tendency fostered by such practices would be to spend more time on the topics that the teacher understands the most and to ignore those that are cognitively demanding.

It is thus not surprising that there is a severe lack of competence in mathematics that results in very weak attainment among S.A students. For instance, the World Economic Forum (WEF) ranked S.A 137th out of 139 countries in terms of mathematics education (Carnoy & Arends, 2014). In addition, Makgato and Mji (2006) cite several studies pointing to high failure rate in mathematics in S.A in comparison with other countries. Examples of such studies include Howie (2003), Centre for Development in Education [CDE] (2004), Naidoo (2004), and Monitoring Learning Achievement Project [MLAP] (2005). Further, the study conducted by Spaull (2011) also points to the lack of mathematics competence by S.A teachers.

Furthermore, studies such as the Trends in International Mathematics and Science Study [TIMSS] (Reddy, 2012), Southern Africa Consortium for Monitoring Quality Study [SACMQS] (Van der Berg & Louw, 2011), Progress in International Reading Literacy Study [PIRLS] (2012), and Annual National Assessment [ANA] (DBE, 2014) in grade one to six and nine have also provided evidence as to the lack of mathematics proficiency in S.A. This is despite the fact that education gets the biggest share of the country's budget and spending per learner far exceeds that of any other African country (Howie, 2003). This disheartening state of affairs has in part been ascribed to teachers' lack of mathematics knowledge (Makgato & Mji, 2006). However, it is not clear how mathematics programmes at teacher training institutions address this quagmire.

1.3 Objectives of the study

The assumption underlying the introduction of technology into schools is the understanding that technology has the potential to facilitate the re-engagement of student interest in challenging subjects such as mathematics, thereby heightening their motivation and impacting positively on their performance (Dwyer, 2008). Given this understanding, and mindful of the fact that most pre-service teachers enter mathematics teacher training programmes with a limited knowledge of mathematics, the objective of the current study is to offer pre-service teachers extra support in mathematics through the use of WIM with the aim of improving their knowledge of school mathematics.

One of the most complicated academic endeavours in mathematics teaching and learning is to generate the democratic participation of all students (Rambe & Bere, 2013). While the potential of WIM to trigger broadened academic participation is increasingly acknowledged in literature, integrating WIM into classrooms and out-of-the-classroom tasks has often been confronted with academic resistance (Bouhnik & Deshen, 2014). Academic uncertainty about WIM is often predicated on its perceived distractive nature and potential to trigger off-task social behaviour (Rambe & Bere, 2013).

My argument however, is that WIM has the potential to create alternative dialogic spaces for student collaborative engagements in informal contexts, which can gainfully increase the participation of silenced voices in mathematics classrooms. To this end, the objective of this study is to utilise WIM in mathematics teaching and learning environment with the intention of increasing pre-service teachers' participation.

Lauricella and Robin (2013) note that WIM is used extensively for social purposes in universities and that, students and their teachers are willing to use it for educational purposes. Given this popularity of WIM among university students and their teachers, together with their willingness to use it for academic purposes, the opportunity exists for its incorporation into mathematics teaching and learning activities (Motiwalla, 2014). To this end, the objective of the current study is to use WIM as a platform for mathematics teaching and learning to serve a tutor and pre-service teachers, with the aim of supplementing face-to-face traditional instruction of mathematics through creative and alternative dialogical interactional spaces.

1.4 Introducing critical research questions

In line with the above objectives, the quantitative phase of the study was organised to address the following research question:

1. How does the use of WhatsApp instant messaging as a platform for teaching and learning influence pre-service teachers' knowledge of mathematics?

The qualitative phase of the study was intended to address the following research questions:

2. What are pre-service teachers' experiences of using WhatsApp instant messaging for mathematics learning?
3. Why do pre-service teachers experience the learning of mathematics using WhatsApp instant messaging in the way that they do?

1.5 Significance of the study

Firstly, the study may be of interest to educators, scholars, researchers, facilitators, tutors, government stakeholders and ordinary citizens who have an interest in the delivery of quality mathematics education. Most significantly, this study is intended to benefit those pre-service teachers who cannot participate in face-to-face mathematics lectures or tutorials due to their limited mathematics knowledge or low confidence. It is hoped that this study has the potential to contribute towards an increase in the mathematics pass rate among pre-service teachers, and ultimately their students. In addition, the current study has the potential to influence the way WIM can be used to supplement traditional face-to-face instructional delivery of mathematics content through creative and alternative dialogical interactional spaces.

Secondly, WIM has a potential to establish mathematics teaching and learning environments that are more inclusive and supportive (Lerman, 2010). Supportive learning environments that are more inclusive have been acknowledged in the literature as significant in enabling equitable learning outcomes in mathematics (Gutierrez & Larson, 2007). Additionally, WIM is a viable mobile learning platform for student-centered and activity-based approach to mathematics teaching and learning (Rambe & Bere, 2013). A student-centered and activity-based approach necessitates the embracing of personalised access to academic resources and collaborative knowledge production, progressively bestowing on students the responsibility for learning and development (Rambe, 2009).

Thirdly, an expansive view of learning and development empowers students by expanding their repertoire of skills and capabilities, reflexivity and reasoning in knowledge production (Gutierrez & Larson, 2007). However, in order to bolster this transformation based learning, the concept of "third space" is very critical (Rambe, 2009, p.35). The third space is where the teacher and students' scripts, the formal and informal spaces of the teaching and learning environment intersect, thereby creating the potential for authentic communication, and a shift in the social organisation of teaching and learning and in what counts as knowledge (ibid). WIM, with its focus on both collective and individual knowledge production in a quasi-formal student controlled environment, can constitute students' third space (Rambe & Bere, 2013).

Finally, the current focus on indigenous knowledge systems and on the value of tacit knowledge has put more emphasis on common knowledge, socio-historically and culturally produced for student learning and development (Ng'ambi, 2011). WIM's ability to support peer-based dialogue and text-based conversations enables the altering of collectively produced personal and practical knowledge into subject matter knowledge which is applicable across different contexts (Rambe & Bere, 2013). To this end, WIM has the potential to enable free expression of shared mathematics knowledge and student "spontaneous concepts" in ways that classroom face-to-face practice generally fail to do (Tzuk, 2013 p.23).

1.6 Operational definitions

The following terms are used in the study and are defined specifically for this purpose:

Mathematical knowledge: Kilpatrick, Swafford and Findell (2011) describe mathematics knowledge in terms of five interwoven strands: conceptual understanding, procedural fluency, strategic competence, adaptive reasoning and productive disposition.

***Subject matter knowledge*:** Includes both facts and concepts in a discipline, in addition to why these facts and concepts are true, and an understanding of how knowledge is generated and structured within the subject (Shulman, 1986).

***Pedagogical content knowledge*:** The particular form of content knowledge that embodies aspects of content most germane to its teachability, which goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching (Shulman, 1986).

***Curricular knowledge*:** The knowledge of the curriculum which "is represented by the full range of programmes designed for the teaching of particular subjects and topics at a given level, the variety of instructional materials available in relation to those programmes, and the set of characteristics that serve as both the indications and contraindications for the use of particular curriculum materials in particular circumstances" (Shulman, 1986, p. 10).

***WhatsApp instant messaging*:** WhatsApp instant messaging according to Amry (2014) is a cross-platform smartphone messenger that employs the user's existing internet data plan to assist him or her to network socially in real time.

Use: According to The Concise Oxford Dictionary (1991), the word use is verb which means "cause to act or serve for a purpose; bring in to service; avail oneself of".

Experience: According to The Concise Oxford Dictionary (1991), the word experience is a noun meaning "actual observation of or practical acquaintance with facts or events; knowledge or skill resulting from this.

1.7 Conclusion

The issue raised in this chapter is that pre-service mathematics teachers enter teacher training programmes with a limited knowledge of high school mathematics. However, in teacher training institutions more emphasis is placed on pedagogical knowledge at the expense of subject matter knowledge. To this end, I argued that WIM is a viable mobile learning platform for offering pre-service teachers an extra support in mathematics. My argument is based on the popularity of WIM among student and teacher population at tertiary institutions for social interactions and also on the fact that teachers and their students are willing to use it for educational purposes.

In a nutshell, this chapter has conceptualised the study by discussing background information to the problem, the statement of the problem, the objectives of the study, the guiding questions, the significance, operational terms and the organisation of the entire dissertation. The next chapter deals with the review of literature related to the current study. This is done with the intention of understanding the different perspectives from which it has been conceptualised and dealt with in academic literature.

1.8 Structure of the dissertation

In ***Chapter One***, the study is conceptualised, that is, the background information, definition of the problem, the objectives of the study, the research questions, the significance of the study, the operational terms and the organisation of the entire dissertation are discussed.

Chapter Two deals with the review of literature related to the current study. This is done with the intention of understanding the different perspectives from which it has been conceptualised and dealt with in academic literature.

In ***Chapter Three***, I provide a discussion of CHAT which is the theoretical framework that guided my study and which was also used as the analytical lens for observations of mathematics interactions between pre-service teachers and the tutor on WIM.

Chapter Four deals with research methodology, the paradigmatic stance, research design, data collection and analysis techniques, validity and reliability and ethical issues in the current study.

In ***Chapter Five***, I present statistical results of the quantitative data analysis. These are the results of the quantitative data collected from pre-service teachers through mathematics proficiency questionnaires.

Chapter Six presents the results of the qualitative data analysis. These are the results of the analysis of the qualitative data collected through semi-structured interviews of purposefully selected pre-service teachers and the observations of mathematics interactions on WIM.

Chapter Seven draws conclusion on the findings of the whole study and makes recommendations based on the findings. In the same chapter, I conclude by reflecting on the whole research process, shedding light on the limitations of the current study and the possibilities for future research.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

In the previous chapter, I discussed the problem of pre-service teachers who enter mathematics teacher training institutions with an inadequate knowledge of mathematics and how this problem is exacerbated by the fact that at teacher training institutions more emphasis is put on pedagogical content knowledge at the expense of subject matter knowledge. I therefore presented WhatsApp instant messaging (WIM) as a viable platform for offering pre-service teachers extra support in mathematics. In this chapter, I discuss the global view of mathematics, the framework of mathematics knowledge for teaching, the relationship between teacher knowledge and student performance in mathematics, pre-service teachers' lack of mathematics knowledge, previous studies on the use of WIM in education and the challenges it represents, all with a view to better understand the different perspectives from which they have been conceptualised and dealt with in academic literature.

2.2 A global perspective of mathematics

Lerman (2010) asserts that mathematics knowledge is about theorems, axioms and methods; and it encompasses concepts such as quantity, structure, space and change. Stylianou (2006) posits that mathematics is used throughout the world in many fields and disciplines such as natural sciences, engineering, medical sciences, computer science, economics and accounting. Naidoo (2011) adds that mathematics is the science of patterns whereby mathematicians investigate patterns found in numbers, space, science and computers. These patterns are probed with the impulsion of formulating new conjectures and establishing their truths by rigorous deduction from appropriately chosen axioms and definitions. Thus, patterns are perceived to be the essence of mathematics and the language through which it is expressed and contemplated (Samson, 2007). For this reason, mathematicians are envisioned as problem solvers and independent thinkers (Lerman, 2010). In addition, Mendick (2010) posits that mathematicians are self-directed individuals who follow their own path of victory.

Further, thinking mathematically is a process through which people make their own decisions and the sense of the world around them, regardless of whether they are at leisure or at work (Samson, 2007; Tanner & Jones, 2010). Again, people utilise mathematical skills in their daily endeavours such as shopping (calculating prices, budgeting or bargaining), cooking (measuring ingredients, estimating time for cooking or calculating the number of portions), travelling (calculating the distance or estimating the next fuel stop) or at work (Naidoo, 2011). Additionally, mathematics is a field of knowledge in which mathematicians attempt to discover truths about the natural world (Herzig, 2008; Dorfler, 2006). Basically, mathematics is a context-independent activity since meanings in mathematics are socially constructed through action and interaction which are significant components of learning (Otte, 2006).

Furthermore, students are exposed to mathematics on a daily basis since they live in a society that values mathematical knowledge and the proficiencies and skills gained through the use of mathematics. In order to ensure that students obtain appropriate mathematical knowledge, Roodt and Conradie (2006) suggest that quality mathematics education is pivotal and that in order to achieve this goal, students should be prepared adequately so that they can function appropriately and efficiently on a global platform. Students should be adequately prepared so that they can become independent thinkers who participate fully and effectively in a democratic society and this active citizenship can be achieved through quality mathematics education, amongst other things (Adler, Ball, Krainer, Lin & Novotna, 2006).

However, while mathematics has the potential to empower people, it can also be used to suppress other sectors of society (Gates, 2001). Gates' perception is critical since mathematical knowledge is recognised as an indispensable component of educational goals and mathematics is a prerequisite subject for many lucrative fields of study (Keijzer & Terwel, 2007). As can be expected with this fact, all stakeholders in education are faced with a huge task of providing quality mathematics education to all students so that the aspirations of the whole world can be achieved (Kyle, 2008). The fundamental purpose of teaching mathematics is to equip students with skills, knowledge and strategies; and also to give them confidence to solve real world problems (Stylianou, 2006; Barnes, 2005).

In contrast, what happens in schools is that mathematics is being "mystified" and not much time is being allocated for the deeper understanding of concepts and ideas (Adler, et al., 2006, p.360). This is due to time pressure and constraints to finish the syllabus and also due to the fact that mathematics is always confined to textbook and curriculum material and not necessarily with the real world (Remillard, 2005). Consequently, deeper and meaningful learning is inhibited by this restricted nature of mathematics. In many schools, mathematics is being taught in ways that allow sections covered to be ticked off the checklist; as a result not much quality time is being spent on modelling real life situations (Naidoo, 2011).

Reyes and Stanic (2008) contend that a profound knowledge of mathematics is essential to all members of the society in order for them to participate fully and reap the benefits of unrestricted career choices in these trying times of rising unemployment rates throughout the world. This is a common fact in S.A.; mathematics is perceived to be the gateway to a better future and it is one of the significant subjects to study in the education system.

Zevenbergen (2010) suggest that parents should encourage their children to take up mathematics at school. This is because students who are not proficient in mathematics cannot enter the scarce and critical skills professions which provide lucrative remuneration, easy and quick access to the world of employment. While this reflects the status quo in the world, it also implies that a person can enter high paying careers, hence high socio-economic status, only if he or she is well qualified in mathematics. Kyle (2008) reiterates that mathematics has the potential to end social exclusion. This is one of the reasons why there is currently a strong focus on the teaching and learning of mathematics in S.A.

Due to the legacy of the prejudicial apartheid era education system, teachers are currently tasked with a massive undertaking of preparing students to function in a democratic society where the education system and opportunities are equitable (Naidoo, 2011). The current study explored the use of WIM as a platform for pre-service teachers' learning of mathematics. This was achieved by investigating the influence of using WIM for mathematics learning on pre-service teachers' knowledge of mathematics, pre-service teachers' experiences of learning mathematics using WIM and why they experienced it in that way.

2.3 Mathematical knowledge for teaching

For decades, researchers have been preoccupied with the mission of attempting to identify the knowledge that is needed by teachers in order to teach effectively (Schoenfeld & Kilpatrick, 2008; Menon, 2009). Although many aspects of teachers' knowledge are agreed upon, the mathematical content that teachers must possess in order to teach is still a bone of contention among researchers (Hill & Ball, 2008). Hence, numerous legitimate competing definitions of mathematical knowledge for teaching are acknowledged by the research community (Ball, Thames & Phelps 2005). Researchers concur with each other that content knowledge or common knowledge of a subject that is not specifically about teaching, is an integral aspect of the knowledge needed by teachers. For instance, Rech, Hartzell, and Stephens (2009) contend that teachers must possess sound mathematical competency in order to effectively teach mathematics; and Ma (2009) supports this assertion, arguing that a profound understanding of fundamental mathematics provides the basis for successful mathematics teaching.

Again, proficiency in mathematics for teaching transcends the knowledge that is needed to reliably carry out a mathematical algorithm (Ball, Thames & Phelps, 2005). The daily duties of teachers such as interpreting students' errors, representing ideas in multiple forms, developing alternative explanations, and choosing usable definitions (Ball & Bass, 2006), require teachers to possess more than common subject matter knowledge. A teacher requires a principled knowledge of algorithms, solutions, mathematical reasoning, and what constitutes adequate proof, in addition to being skilled in error analysis and the usage of mathematical representations (Ball et al., 2005; Ball & Bass, 2006). However, these types of responsibilities require mathematical reasoning in addition to pedagogical thinking (Menon, 2009).

The knowledge needed for teaching became a focus in mathematics education research in the mid-1980s, when Shulman and his colleagues (Shulman, 1986; Wilson, Shulman, & Richert, 1987) explored the subject-matter content required by teachers in their ground-breaking work regarding the knowledge of effective teachers. Their work ushered in a new way of thinking about the content knowledge required for teaching by developing a framework which categorised the knowledge needed for teaching (Shulman, 1986) and posited that subject content knowledge must be transformed for teaching (Wilson et al., 1987). Particularly, teachers must have substantial pedagogical content knowledge that can be used to identify useful representations such as analogies, examples, pictorial representations and drills to effectively communicate subject content knowledge to students (Usiskin, 2010).

The work of Shulman (1986) and Wilson et al. (1987) expanded and contested the commonly held beliefs about how teachers' knowledge might impact their teaching. These new ideas of teachers' knowledge suggested that teachers' effectiveness is influenced by not only the knowledge of content itself, but also by the knowledge of how to teach that content. Ever since then, researchers in mathematics education have increasingly focused on teachers' mathematics knowledge for teaching. In an extensive synthesis of the research, Hill and Ball (2008) discovered that most research studies indicate that in the field of mathematics, how teachers hold knowledge may be more significant than how much knowledge they have. In fact, "teaching quality might not relate so much to performance on standard tests of mathematics achievement as it does to whether teachers' knowledge is procedural or conceptual, whether it is connected to big ideas or isolated into small bits, or whether it is compressed or conceptually unpacked" (ibid p. 332).

Furthermore, researchers postulated that this extra knowledge required by teachers (or lack thereof) will influence their teaching decisions and ultimately their students' achievements in mathematics (Ball & Wilson, 2009; Graeber, 2007; Lee, 2006; Rine, 2008). Anders and Leinhardt (2006) contend that how teachers link their knowledge to their teaching performance, frequently referred to as pedagogical content knowledge, is critically significant for students' learning of mathematics. Ball and Wilson (2009) argue that teachers who themselves are tied to a procedural knowledge of mathematics are not equipped to represent mathematical ideas to students in ways that will connect their prior and current knowledge and the mathematics they are to learn.

Moreover, Graeber (2007) cautions that pre-service teachers who enter the classroom without valuing student understanding, will not be able to assess understanding or use knowledge of students' current understanding to make instructional decisions. Moreover, those teachers who fail to recognise and analyse alternative algorithms and solutions will consider students' reasoning incorrect when correct, or correct when invalid. The current study is therefore, intended to improve pre-service teachers' subject matter knowledge through the use of WIM led by an online tutor in one of the universities in KwaZulu-Natal, South Africa.

2.4 A framework for mathematical knowledge for teaching

Shulman (1986) introduced a new way of thinking about the content knowledge required for teaching in his pioneering work that popularised the concept of pedagogical content knowledge. Firstly, Shulman categorised the knowledge required for teaching into two domains namely, content knowledge for teaching, "the amount and organisation of knowledge per se in the mind of the teacher", and pedagogical knowledge, "the knowledge of generic principles of classroom organisation and management and the like" (p. 14).

Shulman then broke content knowledge for teaching down into three subcategories: subject matter content knowledge, pedagogical content knowledge, and curricular knowledge. Subject matter content knowledge on the one hand, includes both facts and concepts in a discipline, in addition to why these facts and concepts are true, and an understanding of how knowledge is generated and structured within the subject. "The teacher need not only understand that a mathematical algorithm is so; he or she must further understand why it is so, on what grounds its warrant can be asserted, and under what circumstances can belief in its justification be weakened" (Shulman, 1986, p. 9).

Pedagogical content knowledge, on the other hand, is "the particular form of content knowledge that embodies the aspects of content most germane to its teachability," which "goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching" (Shulman, 1986, p. 9). This knowledge includes ways of representing and formulating the subject matter knowledge that make it comprehensible to others, "the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations."

Additionally, pedagogical content knowledge includes an understanding of the conceptions and preconceptions of students, in addition to the factors affecting the difficulty of learning specific topics of study. Furthermore, pedagogical content knowledge is the form of knowledge that is used by teachers in order to guide their actions in highly contextualised classroom settings (Rowan, 2005). Multiple aspects of this knowledge have been further highlighted by being divided into three subcategories namely, content knowledge, knowledge of students' thinking, and knowledge of pedagogical strategies.

Content knowledge is the "knowledge of the central concepts, principles, and relationships in a curricular domain, as well as the knowledge of alternative ways these can be represented in instructional situations" (ibid, p. 5). Knowledge of students' thinking refers to the "knowledge of conceptions, misconceptions, and difficulties that students at various grade levels are likely to encounter when learning various curricular topics" (ibid, p. 5). The knowledge of pedagogical strategies is “the knowledge of the specific teaching strategies that can be used to address students’ learning needs in particular classroom circumstances” (ibid, p.3).

Further, curricular knowledge is the knowledge of the curriculum which “is represented by the full range of programmes designed for the teaching of particular subjects and topics at a given level, the variety of instructional materials available in relation to those programmes, and the set of characteristics that serve as both the indications and contraindications for the use of particular curriculum materials in particular circumstances” (Shulman, 1986, p. 10). This includes knowledge of “alternative curriculum materials for a given topic within a grade, the curriculum materials under study by students in other subjects”, and “familiarity with the topics and issues that have been and will be taught in the same subject area during the preceding and later years in school” (ibid, p. 10).

Hill and Ball (2008) built on the work of several researchers such as Bass, Blume and Lamon (1996), and Leinhardt, Ma, Simon, Smith, and Thompson (2002), who studied teacher knowledge in topics such as fractions, multiplication, division and rate. These studies assisted in clarifying what knowing mathematics for teaching needs and ultimately led to the defining of what Hill and Ball (2008) term specialised and common content knowledge. In mathematics, common knowledge of content is defined as the basic procedural and conceptual knowledge of solving mathematical problems.

This common knowledge is not unique to teaching; bankers, candy sellers, nurses and other non-teachers are likely to possess such knowledge (ibid). In contrast, specialised knowledge of content is “unique to individuals engaged in mathematics teaching” (ibid, p. 333). This knowledge includes an ability to explain why mathematics procedures work, what they basically mean, and appreciation of the methods students use when solving computational problems and determining whether such methods can be generalised to other problems or not.

One question that arises immediately from these definitions is whether relationships exist between common mathematical knowledge and specialised mathematical knowledge. That is, can specialised knowledge for teaching mathematics exist independently from common mathematical knowledge? Analyses of data from large surveys with mathematics teachers suggest that it may. Ball et al. (2005) found that the results for questions representing specialised knowledge of mathematics were statistically separable from the results on the common content knowledge items. They believe that these results suggest that there is a place in the professional preparation of teachers for a concentration on their specialised knowledge.

2.5 Teachers' mathematics knowledge and student achievement

Previous research on teacher knowledge has validated the seemingly intuitive idea that teachers' knowledge plays a pivotal role in what students learn and is directly related to students' performance (Goulding, Chiang & Miller, 2007; Rawland, Martyn, Barber & Heal, 2008; Goulding, Rawland & Barber, 2006; Van Dooren, Verschaffel & Onghena, 2010; Welder, 2007; Wilbourne & Long, 2010; Mathews & Rech, 2010; Monk, 2005). This claim is the basis for significant education policy decisions as well as many research studies. In addition, Rowan, Chiang and Miller (2007) found significant effects of teacher knowledge on student achievement, with greatest effects occurring in combination with other factors such as majoring in mathematics.

Furthermore, Fennema and Franke (2009) assert that a teacher's knowledge is one of the biggest influences on classroom atmosphere and on what students learn. In a meta-analysis of sixty education production function studies, variables used to represent teacher quality such as teacher ability, knowledge and education level, were found to have positive effects on student achievement (Greenwald, Hedges & Lane, 2006). Again, the work of Hill, Rowan and Ball (2005) demonstrates that those teachers with increased mathematical knowledge for teaching produced significantly larger gains in student achievement, even though their study controlled for many other variables such as student socio-economic status, student absence rate, teacher credentials, teacher experience and an average length of a mathematics lesson.

In contrast, some researchers have found weak and contradictory evidence of connections between larger amount of teachers' subject matter knowledge and greater student achievement. For instance, Rowen, Correnti and Miller (2006) reported that in grades one through six, "mathematics students who were taught by a teacher with an advanced degree in mathematics did worse than those who were taught by a teacher not having a mathematics degree" (pp. 13-14). Monk (2005) also found that advanced mathematics coursework by secondary school teachers beyond a set of five courses added little value in terms of student gains. In short, evidence for the claim that teachers' knowledge relates directly to students' learning remains inconclusive. At least four complexities contribute to this situation.

Firstly, the interaction between teachers' knowledge and students learning is not direct; rather, it is mediated by the acts of teaching and learning, as well as curriculum and instructional materials (Ahn & Choi, 2008). Further, researchers expect teachers' knowledge to influence students' learning because they assume that teachers' content knowledge has influence on what they do, both in and out of the classroom in order to support students learning. On the contrary, what individual students actually learn from the contexts created by teachers' choices depends as well on what the students bring to the situation (Welder, 2007).

Secondly, according to Kilpatrick, Swafford and Findell (2011) measuring teachers' knowledge and students' achievement is very complex, both in terms of determining what should be measured and deciding how to measure it. For instance, although many kinds of knowledge such as mathematical content knowledge, general pedagogical knowledge and pedagogical content knowledge would seem to influence a teacher's actions, some kinds of teacher knowledge may be more influential in students' learning than others. Even within a single category of knowledge for teaching, say mathematical content knowledge, different kinds of knowledge such as knowledge of how to carry out a procedure and knowledge of why it works may support student learning in different ways.

Thirdly, Floden and Ferrini-Mundy (2010) point out that another challenge in studying these relationships is the lack of sufficiently sensitive measures for examining teacher knowledge. Rowan et al. (2007) and Monk (2005) suggest that relationships between teacher knowledge and student performance might become more visible if the indicators of teacher knowledge were sufficiently sensitive to the kind of knowledge that is most likely, from a theoretical point of view, to be related to student learning. Furthermore, even though Ball et al. (2005) make headway in conceptualising and measuring mathematical knowledge for teaching at the elementary level, appropriate theoretical frames and instruments to measure such knowledge on a large-scale at secondary school level are missing.

Finally, on the student end, achievement tends to be measured in terms of standardised test scores (Wilson, Floden & Ferrini-Mundy, 2010). Yet, these tests do not measure all that society, as well as experts in mathematics education, believes is important for students to learn. Monk (2005) argues that, not only are some areas of learning in mathematics difficult to measure, and thus typically omitted from such assessments but there are also significant questions about how well these tests measure conceptual understanding and strategic competence as compared to factual and procedural knowledge.

2.6 Pre-service teachers' lack of mathematical knowledge

In S.A. as in other countries, there is a concern over pre-service teachers' knowledge of school mathematics. Why then should there be concern over pre-service teachers' mastery of secondary school mathematical content knowledge given the fact that they have already acquired the knowledge when they were students, and must also have had some significant exposure to university mathematics? There is perhaps the issue of the time elapsed since they were studying mathematics at school level (Schmidt, 2006). If this is the only reason for concern, then enabling the pre-service teachers to wider exposure to school mathematics during their one-year teacher education programme would suffice.

However, the greater concern according to the existing literature is that the knowledge pre-service teachers acquired during their school days could be inhibited since is based mainly on their constrained experiences as students (Jaworski & Gellert, 2006). Again, Wilson and Ball (2007) assert that pre-service teachers usually enter teacher education programmes with inexorable conceptions of mathematics as a set of rules and conventions and therefore, are unable to see the connections between university and school mathematics. To this end, the majority of mathematics education researchers, including Usiskin (2010), emphasise the need for pre-service teachers to acquire content knowledge different from the kind they normally receive in university level instruction.

Additionally, policy documents such as *A call for change*, (Leitzel, 1991) and *The mathematical education of teachers* (Conference Board of the Mathematical Sciences [CBMS], 2001) recommend that the undergraduate preparation of mathematics teachers involve courses that deepen and enhance their knowledge and conceptual understanding of the school mathematics they will teach. In fact, research indicates that many pre-service teachers discover that they never had an opportunity to really study the school mathematics curriculum in depth while at university, yet are expected to know and teach it with meaning to their students when they join the system (Mansfield, 2005).

Pre-service teachers cannot be able to assist their students achieve mathematical proficiency if they themselves have deficiencies in mathematics proficiency. When pre-service teachers' school mathematics content knowledge is weak, they won't be able to explain the conceptual and procedural aspects of mathematics, pose high-order questions, and make the mathematical connections necessary for students to understand, or raise students' performance on state level assessments (Furner & Robinson, 2008). Further, when pre-service teachers do not feel competent with school mathematics content, they won't be able to inspire confidence in their students (Heaton, 2010; Bryan, 2009).

Most studies report major shortcomings in pre-service teachers' content knowledge of school mathematics. For instance, Ball (2009) found that pre-service teachers' understanding of division was based on relatively simplistic and internalised rules which are unconnected to other mathematical operations. Stoddart, Connell, Stofflet and Peck (2006) found that pre-service teachers demonstrated from 37% to 98% accuracy among questions on procedural skills, but only 5% to 10% accuracy among more conceptual based questions. Quinn (2007) found that less than half of the pre-service teachers in his study could solve problems involving geometric concepts. Adams (2008) found that less than one third of the pre-service teachers in her study could describe the number system (real, integers, rational, irrational numbers etc.). Again, Van Dooren, Verschaffel and Onghena (2002) found that pre-service secondary teachers struggle with problems that are more algebraic in nature.

Additionally, Stacey, Steinle, and Irwin and (2010), found that 20% of the pre-service primary teachers did not have a good grasp of concepts related to decimals. Even more current studies confirm these alarming insights, as Tsao (2012) reports that most of the pre-service teachers he studied had poor abilities to solve abstract problems that should only be accessible mentally. Methews and Seaman (2013) report that pre-service teachers in their study struggled when asked to analyse arithmetic algorithms. Pickreign (2014) asked pre-service teachers to write a description of a rectangle and rhombus. Of the 40 teachers surveyed, only nine wrote an acceptable definition of a rectangle and only one wrote an acceptable definition of a rhombus. To this end, the current study attempted to address these issues by using WhatsApp instant messaging as platform for offering pre-service teachers an extra support in mathematics. The study also attempted to increase participation in mathematics learning among pre-service teachers, hence improved proficiency in mathematics.

2.7 WhatsApp instant messaging

WhatsApp instant messaging (WIM) is a cross-platform smartphone messenger that employs users' existing internet data plan to assist them network socially in real time (WhatsApp, 2010). In addition, WIM provides online users with the ability to send and receive a variety of media such as images, videos and audio messages. WIM client software is available for Apple iOS, Google Android, Blackberry OS, Microsoft windows phone, among others. WIM was created in 2009 by Jan Koum and Brian Acton, both formerly of Yahoo (Eric, 2012). Over the last six years, the application has become very popular in the market, gaining over 350 million users and being rated the most downloaded application in 127 countries worldwide (Cohavi, 2013). Everyday an average of 31 billion messages are sent via WIM (Tzuk, 2013). The figure below shows a smartphone with WhatsApp instant messaging application.

Figure 1: A smartphone with WhatsApp instant messaging application
(Adopted from Amry, 2014, p. 119)

According to Eric (2012), WIM enables communication with anyone who possesses a smartphone, has an active internet connection, and has installed the application. The overall cost of WIM is very low, up to an average of R12 a month in S.A depending on the network provider. One of the WIM's unique features is the option to create a group and to communicate within its boundaries. The creator of the group becomes its manager, a position that includes the privilege of adding and removing participants without the need for approval from them. Aside from this, all members of the group enjoy equal rights (Cohavi, 2013).

Further, WIM enables participants to receive an alert for each message sent or, alternatively, to mute the in-coming alerts for the duration of 8 hours, a day, or a whole week (Eric, 2012).

The high infiltration of smartphones into the market has initiated a growing use of WIM as a communication platform for various student groups, and more recently for groups of teachers and their students as well (Amry, 2014). The reasons why people use WIM as their main communication channel, rather than alternatives such as SMS, Facebook and Mxit were listed by Church and de Oliveira (2013) as: the low cost of the application, immediate delivery of messages, the desire to feel a part of the trend, the capacity to conduct an on-going conversation with many friends simultaneously, the knitting together of a community of friends or family and a simple operation scheme that makes the platform accessible to a variety of people of different ages and from different backgrounds. The table below illustrates WhatsApp instant messaging's collaborative features.

Table 1: WhatsApp instant messaging's collaborative features

Group Chat	Supports the interaction of up to 11 group members. Members can engage in discussion forums.
Unlimited Messaging	WIM's interactants enjoy abundant messaging without limits. The application uses 3G/EDGE internet data plan or Wi-Fi to ensure continuous data transmissions across platforms.
Cross platform engagements	Interactants with different devices (personal digital assistants, Smart phones, Galaxy tablets) can message one another through various media (text messages, pictures, videos, voice notes).
Offline messaging	Messages transmitted when the device is off or is located outside the coverage area are automatically saved and retrievable when network coverage is restored or when the device is turned on.

2.8 Studies on the use of WhatsApp instant messaging in education

In general, a number of studies have demonstrated that WIM was widely adopted by individuals as it allowed better accessibility and ease of communication offering real-time messaging, empowerment, sense of belongingness and sociability, enjoyment, quick information-sharing and cost benefits (Bere, 2012; Plana, Gimeno, & Appel, 2013; Church &

Oliveira, 2013; Yeboah & Ewur, 2014; Soliman & Salem, 2014; Devi & Tevera, 2014; O'Hara, Massimi, Harper, Rubens & Morris, 2014). Again, Church and Oliveira (2013), in their multi-method study involving 140 individuals (between 20 and 60 year olds) in Spain, found that WIM was commonly adopted for convenience in communication and cost benefits.

Similar Soliman and Salem (2014) investigated WIM use and its motivational factors, among 450 college students (between 18 and 55 year olds; including post-graduate students and faculty members) in Riyadh. They reported that WIM use was popular for entertainment purposes such as to share jokes or funny messages. On the other hand, O'Hara et al. (2014) investigated WIM use among 20 individuals (between 17 and 49 year olds) in the United Kingdom (UK). They found that WIM messaging was primarily used to 'dwell' with significant others in the virtual space. They also concluded that the effects of WIM use on social relationships included a sense of belongingness, as well as a secured and committed bond. However, some of the major limitations of these studies included the fact that sampled age groups were quite diverse and thus the results could not be generalised.

Bere (2012) investigated motivational factors that affected WIM use among 118 undergraduates in South Africa. In his study, it was highlighted that a majority of undergraduates preferred ubiquitous learning via WIM; however this was particularly significant among younger and single (unmarried) undergraduates. Meanwhile, Yeboah and Ewur (2014) conducted a study to investigate the impacts of WIM use on students' performance in tertiary institutions in Ghana.

Like Yeboah and Ewur (2014), Plana, Gimeno and Appel (2013) was interested in exploring the benefits and drawbacks of using WhatsApp instant messaging to reading skills in English as a foreign language (EFL). Their study found that a majority of students reported a high level of confidence and interest in reading English via WhatsApp messages. In relation to how university students use social networking sites, Devi and Tevera (2014) found that both Facebook and WhatsApp instant messaging were commonly used for academic communication and information sharing.

Additionally, Rambe and Bere (2013), report an instance where WIM was adopted for an information technology course at a South African university with a view to heighten lecturer-student and peer-based participation, and enhance pedagogical delivery and inclusive learning in formal and informal spaces. The findings suggest that WIM heightens student participation, fosters learning communities for knowledge creation and progressive shifts in the lecturer's mode of pedagogical delivery.

Further, Bere and Chipunza (2013) investigated the potential of WIM to bridge information divides between educators and students, and to allow the sharing of collectively generated educational resources among previously disadvantaged students at a South African university. The results suggested that students conceived WIM as a lever for bridging access to peer generated resources, heightening on-task behaviour and promoting meaningful context for free learning. Again, an exploration of the use of WIM in a South African university class by Chipunza (2013) reported positive feedback from students who claimed that it was an easier way to communicate with their teachers and the rest of the class and that it enabled productive discourses on relevant issues in an informal context where students could learn intimately and authentically. Such cooperation was felt to bridge gaps in knowledge and physical distance.

Furthermore, in another study Bere (2012) used WIM, together with the Blackboard learning management system (known as e-thutho) to create a ubiquitous space where students could connect with others and collaborate academically. Students created virtual platforms on both WIM and Blackboard. A comparison was made using students' experience to deduce a popular ubiquitous learning platform for the participants. The results indicated that most students preferred the ubiquitous learning enabled by WIM compared to Blackboard. Edutainment and multitasking are among the aspects that made WIM a popular learning platform among students.

Moreover, Amry (2014) explored the impact of using WIM for learning on the achievement and attitudes of online students using mobile devices at university level. Specifically, this study compared an independent sample of students in an experimental group (15 students) with a control group (15 students) from a university class. The mobile learning process of the experimental group was based on WIM learning activities. The control group was without WIM learning activities and received only face-to-face instruction in the classroom. The *t*-test was used to compare the differences between the experimental and control groups. The results indicated that there were real and positive differences, at 0.05 alpha level, in the achievements and attitudes of the experimental group compared with that of the control group.

Finally, Bouhnik and Dashen (2014) conducted an exploratory research project with WIM employing a qualitative method. Twelve semi-structured interviews were carried out with teachers who used WIM application in order to communicate with their students. It turned out that WIM groups were used for four main purposes: communicating with students; nurturing the social atmosphere; creating dialogue and encouraging sharing among students; and as a learning platform. The participants further identified as educational advantages the creation of a pleasant learning environment, an in-depth acquaintance with fellow students which had a positive influence upon the manner of learning, the accessibility of learning materials, teacher availability and the continuation of learning beyond class hours.

While a growing body of literature has investigated the use of WIM (Church & Oliveria, 2013; Soliman & Salem, 2014; O'Hara, Massimi, Harper, Rubens & Moriis, 2014; Devi & Tevera, 2014), there is little research on the effects of WIM use in students' mathematics learning and performance (Bere, 2014; Yeboah & Ewur. Thus, the current study aims to extend the current body of knowledge on the use and effects of WIM in mathematics learning by pre-service teachers, highlighting the challenges and successes. The purpose of this study was to explore the use of WIM in mathematics learning between pre-service teachers and the tutor. This study sought to contribute to and expand the limited knowledge in this area. The findings of study would be of interest to policy makers, lecturers, educators, marketers, parents and even pre-service teachers themselves.

2.9 Challenges posed by WhatsApp instant messaging in education

Despite all these opportunities afforded to students and their teachers by WIM, Sweeny (2010) contend that WIM has a negative impact on academic writing as students begin to overlook grammatical rules such as vowels and punctuation. Again, Makoe (2010) warns that the misuse of WIM while online could be distracting to students. Also, given the fact that a single text message is limited to only 140 characters, users may be challenged by the brevity of the language used and lack of mathematical symbols and formulae (Keegan, 2010).

Additionally, a study conducted in Kuwait, showed a negative effect of the use of WIM on students' ability to develop writing skills in English as a foreign language (Salem, 2013). Furthermore, the provision of academic materials after hours via WIM may be disruptive to married students' family life as quality family time become seamlessly integrated into academic pursuits (Lauricella & Robin, 2013). Finally, WIM distracts students from studies and completing assignments, damaging language spellings and grammar and causes lack of focus in lecture halls (Yeboah & Ewur, 2014). To this end, the current study was intended to contribute to the literature on the experiences of using WhatsApp instant messaging in academic activities. This was achieved by investigating the experiences of pre-service teachers when they learn mathematics using WhatsApp instant messaging.

2.10 Conclusion

In this chapter, I reviewed the literature on the global perspective of mathematics and mathematical knowledge for teaching. In the same chapter, I also reviewed previous studies on WIM in educational activities and the challenges posed by WIM in education. I conducted the literature review with an intention to better understand how the literature dealing with topics such as mathematics knowledge and the use of WIM can inform my topic. The literature review reveals that globally, there is a concern over teachers' knowledge of mathematics particularly that of pre-service teachers, and this therefore indicates that something must be done.

The literature review also reveals that even though WIM has been used in education, none of the studies focused on the use of WIM in mathematics teaching and learning situations and also none of the studies used a mixed methods approach. The next chapter provides a discussion of Cultural-Historical Activity Theory (CHAT) which is the theoretical framework that guided my study and which was also used as analytical lenses for observations of mathematics interactions between pre-service teachers and the tutor on WIM.

CHAPTER 3: THEORETICAL FRAMEWORK

3.1 Introduction

In the previous chapter, I reviewed literature on the global perspective of mathematics, mathematics knowledge for teaching and the use of WhatsApp instant messaging (WIM) in educational activities, in an attempt to better understand how these topics have been conceptualised and dealt with in academic literature. In chapter one, I argued that even though pre-service teachers enter teacher training programmes with an inadequate knowledge of school mathematics, more emphasis is placed on pedagogical knowledge at the expense of subject matter knowledge. I therefore, argued that WIM is a viable mobile learning platform for providing pre-service teachers with extra support in school mathematics. In this chapter, I discuss Cultural-Historical Activity Theory (CHAT), which is the theoretical framework within which the current study is located and which was also used as analytic lenses for the observations of mathematical interactions on WIM by pre-service teachers and their tutor.

3.2 The theoretical basis for human computer interaction

3.2.1 Vygotsky and semiotic mediation

Contentiously, Vygotsky (1978) developed the first well-documented formulation of what he termed the basic activity system.[1] Vygotsky's thinking about cultural development is that human interaction with the social world is not direct, rather semiotic tools (language) and signs (symbols, numbers, and formulae) mediate it. Vygotsky's stimulus-response theorisation on human action mediated by cultural tools constitutes the basic activity system. In the current study, WIM and language are mediational tools used by the tutor and pre-service teachers in their appropriation of mathematical content into systematically structured knowledge, what Vygotsky (1978, p.145) terms "scientific concepts".

[1] Although the theorisation about activity has its roots in the writings of Hegel (1975, 1977) and Marx (1970), in particular in their work on human relationship with the environment, work (division of labour), and the use of tools, it was Vygotsky (1978) who popularised the concept through his subject-tool-object triad.

Vygotsky's argument is that cultural development originates from the social world and progresses into the individual world where internalisation and transformation through mastery of knowledge occurs. This understanding is captured in his general genetic law of cultural development:

> Any function in the child's cultural development appears twice, on two planes. First it appears on the social plane, and then on the psychological plane. First it appears between people as an interpsychological category, and then within the child as an intrapsychological category (Vygotsky, 1981, p. 163).

To this end, it is clear that in this framework social interactions mediated by psychological tools are critical to human psychological functioning and development. In fact, semiotic tools and symbols constitute the material artefacts through which human beings draw on and learn about the social world around them. My view therefore, is that during their interactions on WIM, pre-service teachers' mathematics knowledge may be improved as they interact with knowledgeable peers and the tutor through questions, answers and elaborations. I wished to explore whether in this way they would acquire new mathematical knowledge and discard or reconstitute old notions regarding mathematical concepts.

3.2.2 The concept of scaffolding

Although the concept of scaffolding was coined by Wood, Bruner and Ross (1976), it has its intellectual roots in Vygotsky's notion of mediation (1978). Actually, when Wood and his colleagues introduced the term scaffolding, they were talking about how teachers set up or structure learning environments for students' learning. Vygotsky's theory rather implies more dynamic exchanges between students and the teacher that enable the teacher to support students in the parts of the task they cannot do alone (Schunk, 2008). Explaining scaffolding, Vygotsky employs the concept of the Zone of Proximal Development (ZPD) and defines it as:

> [...] the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers (Vygotsky, 1978, p. 86).

What Vygotsky is saying here is that scaffolding involves an adult, expert or knowledgeable peer interacting with the novice using tools to assist him or her in more complex problem solving that the novice may not otherwise achieve independently. Human agents such as instructional support and technological tools can be used to scaffold students (Rambe, 2009). DeVries (2000) notes that Vygotsky provides some hints regarding the types of assistance which students can get through scaffolding: "clues, reminders, encouragement, breaking the problem down into steps, providing an example or anything else that allows the student to grow in independence as a learner" (p. 209).

3.3 The Cultural-Historical Activity Theory

Cultural-Historical Activity Theory (CHAT) is based upon the work of Vygotsky and his student Leont'ev from their studies of cultural-historical psychology in the 1920s (Verenikina, 2001). "CHAT is a conceptual framework based on the idea that activity is primary, that doing precedes thinking, that goals, images, cognitive models, intentions, and abstract notions such as definition and determinant grow out of people doing things" (Morf & Weber, 2000, p.81). Further, CHAT uses the whole work activity system as a unit of analysis, where the activity is broken into analytical components of subject, tool (instrument) and object, where the subject is the person being studied, the object is the intended activity, and the tool (instrument) is the mediating device by which the action is executed (Hasan, 1998).

Engeström's modification of Vygotsky's original theory provides for two additional units of analysis, which have an implicit effect on the work activity system. The first is rules; these are sets of conditions that assist in determining how and why individuals may act as a result of social conditioning. The second is division of labour; this provides for the distribution of actions and operations among a community of workers. These two elements affect a new plane of reality known as community, and through this, groups of activities and teams of workers are anchored (Verenikina, 2001).

In a nutshell, Engeström (1996) states that the work activity system is comprised of the following constitutive components: individual workers, their colleagues and co-workers; the conceptual models, tools and equipment they use in their work; the rules that govern how they work or interact, and the purpose to which members of the workplace community direct their activities. These concepts are illustrated in Figure 2 below.

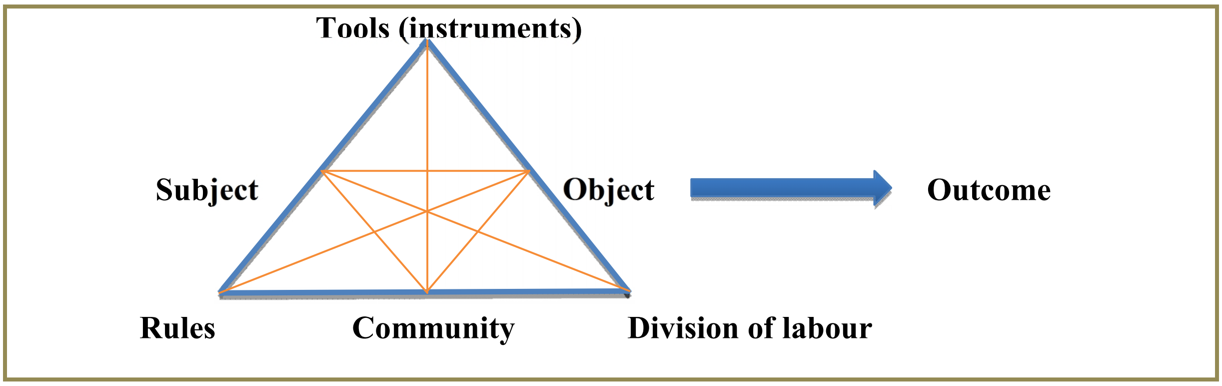

Figure 2: Engeström's expanded activity theory model
(Adopted from Engeström, 2001, p. 78)

Furthermore, the above figure indicates that CHAT is the basis for integration of tools into the social activity system as tools which mediate social action. These tools, or instruments, include artefacts, signs, language, machines and computers (Hardman, 2005). The relationship between the individual and their environment is considered through community. The relationship between subject and community is mediated by rules and the relationship between object and community is mediated by the division of labour (Hettinga, 1998). Due to the fact that those tools which have been incorporated into the social activity system have been created and transformed by human beings during the development of the activity itself, they will carry with them remnants of the cultural and historical evolution (ibid).

Finally, mediation through cultural tools such as technology is therefore, not a neutral process. This means that the tools will have an influence over the interaction between the subject and the object. Leont'ev (1981) refers to this phenomenon as *Ringstruktur*, or "ring structure", a combination of three code terminating elements: subject, activity, and object; where the subject is primary and where the object completes the circle by influencing the subject. For instance, the tool which the Palaeolithic tool-maker holds in his hand affects his mental representations (his plan or goal) as much as those representations affect the changing object; as a result, "reciprocal relationships prevail" (Morf & Weber, 2000, p. 84).

3.4 Historical development of Cultural-Historical Activity Theory

CHAT evolved over time resulting in three generations. The first generation centred on Vygotsky's work (Engeström, 2001) and it created the idea of mediation. The initial model used to illustrate Vygotsky's basic framework resembled figure 3 below.

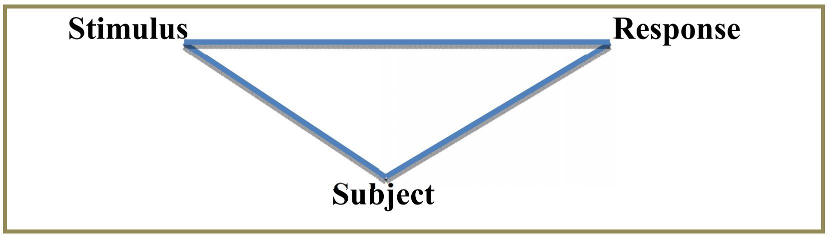

Figure 3: Vygotsky's model of a mediated action
(Adapted from Engeström, 2001, p. 134)

Initially, it was not clear whether the subject was incorporated within this activity system or not. Some literature represents this activity system in such a way that the subject does not appear as one of the vertices of the activity system triad. Instead of the subject, an arbitrary symbol X appears. Due to the lack of transparency and the existence of numerous different interpretations of this model, Vygotsky's model was refined as shown in Figure 4.

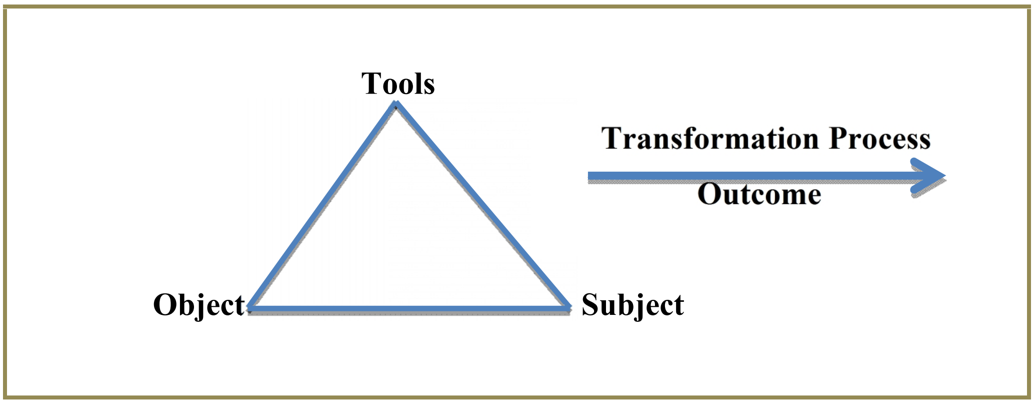

Figure 4: Vygotsky's refined model of mediated relationship at individual level
(Adapted from Kuutti, 1996, p. 28)

An interpretation of Figure 4 above implies that an activity system necessitates a subject and object, both of which are required to be mediated by a tool (Naidoo, 2011). Uden (2007) explained that this is done in an attempt to attain the outcome of the activity. Rajkumar (2005, p.35) regards the motive of the activity system as the "problem space" at which the activity is focused in order to bring about a change or desired outcome. "The object can be material (mathematics curriculum), or less concrete (a plan) or even elusive (a common idea)" (Naidoo, 2011, p.73). All these can be achieved, provided the object can be managed and transformed by the subject(s) of the activity (Kuutti, 1996).

However, Engeström (2001) contends that the model in Figure 4 above does not capture the absolute relationship between the subject and the environment in an activity. The reason he gives is that the model is still individually focused. Since most human activities are shared and occur in rich social milieus, this model is inadequate in expressing these relationships (Kuutti, 1996). In fact, he argues that the model falls short of demonstrating a complete association between an individual and his or her environment in an activity system.

This shortfall has necessitated the second generation activity system which centres on Leont'ev's research. In his example of the "primeval collective hunt", Leont'ev (1981, pp. 210-213) gives the scenario of the "bush beater" in order to explain the relationship between an individual action and a collective action. According to Leont'ev (1981) primitive hunters embarking on a collective hunt would comprise two groups: one group would beat the bushes and scare the prey, and the other group would trap the scared animal and conclude the hunt.

If taken out of the context of the larger activity, it would be difficult for an anthropologist to understand why individuals were "beating the bushes". In fact, individual members of the hunting party may not understand the subtleties of their roles in the overall activity. It is only when viewing the larger activity that individual actions are comprehensible. This was the basis for making Engeström's (2001) distinction between an activity, action and operation.

The upper level of activity, often collective, is driven by an object-related motive while the middle level of the action, often individual, is driven by a conscious goal; and the lowest level of automatic operations is driven by the environment and tools of the action at hand. However, the shortcoming of Leont'ev's research was that he did not use a graphical representation to extend the first generation activity system (Uden, 2007). While Leont'ev himself never graphically expanded Vygotsky's original model into a model of a collective activity system, Engeström did so (Daniels & Cole, 2002). This model was more proficient at illuminating shared activities and collective work. Figure 5 below is based on Engeström's (1987) conceptualisation. This model is referred to as the second generation activity system.

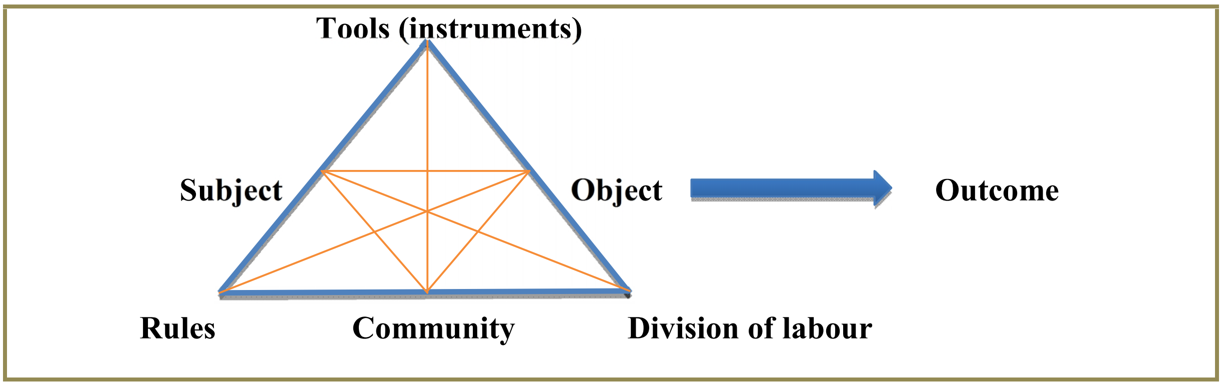

Figure 5: Conceptual model of the second generation activity system
(Adapted from Engeström, 1987, p. 78)

Thus, with this new improved model, two new relationships were formulated; subject-community and community-object, both of which were mediated by tools (Uden, 2007). This implied that in order for the subject to work on achieving the object of the activity system, mediating tools were required (Slay, 2002). The subject-community was mediated by rules, demonstrating that in order for a relationship to exist between the subject and community of the activity system, the rules of the activity system needed to exist (Uden, 2007).

Finally, the division of labour mediated the community-object relationship and each member within the community was required to have a responsibility within the activity system (Roth & Lee, 2004). Uden (2007) asserts that one or more individuals, who share the same object as the subject, constitute the community and that the unit of analysis within the activity system is the actual activity. When the activity system under consideration adopts a new element that is external to the activity system, the new element creates tension. This conflict invokes the third generation activity system (Naidoo, 2011). The third generation activity system addresses cases where there is more than one activity system influencing the one under scrutiny. Figure 6 below represents a model for a third generation activity system.

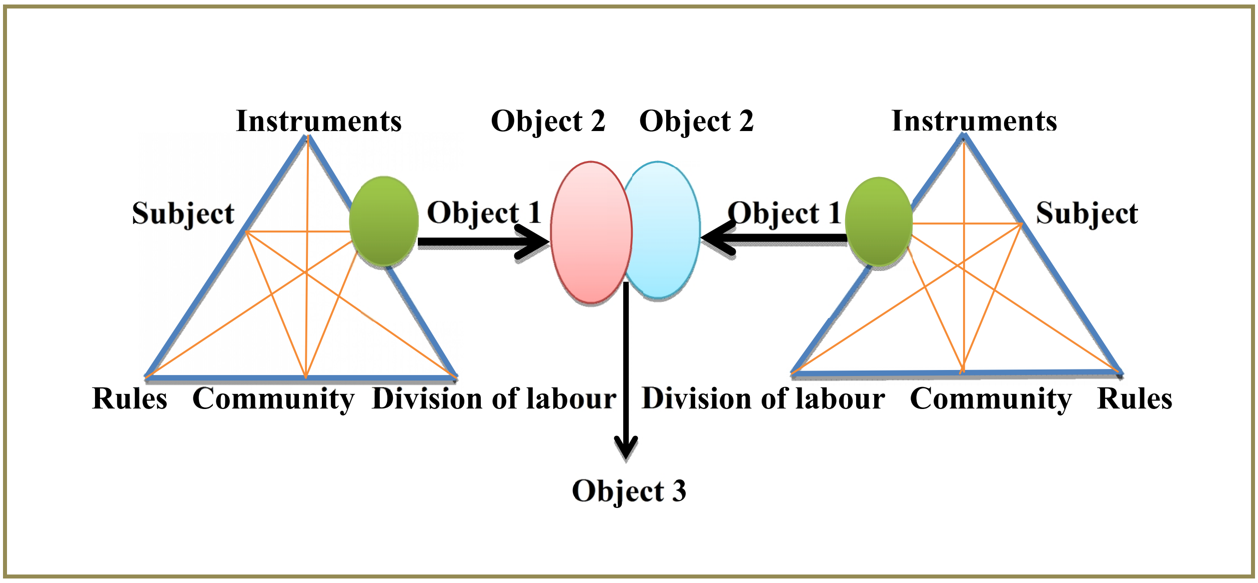

Figure 6: Two interacting systems as a model for a third generation activity system (Adapted from Engeström, 2001, p. 136)

The third generation activity system is aimed at developing conceptual tools for comprehending discourses, multiple perspectives and networks of interrelated systems (Daniels & Cole, 2002; Engeström, 2001). In this case, knowledge is simultaneously acquired through development and transformation of the object within the activity system, and new mediating tools are enabled to alter activity systems (Kuutti, 1996). Daniels and Cole (2002) postulate that an on-going production of problem solving tools provides an opportunity for expansive learning. Expansive learning encompasses the creation of new knowledge for a newly emerging activity and new mediating tools and rules.

Engeström (1987, 2001) broadens the scope of Vygotsky's triad model and Leont'ev's (1981) hierarchy of activity system by specifying the societal and contextual factors, namely, rules, community and roles. While I recognise Engeström's (1987, 2001) work as central to CHAT advancement, I however use Russell and Schneiderheinze's (2005) activity system analytical framework for analysing mathematics interactions between pre-service teachers and the tutor on WIM. Russell and Schneiderheinze's CHAT analytical framework fits the intent of my observations of mathematics interactions between pre-service teachers and the tutor using WIM: to track and monitor pre-service teachers and their tutor's interaction on WIM as the basis for inferences on pre-service teachers' learning trajectory and mathematical development.

3.5 Basic principles of Cultural-Historical Activity Theory

CHAT assimilates the ideas of planning, negotiation, history and cooperation with the intention of understanding how consciousness and activity are interrelated and integrated (Nardi, 1996; Uden, 2007). Kuutti (1996) asserts that by utilising CHAT as a theoretical framework and an analytic lens, it is inevitable that one will discuss issues related to various levels within the framework. These levels are operations, actions and activities. In addition, CHAT comprises a set of rudimentary principles that may be utilised as the foundation for more specific theories. These principles include: the hierarchical structure of an activity; object-orientatedness; externalisation and internalisation; mediation; and development. While these principles are discussed separately below, it is important to note that in reality they function as components of an integrated activity system.

3.5.1 Hierarchical structure of activity

Uden (2007) posits that activities occur simultaneously at different levels and also undergo transformation and progression on a continuous basis. Again, activities consist of a series of actions and actions, in turn, consist of a series of operations. These levels, according to Naidoo (2011) are hierarchical in nature. At the top level, there are activities followed by actions at the second level and then at the lowest level, there are operations. Further, on these levels operations are actions when they are first carried out, implying that actions are a series of operations. The actions which occur at the second level are aimed at specific goals (Uden, 2007). Figure 7 below is a hierarchical representation of these levels.

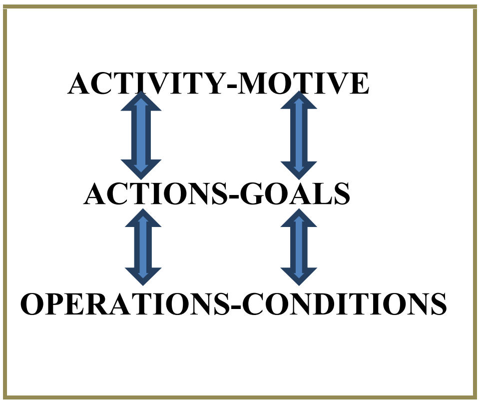

Figure 7: The hierarchical structure of an activity
(Adapted from Daniels & Cole, 2002, p. 119)

Zinchenko (1996) pointed out that activity and action are explanatory principles for all human activities and that the boundary between them is always indefinite due to the possibility of movement in both directions. Figure 7 above does not only illustrate the hierarchical nature of an activity but it also illuminates the consummate and interchangeable relationship among activity, action and operation. This implies that an activity may be an action and an action may be an operation (Kuutti, 1996).

3.5.2 Object-orientatedness

Morf and Weber (2000) explained that an activity involves individuals who are focused on achieving a specific goal or object. For instance, in a mathematics classroom, individuals within the activity system would be a mathematics teacher and students. These individuals would be focused on the teaching and learning of specific concepts in mathematics. Activities differ depending on the object in question and in the case of mathematics teaching and learning, activities could include students actively engaged in group work in order to understand mathematics concepts, rules, theorems and algorithms.

On the other hand, an object may be something physical such as a library that is being built, software such as a computer programme for calculating volumes of 3D shapes, or even something conceptual such as a theory of an activity that is being discussed (Rohrer-Murphy, 1999; Kuutti, 1996). In addition, the objects which guide the interactions of individuals with the world are not fixed, that is, they are always changing and developing and they influence the relationship between subjects and objects (Uden, 2007). Therefore, the presence of objectives enables object-orientatedness to become more tangible (Kuutti, 1996).

Nardi (1996) explains that activities are dynamic and are defined with the aid of the concept of the object. This implies that the activity cannot be understood without the holistic consideration of the role of the artefact in consideration. This means that one has to understand the role of the artefact in its everyday use. The activity in question comes before any other process since abstract notions arise as a result of individuals performing tasks. For instance, before an action is carried out in the real world, it is first planned in the mind using a model. The more user friendly the model, the more successful the action becomes (Uden, 2007). However, if for some reason the model does not prove to be suitable, the reformulation and reconstruction of the model is given more thought. This phase, according to Kuutti (1996), is referred to as orientation; at this stage the models are flexible and tentative resources.

3.5.3 Externalisation and internalisation

Externalisation and internalisation are combined as one of the five principles of CHAT. According to Naidoo (2011), internalisation is the altering of external activities into internal ones. It gives individuals an opportunity to utilise mental simulation and imagination, and to consider alternative plans. This assists in giving the individual an opportunity to use virtual images before interacting with the real object. The process of internalisation is mediated by tools and language, and it is one of the most significant tools for this purpose (Swain & Brooks, 2002).

Even though a student's mother tongue language is an indispensable learning resource, where English is the medium of instruction as is the case in S.A, the more proficient a student is in English, the better he or she is at comprehending mathematical concepts (Setati, 2006; Kazima, 2008). Unfortunately, as Setati (2006) laments this may be problematic for the majority of students in S.A., since the language of learning and teaching (LoLT) is not their mother tongue language. Therefore, given the disjunction between the LoLT and students' mother tongue language, challenges in the internalisation process are likely to be encountered. Uden (2007) says that in an instance where an individual encounters a challenge with regard to the internalisation process, externalisation often becomes handy. This means that one cannot understand internal activities if they are divorced from external activities.

In addition, Uden (2007) perceive external and internal activities to be interrelated and interchangeable. However, sometimes external influences change some components of activities, thereby causing contradictions. CHAT utilises the term ‘contradictions’ to refer to a breakdown between activities or components in the activity system (Kuutti, 1996). This is perceived to be a source of development and progress, given the fact that contradictions lead to activities designed to work through them, and this process leads to transformation (Uden, 2007). Breakdowns related to the function of a process happen when the work is interrupted, and the likelihood of this happening is when the artefacts within the activity system function differently from what is expected (Bodker, 1996). While contradictions result in disturbances, they also present an opportunity for identifying different ground-breaking strategies for changing an activity.

3.5.4 Mediation

Kuutti (1996) claims that all human activities are mediated by culturally created signs or tools. For instance, the teaching and learning of mathematics is an activity and therefore participants (teachers and students) use tools such as language, books and technology for this activity. Tools can be anything ranging from a sign or a language to machines and computers (Hashim & Jones, 2007). Vygotsky (1978) claimed that signs are the products of the internalisation process and referred to them as “psychological tools”. According to Maschietto and Bartolini (2009) these tools can be both the input and the output of the activity. Based on their dynamic nature, tools can constantly alter as a result of the activity.

Chandler (2009, p.1) argues that “people think only in signs and signs take the form of words, images, sounds, acts or objects”. However, all these signs have no inherent meaning therefore; they become signs only when people consider them as such. This implies that nothing is a sign unless it is interpreted as such. There are three types of signs, namely icons, indications and symbols. Icons identify aspects of the material they represent by emulating them while indications communicate the meaning of things they represent by being connected with them. On the other hand, symbols convey the meaning of things they represent through usage.

Chandler (2009) discusses a dual model of the sign: as a "signifier", the form which the sign takes, and as the "signified", the concept which the sign represent (p.36).

3.5.5 Development

CHAT underpins the notion that development is not only the object of analysis but is also a general research methodology (Nardi, 1996). This is because activities are not static; instead they are transforming and developing. The basic research methods that support CHAT are those that advance active participation (Waite, 2005). These methods involve the monitoring of the development that happens to the participants. Although activities are based on social, cultural and historical aspects, each activity has a history of its own which is conveyed to the objects and tools (Nardi, 1996). For instance, my view is that when pre-service teachers learn mathematics using WIM, the problem solving process would be incorporated in a history of its own. This history could relate to pre-service teachers' tacit knowledge, experience and subject matter knowledge. The use of WIM in this study was designed in such a manner that it would initiate and encourage a student-centred activity-based approach to mathematics teaching and learning.

3.6 Conclusion

In this chapter, I have discussed CHAT as a theoretical framework which underpinned my research on mathematics teaching and learning using WIM, and which was also used as an analytical lens for observations of mathematical interactions between the tutor and pre-service teachers. The chapter commenced with the discussion of mediation and scaffolding as the theoretical basis for human-computer interaction. I then continued to provide a brief overview of CHAT and the historical development which spanned its three generations. The chapter concludes by presenting a detailed discussion of the rudimentary principles of CHAT that may be utilised as the foundation for more specific theories. The next chapter deals with the research methodology, the paradigmatic stance, research design, data collection and analysis techniques, validity and reliability issues and ethical considerations in the current study.

CHAPTER 4: RESEARCH METHODOLOGY

4.1 Introduction

This chapter provides a detailed discussion of the paradigmatic stance and the ontological, epistemological, and methodological positions of the current study. The chapter also discusses the research design, data collection and analysis techniques, issues of validity and reliability and ethical considerations for the study. The purposes of methodology are manifold, inter alia, to unravel "puzzlement", a quest for "fitness of purpose" of techniques adopted and to describe and critique (Creswell, 2014 p. 145). My methodology strives to explore the use of WhatsApp instant messaging (WIM) as a platform for mathematics teaching and learning and how these mathematics interactions on WIM would influence pre-service teachers' knowledge of school mathematics. For this purpose, a mixed methods approach was adopted.

4.2 The paradigmatic stance of the study

Ernest (1994) claims that a paradigm is a set of interrelated extrapolations about the social world which provide philosophical and conceptual framework for the organised study of that world. Whether conscious or not, every researcher's investigation process is influenced by a paradigmatic stance (ibid). Denzin and Lincoln (2011) contend that the selected paradigm guides the researcher's actions in the research process in terms of tools, participants, methods, and results rendering. Mertens (2009) posits that the major research paradigms are positivism, interpretivism, constructionism, transformative and pragmatism, and that each paradigm has four constitutive components: ontology, epistemology, methodology and axiology.

Since in the current study I explore both the effectiveness of a technological tool to advance participants' mathematical knowledge and also the experiences of participants in using such a technology, the overall paradigmatic stance of my study is pragmatism. Pragmatism transcends quantitative and qualitative exclusivity or affiliation (Onwuegbuzie & Leech, 2006; Teddlie & Tashakkori, 2010). Pragmatism as a worldview accrues out of actions, situations, and consequences rather than out of the precursor conditions (Creswell, 2014). In pragmatism, there is a concern for applications and with strategies that function to find solutions to problems (Patton, 2010). Instead of concentrating on methods, pragmatic researchers accentuate the research problem and use all approaches available to comprehend the problem (Creswell & Plano Clark, 2011).

As a philosophical foundation for mixed methods research approach, pragmatism focuses first on the research problem and then utilises numerous approaches to solve the problem (Patton, 2010). This approach was ideal for the current study since its core objective was to utilise both numeric and narrative data in order to explore how mathematics teaching and learning unfolded on WIM and the influence of WIM-mediated mathematics interactions on pre-service teachers' knowledge of mathematics. This approach enabled me to probe meanings, practise corroboration and triangulation, and gather rich data so that new modes of thinking could emerge where paradoxes between two individual data sources were found.

The investigation in this study was driven by the research questions which were more than one in number and required both quantitative and qualitative data to address them, rather than by my own methodological preferences as a researcher. A wide area of agreement in the mixed methods research community is that methodology follows from the objectives and questions in the research rather than vice versa, and that different kinds of mixed methods research designs follow from different kinds of research objectives, such as hypothesis testing, exploring, explaining and understanding (Creswell & Plano Clark, 2011).

4.2.1 Ontological and epistemological assumptions within pragmatism

Ontology is " the claims and assumptions that are made by the researcher about the nature of reality, what exists, what it looks like, what units make it up, and how these units interact with each other" (Blaikie, 2007, p.15). Pragmatists do not recognise the world as an absolute unity and therefore, regard knowledge as both objective (empirical) and subjective (socially constructed) (Jonson & Onwuegbuzie, 2004). To them (pragmatists) reality is what works at the time; it is not based on the duality between the reality that is independent of the mind and the reality within the mind (Mertens, 2009). Again, the agreement among pragmatists is that research always occurs in social, historical and political contexts, therefore they believe in an external world independent of the mind as well as that which is harboured within the mind (Creswell, 2014). To this end, pragmatism is a suitable paradigm for the current study since the research views knowledge as both objective and subject as evidenced by the critical research questions. This approach addressed the research questions comprehensively.

On the other hand, epistemology is concerned with how knowledge or truth can be garnered and bestowed to other human beings (Willis, 2007). Pragmatism is not committed to any one system of philosophy and reality. This applies to mixed methods research approach in that investigators draw liberally from both quantitative and qualitative assumptions when they engage in their research endeavours (Creswell, 2014). Individual researchers have a freedom of choice. In this way, they are at liberty to choose methods, techniques, and procedures of investigation that best help them attain their research objectives (Mertens, 2009).

Additionally, mixed methods investigators look to multiple approaches for collecting and analysing data rather than subscribing to a single way (Blaikie, 2007). In fact, pragmatists contend that researchers need to stop debating about reality and the laws of nature (Mertens, 2009). They would simply like to alter the subject. Thus, for them, pragmatism is a gateway to multiple methods, different worldviews, and different assumptions as well as different forms of data collection and analysis (Creswell, 2014).

4.3 The mixed methods research approach

4.3.1 Definition of mixed methods research approach

Mixed methods research is defined as the "mixture of qualitative and quantitative approaches in many phases in the research process" (Creswell & Plano Clark, 2011, p. 5). As a method, it concentrates on collecting, analysing, and combining both quantitative and qualitative data in a single study or series of studies (ibid.). The underlying idea of mixed methods investigation is to blend different strengths and non-overlapping weaknesses of quantitative methods (large sample size, generalisation) with qualitative methods (small sample size, in-depth). Many different terms are used for this approach, such as integrating, synthesis, quantitative and qualitative methods, multimethods, and mixed methodology. However, recent writings tend to use the term mixed methods frequently (Tashakkori & Teddlie, 2010).

4.3.2 Philosophical and historical foundations of mixed methods

Creswell and Plano Clark (2011) posit that it is crucial for mixed methods investigators to present the philosophical and historical foundations of the method. While such philosophical and historical overviews might be unnecessary in purely quantitative or qualitative research, which is firmly rooted in well-established historical and philosophical traditions, the relative newness of mixed methods research warrants a brief overview. Furthermore, since mixed methods research involves philosophical assumptions that guide the collection and analysis of both qualitative and quantitative data, it is relevant to briefly outline those philosophical assumptions as they apply (Tashakkori & Teddlie, 2010).

4.3.2.1 Positivism vs. interpretivism

According to Onwuegbuzie and Leech (2006), logical positivism overshadowed scientific philosophy up until the late nineteenth century. Positivists of this era contended that the observer was independent of observable reality and could objectively separate him or herself from the observed. Further, they believed that social phenomena existed independent of the observer's values, and thus generalisations could be made regardless of time and context. However, at the turn of the twentieth century, social scientists began questioning the exclusive use of the scientific method in investigating social issues. These interpretivists argued that since the concern was on the processes and products of the human mind, no objective reality existed in the study of social phenomena. Generalisations could only be made in the physical sciences when dealing with inanimate variables existing independently of human beings.

4.3.2.2 Pragmatism

In the 1950s and 1960s, post-positivist researchers conceded that although multiple realities exist in the social sciences, and research is affected by values of the investigators, there still exist some universal and knowable relationships among social phenomena. During this time, pragmatists began advocating for combining of methodologies. Pragmatists expostulated that a false dichotomy existed between qualitative and quantitative approaches, and therefore suggested that investigators should harness the strengths of both approaches in order to accomplish a more complete comprehension of social phenomena.

Pragmatists held that objective truth might exist, however the human mind lacked the objectivity needed to discover such knowledge. They therefore, employed both inductive and deductive logic and valued both objective and subjective points of view. While extremists on both sides (positivists and interpretivists) advocated for the incompatibility thesis (Creswell, 2014), which posits that paradigms and methods could not and should not be mixed, pragmatist rebutted that quantitative and qualitative research approaches were not mutually exclusive. One could value both the generative nature of qualitative research and the reductive nature of quantitative research depending on the topic, the research context and questions.

4.3.2.3 Formative period (1959-1979)

By the late-1950s, the social sciences community was receptive to mixing methods as a means of triangulating data. They valued using multiple quantitative methods with counterbalancing strengths and weaknesses in order to explore the same phenomenon. According to many accounts (Creswell & Plano Clark 2011, Onwuegbuzie & Leech, 2006), it was Campbell and Fiske (1959) who first introduced the idea of using multiple quantitative research methods as a source of triangulation. Later in the formative period (1960s and 1970s), investigators began combining surveys and interviews and finally, qualitative and quantitative techniques.

4.3.2.4 Paradigm debate period (1985-1997)

During the mid-1980s to the mid-1990s researchers continued debating whether qualitative and quantitative data could be combined (Creswell & Plano Clark, 2011). Prior to this time, many qualitative researchers maintained that the two approaches assumed different worldviews and thus, were incompatible. Rossman and Wilson (1985) referred to those who believed the two methods to be incompatible as purists, those who adapted their methods to the situation as situationalists, and those who believed that research problems could be addressed employing a variety of lenses as pragmatists. Pragmatic investigators such as (Bryman, 1988; Reichardt & Rallis, 1994; Greene & Caracelli, 1997) challenged the notion of the incompatibility thesis by suggesting connections between the two paradigms, and therefore, urged researchers to move beyond the paradigm debate.

4.3.2.5 Procedural development period (1989-2000)

In the 1980s and 1990s, researchers began to define and describe types of mixed methods research approaches and procedures for conducting mixed methods studies (Creswell & Plano Clark, 2011). For instance, Morse (1991) described simultaneous and sequential triangulation. With simultaneous triangulation, qualitative and quantitative data are collected independently. The findings complement one another at the interpretation stage. With sequential triangulation, the results of one method inform the planning of the next method. Later researchers such as Creswell (1994) expanded on this classification system.

4.3.2.6 Advocacy as a separate design period (2003-present)

Creswell and Plano Clark (2011) indicate that there has recently been a surge of mixed methods studies. Furthermore, mixed methods researchers are increasingly advocating that mixed methods research approach be seen as a third approach along with qualitative and quantitative approaches. Studies such as Tashakkori and Teddlie (2003) and Johnson and Onwuegbuzie (2004) provide evidence that mixed methods research approach is increasingly viewed as a third stream along with its qualitative and quantitative counterparts. In his research design text book, Creswell (2014) illustrates qualitative, quantitative, and mixed methods research approaches as three separate approaches throughout the whole book.

The uprising of mixed methods research approach is evidenced by the number of recent papers and special issues of journals such as *Evaluation and Research in Education*, 19 (2), (2006), an entirely new *Journal of Mixed Methods Research*, *International Journal of Mixed Methods in Applied Business and Policy Research,* the online journal *International Journal of Multiple Research Approaches*, the *Handbook of Mixed Methods Research* (Tashakkori & Teddlie, 2003) and its subsequent *Foundations of Mixed Methods Research* (Teddlie & Tashakkori, 2009) and *Designing and Conducting Mixed Methods Research* (Creswell & Plano Clark, 2011). Along with increased growth in mixed methods journals and textbooks has come an increase in the number of dissertations and theses with mixed methods in their titles.

4.3.3 Rationale for the choice of a mixed methods research approach

One might ask why researchers would go to the trouble of combining methods or creating new research techniques when there already are rich traditions within each of the paradigms. While certain research problems can be adequately addressed through the use of a singular mode of inquiry, there are others for which a mixed methods research approach can be of significance. For instance, determining whether the use of WIM for mathematics teaching and learning was effective for improving pre-service teachers' knowledge of mathematics, would not require the collection of qualitative data. However, determining if the use of WIM as a platform for mathematics teaching and learning is effective for improving pre-service teachers' knowledge of mathematics while also exploring the pre-service teachers' experiences of being involved in this activity, would require a mixed methods approach.

In addition, researchers use mixed methods research because they acknowledge different worldviews and paradigms, the need to ask more complex questions than one can answer with a purely quantitative or purely qualitative approach, the need to generalise and contextualise, explain and understand, and deduct and induct, as well as the need to integrate data collection and analysis to overcome limitations in using one method solely (Gelo & Benetka, 2008).

Further, Creswell and Plano Clark (2011) suggest four instances when a mixed methods research approach might be appropriate for addressing a research problem: when a need exists for both qualitative and quantitative approaches (Triangulation Design), when a need exists to enhance the study with a second source of data (Embedded Design), when a need exists to explain the quantitative results with the qualitative results (Explanatory Design), and when a need exists to first explore qualitatively and then quantitatively (Exploratory Design).

Furthermore, Putnam (1990) argues that social reality is both causal and contextual; therefore the mixture of quantitative and qualitative research methods is actually unavoidable. Other benefits of combining methods include the converging or corroborating of findings, minimising alternative explanations for findings (Jonson & Turner, 2003), reporting of more accurate and comprehensive perspectives (Coyle & Williams, 2000), providing more breadth, depth and richness of phenomena (Schulze, 2003) stronger inferences (Tashakkori & Teddlie, 2003) and the expansion of the study's scope (Morse & Chung, 2003).

Finally, Sieber (1973) believes that survey and field research possess unique characteristics that make them non-interchangeable and with these unique characteristics, each method can be strengthened by the other. Moreover, Vidich and Shapiro (1955) state that the representative coverage of the population is probably of no greater value than the depth of understanding provided by interviews. That is, surveys provide representative information which can only mean something because of the information gathered from interviews.

4.3.4 Explanatory sequential mixed methods

In the current study, an explanatory sequential mixed methods design was adopted. The explanatory sequential mixed method involves a two-phase research process in which the researcher collects quantitative data in the first phase, analyses the results, and then uses the results to plan or build on to the second, qualitative phase (Creswell, 2014). The quantitative results typically inform the type of participants to be purposefully selected for the qualitative phase and the types of questions that will be asked from the participants (Leedy & Ormrod, 2013). The overall objective of the design is to have qualitative results assist in explaining in more detail the initial quantitative results (McMillan & Schumacher, 2010). Figure 8 below illustrates the visual model of the explanatory sequential mixed methods design.

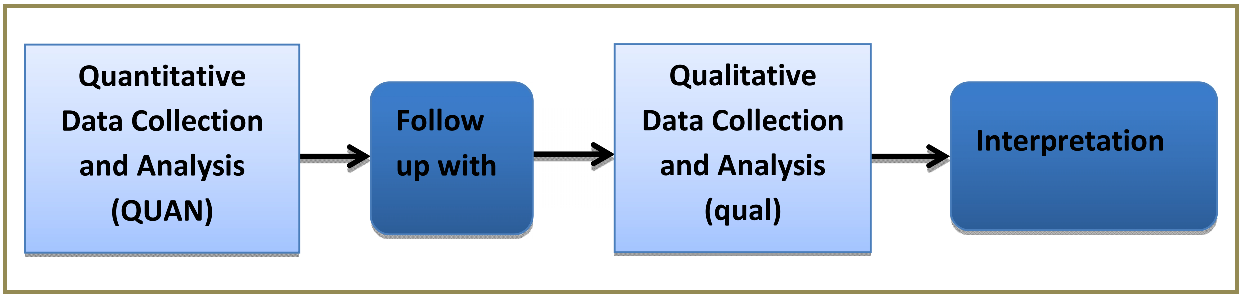

Figure 8: Visual model of the explanatory sequential mixed methods (Adapted from Creswell, 2014, p. 220)

4.3.5 Challenges posed by mixed methods to the researcher

Although mixed methods research offers many benefits to the investigator as explicated above, it also poses a number of challenges (Creswell, 2014). These challenges include but are not limited to: the need for extensive data collection, the time-intensive nature of analysing both qualitative and quantitative data; and the need for the researcher to be familiar with both quantitative and qualitative forms of research (ibid). Again, the complexity of the mixed methods research approach calls for clear visual models to understand the details and the flow of research activities in this approach (Opie, 2004). It is on these grounds that Leedy and Ormrod (2013) urge novice researchers to think about conducting mixed methods only after they have had some experiences with either strictly quantitative or strictly qualitative studies.

4.4 Research design for the quantitative phase

As mentioned earlier in the introduction of this chapter, the purpose of this study was to explore pre-service teachers' use of WIM as a platform for mathematics teaching and learning. For this purpose, a mixed methods research approach which involves the collection and analysis of both quantitative and qualitative data was utilised. The quantitative data were utilised to address the following question: *How does the use of WhatsApp instant messaging as a platform for teaching and learning influence pre-service teachers' knowledge of mathematics*? To this effect, a quasi-experimental research design where participants were assigned to either an experimental or a control group was adopted. A quasi-experimental, non-equivalent comparison group design was adopted since it was not possible to randomly assign participants to either control or experimental group as the groups were already streamed for other academic reasons. Figure 9 below shows a quasi-experimental, non-equivalent comparison group design study.

	Pre-intervention	Intervention	Post-intervention
Experimental group:	O_1	X_1	O_2

Control group:	O_1		O_2

Figure 9: Non-equivalent comparison group design

(Adopted from Campbell and Stanley, 1963, p. 46)

In figure 9 above, X represents the intervention with WIM; O_1 and O_2 represent the pre-intervention and the post-intervention mathematics proficiency questionnaires (MPQ) respectively. A quasi-experimental, non-equivalent comparison group design was chosen because the researcher strongly believes that this design has the best capability of establishing whether or not there was a cause-effect relationship between learning mathematics using WIM and pre-service teachers' knowledge of school mathematics.

Also, given the fact that extraneous effects could really falsify outcomes in a research design such as this one, which seeks to establish a causal relationship (Opie, 2004), the quasi-experimental research design stands out as the best option in exercising far more control of extraneous variables than any other research design. In this way, it would be possible to ascertain the influence of WIM use on pre-service teachers' knowledge of mathematics.

4.4.1 Population and research context

The population that constituted the current study was 1200 pre-service teachers at one of the universities in KwaZulu-Natal, S.A. Although the admission criteria of this university are generally regarded as high, the majority of students enrolled in teacher education are mathematically underprepared (Biyela, 2012). This is due to the insurmountable difficulty of recruiting mathematically advanced students into the teaching profession (Pournara, 2005). The university's population is largely drawn from different parts of S.A., including some remote, rural communities; most of them are second or third English language speakers.

Prior to entering higher education, these students were taught by teachers who used code-switching. Thus, most of them struggle to converse effectively in English which is the language of learning and teaching (LoLT) in institutions of higher learning in S.A. Cognisant of the S.A. government's critical role in financing higher education and its deliberate policy of widening access to tertiary education, university educators are under pressure to accommodate and support these previously disadvantaged students (PDS). The study was conducted at an elite, historically white university that is currently undergoing transformation in terms of enrolment of students and recruitment of staff from historically disadvantaged backgrounds.

4.4.2 Sampling

A total of 93 pre-service mathematics teachers from second year to fourth year who were registered for the Mathematics 110 module were selected as a sample for the quantitative phase using convenience sampling. In convenience sampling (also known as available or accidental sampling) (Leedy & Ormrod, 2013), a group of participants is selected on the basis of being accessible or expedient. Mathematics 110 is a foundational module at the participating university that is generally offered to pre-service Further Education and Training (FET) mathematics students. A precondition for all students taking this module is a pass in mathematics at matric level with at least 40% to 49%. The purpose of this module is to prepare student teachers to effectively facilitate the learning of mathematics in the FET phase.

There were two tutorial groups for Mathematics 110 module (group A and B). In tutorial group A, there were 45 students while in tutorial group B there were 48 students. Tutorial group A constituted the experimental group and tutorial group B constituted the control group.

Both tutorial groups were taught Mathematics 110 by the same lecturer. These tutorial groups were not streamed according to academic ability of students; instead they were streamed according to availability of space, time and other modules which students have registered for.

At this point, I must emphasise that due to ethical reasons, the students who constituted the control group were offered a face-to-face tutorial by the tutor. This was done in an effort not to exclude the control group from extra mathematics assistance which could have been very beneficial to them. Furthermore, all the pre-service mathematics teachers were included in the project on a voluntary basis after data collection was completed.

4.5 Data collection for the quantitative phase

The first phase of the study was aimed at investigating the effectiveness of teaching and learning mathematics using WIM to advance pre-service teachers' knowledge of mathematics. The MPQ was used for this purpose. It comprised mathematical problems that covered most areas of FET mathematics content knowledge. Data for this phase were collected over a period of six months. Before the commencement of the tutoring programme with WIM in the first week, the pre-intervention MPQ was administered to both groups. The pre-intervention MPQ and the post-intervention MPQ contained the same items. Both pre-intervention and post-intervention MPQs were written under strict examination conditions for 90 minutes. The participants were not allowed to share ideas while responding to MPQ.

The researcher ensured that a questionnaire was placed on every desk before participants could enter the tutorial hall. On entering the tutorial hall, participants were advised to read the instructions carefully. They were also requested to write their student numbers, gender and the year of study on their answer sheets. The same procedure was followed in both the pre-intervention and the post-intervention MPQs. Both pre-intervention and post-intervention MPQs had 35 questions and each correct answer was awarded one mark. This meant that the highest possible score would be 35 marks while the lowest possible score would be zero.

Scores were categorised into three levels of performance. Scores from 30-35 were considered as level 1 (excellent performance). Hypothetically, teachers at this level were likely to have adequate knowledge to teach FET mathematics effectively if equipped with proper pedagogical techniques. Scores from 20- 29 were considered as level 2 (moderate performance). While teachers at this level can teach FET mathematics, one may nevertheless expect them to have shortcomings in their teaching. Scores below 20 were considered as level 3 (inadequate or mediocre performance). Presumably, these teachers have inadequate mathematics content knowledge necessary for teaching mathematics at FET level.

4.5.1 Mathematics proficiency questionnaire

MPQ is the subtest of the Academic Aptitude Test [AAT] (Minnie & Paul, 1982) which is based on FET mathematics content. It contains a variety of mathematics problems for algebra, trigonometry and Euclidean geometry. The researcher surmised that this subtest would elicit the pre-service teachers' knowledge of mathematics content needed for FET mathematics teaching. The test came about as an initiative of the Department of Education and Training (DET) to design a comprehensive test to be used to evaluate standard 10 then (now grade 12) students' level of mathematical knowledge for the purpose of guiding them in choosing courses at university (Biyela, 2012). It was also used by the universities to obtain information that could be used at first year level in order to guide and select students for particular courses and academic programmes. The table below illustrates the distribution of questions according to content domains in both the pre-intervention and post-intervention MPQs.

Table 2: Distribution of questions according to domains in pre- and post-intervention MPQs

CONTENT DOMAIN	NUMBER OF QUESTIONS
Numbers (inequality, absolute value, exponents)	13
Trigonometry	15
Geometry	3
Algebra (equations)	1
Modelling	3
TOTAL	**35**

4.5.2 Validity and reliability of mathematical proficiency questionnaire

According to Soman (2006), validity and reliability are the two psychometric properties that are of critical significance in any measuring instrument in social science research. The validity of an instrument is the extent to which it measures what it supposed to measure, while reliability is the degree of accuracy and consistency with which an instrument measures the same trait with repeated measurements (Minnie & Paul, 1982). In order to determine the validity of the AAT battery of tests, correlations between examination marks obtained in various subjects and scores of the battery were calculated. The AAT was standardised on a representative standardisation sample of 1463 matriculants in September 1972. The standardisation sample consisted of male and female students from all races.

Initially, three equivalent forms or sets of questions were formulated and administered to the standardisation sample. The scrutiny of items led to the establishment of two parallel forms: form A and form B. These forms were administered to matriculants and to university students, respectively, for item analysis. In order to establish the norms, the final form of the test battery for matriculants was applied to a representative sample of 1298 students in 1973. The whole administration process was done under the supervision of a psychologist registered with the Health Professions Council of South Africa (HPCSA). The validity correlation coefficients between mathematics proficiency and school subjects are shown in table 3 below.

Table 3: Validity correlation coefficients between mathematics proficiency and school subjects

Subject list	School subjects	Correlation coefficients	Strength	R^2%
A	Ethnic languages	0.15	Very light	2.3
B	Afrikaans	0.25	Slight	6.3
C	English	0.34	Slight	11.6
D	Biology	0.32	Slight	10.6
E	Physical sciences	0.42	Moderate	17.6
F	Mathematics	0.76	High	57.8
G	Geography	0.23	Slight	5.3
H	History	0.36	Slight	13.0

This is the internal consistency method for establishing validity. The AAT has a manual that contains norms, procedures for administration, scoring and interpretations. The correlation coefficients between mathematics proficiency and school subjects range from 0.15 (very slight) through 0.42 (moderate) to 0.76 (high). These correlation coefficients were tested for statistical significance at the 1% and 5% levels. The correlations between mathematics proficiency test and subjects B to F were significant at the 1% level. There were no significant correlation coefficients between mathematics proficiency test and two subjects, namely Ethnic Languages and Geography.

In the present study, the researcher attempted to determine the effect size of the significant correlation coefficients. Table 3 above contains these values in the last column. A measure of the effect size should follow statistically significant results to approach statistical sophistication. The effect size informs us about the magnitude of change among variables. Here we attempt to find an answer to the question of how much change in one variable is accounted for in another variable. Put differently, how big is the association between mathematics proficiency and subjects? How strong is the correlation? Table 3 above indicates that a correlation coefficient of 0.15 has an effect size of 2.3%, 0.42 has an effect size of 17.6%, and 0.76 has an effect size 57.8%. The implication of these percentages is that a change in one variable will account for an equal change in another.

If we know these values for one subject score, we can predict an equal condition that obtains in another subject. Therefore, the effect size percentages inform us about the magnitude of change between two variables, that is, the explained variation. For the correlation coefficients of 0.15, 0.42 and 0.76, the unexplained variance is 97.7%, 82.4% and 42.2% respectively. The correlation coefficients of the test indicate the validity of all the mathematics proficiency tests.

The reliability of the AAT was established for the battery as a whole. The Kuder-Richardson Formula (KRF) 20 was applied to get accurate values of reliability. For all the subtests, the reliability coefficients range from 0.69 to 0.90. Their values can be regarded as very high coefficients of reliability. The subtest on mathematics proficiency test is reported to have a KRF 20 reliability of 0.75 (Minnie & Paul, 1982). MPQ is a subset of a standardised instrument (ATT), the norms of which have been established. To this end, MPQ is both valid and reliable; it is used for research purposes and not for psychological assessment.

The standardisation sample of the test was made up of matric students consisting of males and females. The test was designed to test students' proficiency in FET mathematics. The present study intends to determine the proficiency of pre-service teachers in FET mathematics after they have been involved in an online tutoring programme using WIM. The pre-service teachers are expected to teach effectively the same mathematics content which was applied to the standardisation sample when they join the teaching profession. To this end, the researcher deemed MPQ to be suitable for assessing pre-service teachers' mathematics proficiency.

4.6 Data analysis for the quantitative phase

The data from both pre-intervention and post-intervention MPQs were analysed using statistical tests (*t*-test), measures of central tendency (means and modes only) and variability (standard deviation, and ranges). There are actually three variations of the *t*-test: single sample, two-sample with different groups (independent groups) and two-sample with the same group (dependent groups). The current study used the two-sample with dependent groups because this test is used in situations in which the subjects from the two groups are paired or matched in some way (McMillan & Schumacher, 2010). A common example of this case is the same group of subjects tested twice, as in pretest-posttest study such as in the quantitative phase of this study. Whether the same or different subjects are in each group, as long as there is a systematic relationship between the groups, it is necessary to use the paired *t*-test (Leedy & Ormrod, 2013).

In order to use the *t*-test, the following assumptions must be met: there should be one random sample of interval or ratio scores; the scores of the population from which the sample is taken should be normally distributed and have equal variances; and each score within the sample should be independent of all other scores (McMillan & Schumacher, 2010). The selection of the *t*-test was based on the fact that the data collected in the quantitative phase of the study reasonably met the assumptions and that it is a parametric measure. The parametric tests are often powerful because they produce minimal errors (Leedy & Ormrod, 2013).

For the analysis within a group, only data from pre-service teachers who responded to both pre-intervention and post-intervention MPQs were utilised. Pre-service teachers, who answered either one or none of the two MPQs, were systematically removed from the analysis. For inter-group analysis, only data from pre-service teachers who answered the corresponding MPQs (pre-intervention or post-intervention) were used. The magnitude of all relationships reported in this study used the conventions from Davis (in Waldron, 2004). The correlation coefficient as well as the *p*-value was used in the analysis of pre-service teachers' achievement that compared teachers who used WIM as a platform for mathematics teaching and learning and those who did not. These descriptors are illustrated in table 4 below.

Table 4: Descriptors of the magnitude of relationships used in the study

COEFFICIENT	DESCRIPTOR
.70 or higher	Very strong correlation (relationship).
.50 to .69	Substantial correlations (relationship).
.30 to .49	Moderate correlations (relationship).
.10 to .29	Low correlations (relationship)
.01 to .09	Negligible correlation (relationship)

4.7 Validity and reliability in the quantitative phase

One of the key problems with using an experimental or quasi-experimental research design is the establishment of a suitable control so that any change in the scores on the post-test can be attributed only to the independent variable that was manipulated by the researcher (Spector, 1981; Singleton, Straits, Straits & McAllister, 1988). Therefore, the control of extraneous variables is fundamental to the validity of an experimental or quasi-experimental research design (Campbell & Stanley, 1963). Campbell and Stanley (1963) identify various factors that can threaten the internal and external validity of any experimental study.

Internal validity refers to the control of extraneous variables so that it can be concluded strongly that the independent variable produced the observed changes in the dependent variable. External validity on the other hand, is concerned with the questions of generalisability (Campbell & Stanley, 1963). External validity, therefore, ask the question as to the extent in which the results from the experiment can be generalised from the sample to the population. In what follows, I discuss how factors threatening the internal validity were dealt with in the current study. The reliability (generalisability) of the quasi-experimental design for this study will be dealt with in the last chapter under the research limitation.

4.7.1 Control of internal validity

There are eight main types of extraneous factors that can threaten the internal validity of a quasi-experimental research design namely: the effects of history, maturity, statistical regression, selection, and testing, experimental mortality, instrumentation, and design contamination (Spector, 1981; Campbell & Stanley, 1963; Singleton et al, 1988). Campbell and Stanley (1963) however, note that in a quasi-experimental, non-equivalent control group design such as the current study, there is an inherent control of the main effects of history (events occurring within the time lag of pre-test and post-test in addition to the independent variable), maturation (biological or physiological changes that occur in the participants during implementation phase), testing (pre-test affecting the score of post-test) and instrumentation (change in measurement method) in the design itself.

This is due to the fact that the effects of these variables are the same for both the control group and the experimental group (Campbell & Stanley, 1963) as is the case in the current study. Both groups experienced the same current events; both experienced the same cognitive developmental processes. Again, participants did not know they were going to answer the same post-intervention MPQ as the pre-intervention MPQ. Lastly, there was no change in the method of questionnaire administration in both pre-intervention and post-intervention MPQs.

Campbell and Stanley (1963) mention statistical regression as one of the key factors that could compromise the internal validity of a quasi-experimental research design. Statistical regression refers to the tendency for extreme scorers on a test to regress closer to the mean (McMillan & Schumacher, 2010). It occurs when groups have been selected based on their extreme scores. This was not the case in the present study. Another variable which threatens internal validity is experimental mortality. To control experimental mortality, only results from pre-service teachers who answered both pre-intervention and post-intervention MPQs in both groups were used in the data analysis across groups.

A seventh threat to internal validity is selection, which refers to how the subjects were assigned either to the experimental or to the control group. As indicated earlier, the selection was non-random since the tutorial groups were already streamed into groups A and group B. Even though the control and the experimental groups had the same mathematics lecturer, and tutorial groups were not streamed according to mathematical ability, there was still no guarantee that both groups had the same mathematics ability. The pre-intervention MPQ results were therefore, used to match or compare mathematical ability of both groups before the intervention. The *p*-value of test (both *t*-test and nonparametric test) was used to analyse the pre-intervention data to determine if there was a significant difference between the mathematical ability of the control group and that of the experimental group.

As for the control of design contamination, which is concerned with whether the control or the experimental group found out about the experiment and therefore tried to make the experiment either succeed or fail, there was no observable attempt by the participants to either make the research succeed or fail during the entire research process. Finally, there was no need for test of homogeneity of variance since both the experimental and the control group were almost equal in size (45 experimental group and 48 control group).

4.8 Research design for the qualitative phase

The qualitative phase of the study was intended to address the following research questions: *What are pre-service teachers' experiences of using WhatsApp instant messaging for mathematics learning*? *Why do pre-service teachers experience the learning of mathematics using WhatsApp instant messaging in the way that they do*? For this purpose, a phenomenological research design was utilised. Leedy and Ormrod (2013) observe that a phenomenological research approach focuses on understanding peoples' experiences, perceptions, perspectives, and understandings of a particular situation. In other words, a phenomenological research design attempts to answer the question, what is it like to experience a certain phenomenon in the participants' own words?

By looking at multiple perspectives on the same situation, the researcher can make generalisations of what the experience is like from the participants' accounts. A phenomenological research design was adopted because it focused on describing the experiences of participants individually, while also identifying their common features (McMillan & Schumacher, 2010). This approach enabled the researcher to gather as much information as possible about the phenomenon as experienced by the participants. The goal of this phenomenological design was not to explain the phenomenon under investigation, but to describe the phenomenon and find its meaning in participants' actual words.

4.8.1 The concept of epoché

According to Stanghellini (2005), in order to understand the phenomenon exactly as participants experience and perceive it, the concept of epoché, which evolved from the Greek word 'check', is a prerequisite. Initiated by Husserl, epoché is the bracketing of the researcher's biases, prejudices, and any preconceived ideas about the phenomenon being investigated (Field & Morse, 1985). As suggested by Moustakas (1994), researchers should engage in the process of epoché before conducting each interview to minimise any biases.

In the current study, the concept of epoché enabled for each participant's experiences to be considered as a single entity in and of itself. This perception of the phenomenon thus, calls for looking, watching, and becoming aware without importing the researcher's judgment. I made every attempt to bracket any prejudices and biases I might have. This, I achieved by noting them in a journal along with my expectations prior to and subsequent to each interview.

For instance, before each interview, I would briefly describe my expectations of pre-service teachers, such as the expectation that those who obtained high marks in the MPQs would report positive experiences and perception about learning mathematics using WIM or the expectation that pre-services teachers who participated in the WIM-mediated mathematics intervention programme, would have greater mathematics knowledge than those who did not participate in the programme. By confronting my own expectations, I tried to minimise their influences as I listened to and interpreted what the participants said in interviews.

4.8.2 Selection of interview participants

According to Leedy and Ormrod (2013), data collection in a phenomenological research design may involve a purposeful sampling of five to twenty-five individuals. In purposeful sampling, the researcher selects certain participants from the population that will provide information about the topic of interest (McMillan & Schumacher, 2010). On the basis of the researcher's knowledge of the population, a judgment is made about which subjects should be selected in order to provide the best information to address the purpose of the research.

The goal of purposeful sampling is to understand a specific phenomenon, not to represent a population, by selecting information-rich cases for the investigation (Creswell, 2014). Studying information-rich cases yields in-depth understanding of the phenomenon and gives insight into critical questions under investigation. One strategy of purposeful sampling that captures variations between cases studied is stratified purposeful sampling. Stratified purposeful sampling illustrates characteristics of specific subgroups to facilitate comparisons by selecting participants based on key dimensions (Patton, 2010). Potential cases are then divided into strata containing variations of the phenomenon.

In the current study, the phenomenon to be investigated was participants' experiences and perceptions of learning mathematics using WIM. Participants, all of whom participated in both pre-intervention and post- intervention MPQs, were asked to provide their contact information for follow-up interviews. Those pre-service teachers who gave consent to participate in a follow-up interview were purposefully selected based on their gender and performance on both pre-intervention and post-intervention MPQs. Six pre-service teachers were selected (three males and three females). This meant that two pre-service teachers from level 1 (excellent performance), two from level 2 (moderate performance) and two from level 3 (inadequate performance) were selected.

4.9 Data generation for the qualitative phase

4.9.1 Observations of interactions on WhatsApp instant messaging

As the researcher, I secured the consent of the tutor and pre-service teachers to observe their WIM-mediated mathematics interactions. In order to do this, I had to join WIM-mediated tutorial groups. This move afforded me the opportunity to observe the tutor and pre-service teachers interacting on WIM in a natural setting, thereby limiting the Hawthorne effect. The Hawthorne effect is the tendency for the observed participants to behave in a conformist manner (Rambe, 2009). By observing interactions live, I had the opportunity to:

- Understand how mathematics interactions unfolded between pre-service teachers and the tutor on WIM.
- To unravel other contextual and structurally derived factors that could also be at play in influencing mathematics interactions on WIM.
- To crosscheck the authenticity of pre-service teachers' accounts of their experiences of learning mathematics using WIM as espoused in interview transcripts.

4.9.2 The interviewing process

The interviewing process followed a phenomenological tradition of inquiry focusing on the essence of the phenomenon. In this case, the phenomena were pre-service teachers' experiences and perceptions of mathematics learning using WIM. A semi-structured interview protocol was utilised. Some of the questions were open-ended in order to allow respondents to develop narrative accounts of their experiences of the activity. All interview participants were allocated pseudonyms and the interviews took approximately 30 minutes. The interviews were recorded and videos were stored in the researcher's computer and transferred into Hyper Transcribe (HT) for transcription into a Word document. This software allowed for easy transcription of MP3 audio files into a Microsoft Word document.

4.10 Data analysis for the qualitative phase

4.10.1 Analysis of observations

I used the CHAT analytical framework (Russell & Schneiderheinze, 2005) for the analysis of observations of mathematics teaching and learning using WIM by pre-service teachers and the tutor. For Barab et al. (2001, p. 69), "an activity system can be an entire course, a particular class, or even an isolated event." For the current study, WIM-mediated mathematics interactions were adopted as activity systems, hence the unit of analysis. Although Russell and Schneiderheinze's (2005) analytical model is influenced by Engeström's (1987, 2001) CHAT model, it transcends it due to the suggestions it makes in the contradictions area. I will therefore, briefly explicate Russell and Schneiderheinze's analytical model.

Russell and Schneiderheinze's (2005) analytical framework suggests that research questions be developed during data structuring to aid the researcher in understanding how the subjects (in this case the tutor and pre-service teachers) respond to the activity implementation process (WIM-mediated mathematics interactions). Russell and Schneiderheinze's analytical model consists of: the subject, object, outcomes, mediated by tools (instruments), rules, roles and community as shown in Figure 10 below.

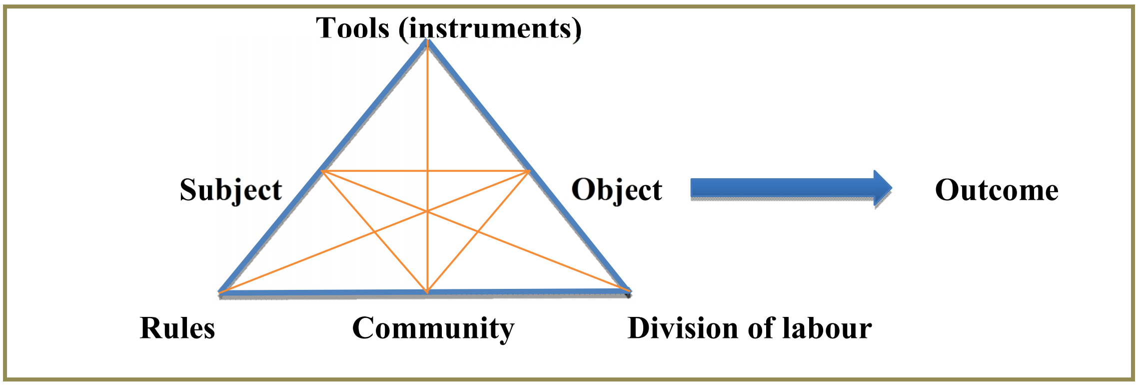

Figure 10: Engeström's Cultural-Historical Activity Theory model (Adapted from Engeström, 1987, p. 78)

Russell and Schneiderheinze (2005) suggest that an activity system analytical framework should involve the following stages among others:

- *A detailed description of the subjects' experiences of participating in the work activity over an extended time frame, drawing upon multiple sources*. My research explored the experiences of pre-service teachers when using WIM for mathematics teaching and learning over a period of approximately one semester (six months). My multi-source framework comprised pre-service teachers' interviews and observations of mathematics interactions between the tutor and pre-service teachers using WIM.

- *The researcher identifies the nodes of the subject's work activity system and creates the activity system model for each subject using the subject's voice in his or her collaborative interaction with the other subjects.* I created an activity system model for the tutor and pre-service teachers based on my observations of their interactions.

4.10.2 Coding and analysis of interview transcripts

The coding and analysis of phenomenological data as described by Moustakas (1994) includes horizonalising of the data, clustering common categories, and developing textual descriptions of the participants' experiences. Horizonalisation refers to listing of every horizon or expression relevant to the experience and regarding them as having equal value. The coding of data consists of looking at the content of the responses elicited by participants and arranging them with a colour scheme in terms of frequency or repetition. Reoccurring concepts, events, and experiences serve as key descriptions, which serve as first-level codes (McMorris, 2002).

The second step involves clustering the first-level codes or relevant expressions into common categories or themes without repetition. After first-level codes are clustered into categories, commonalities or trends in the data are examined for the development of major themes. The last step in the analysis requires the development of textual descriptions of the phenomenon for each participant. A thematic analysis follows and it analyses all components in participants' interviews to form a comprehensive picture of a collective experience. After themes have been found and reflected upon, an individual textual description is constructed for each participant in order to construct the essence of the experience (Creswell, 2014). This last step in the analysis brings the themes identified into real life in order to understand participants' experiences.

Additionally, the analysis of phenomenological data includes the invitation of two colleagues to blindly validate research findings, discussing and adjusting three lists of categories. Once patterns are established, the results should be compared and all patterns be developed into themes. Furthermore, the analysis of phenomenological data entails re-examining of the transcripts and categories, identifying data relating to each category, linking data to category headings, coding transcripts according to developed categories and sub-headings where applicable, and linking themes and findings to the supporting theory. Respondents are then asked to blindly validate and check categories so that necessary adjustments can be made. Finally, the write up is conducted section by section with references being made to interview transcripts. So, all these processes were followed during the analysis of interview transcripts in the current study.

4.11 Validity and reliability in the qualitative phase

Creswell (2014) argues that validity does not carry the same connotations in qualitative research as it does in quantitative research, nor is it a companion of reliability and generalisability (the external validity of applying results to new settings, people, or samples). In a qualitative design, validity means that the researcher checks for the accuracy of the findings by employing certain procedures, while reliability indicates that the researcher's approach is consistent across different researchers and different projects (ibid.). In qualitative approaches, terms that are used to address validity are credibility, transferability and dependability (Lincoln & Guba, 2011).

4.11.1 Credibility

Polit and Hungler (2009) posit that credibility deals with the focus of the research and refers to confidence in how well data and processes of analysis address the intended focus. The first question concerning credibility arises when making a decision about the focus of the study, selection of context, participants and an approach to gathering data (ibid.). The inclusion of PDS in a study that focused on providing extra mathematics support was significant given the fact that WIM mathematics interactions were designed in such a way that pre-service teachers could consult on any mathematics concept at their own time and space.

Additionally, selecting interview participants with a varied performance on MPQs increased the possibility of shedding light on the research questions (Graneheim & Lundman, 2008). Polit and Hungler (2009) note that credibility of the findings in qualitative research approach also deals with how well categories and themes cover data, that is, no relevant data have been inadvertently or systematically excluded or irrelevant data included.

In the current study, I therefore documented verbatim extracts of interview transcriptions, particularly those that reflected on popular opinions, highlighting differences and concurrences of participants' experiences. I also inserted trails of my online observations (textual messages that participants send on WIM during their interactions) as evidence. Furthermore, credibility of the qualitative study can also be achieved by availing others with the raw data so that they can analyse it and also through member checking, in which research participants are required to corroborate findings (Lincoln, Lynham & Guba, 2011).

In my case, a Master's degree in education student, who was conducting a study on the appropriation of Mxit in improving participation in mathematics, and another Master's degree student in educational psychology, were asked to conduct a thematic exploration of the interviews to ensure uniformity and validity of the findings. Since research participants' perspectives of reality are central to guarantee of research credibility, six pre-service teachers who were interviewed were requested to blindly review and validate the categories and findings, after my transcription and development of categories from interview transcripts.

This was undertaken in order to crosscheck whether categories and overall analysis adequately reflected research participants' views on the matter investigated, which is their experiences of learning mathematics using WIM. The credibility of a qualitative study depends less on sample size than on the richness of information gathered and on the analytical skills of the researcher (Patton, 2010). My analysis of multiple sources of data (interviews and WIM observations) ensured the credibility of this study through corroboration of evidence.

4.11.2 Transferability

Trochim (2010) emphasises that transferability of the findings refers to the degree to which the results of qualitative research approach can be generalised or transferred to other contexts or settings. The qualitative researcher can enhance transferability of his or her qualitative study by doing a comprehensive task of describing the population and research context in detail. In this chapter, I provided a detailed description of the population and research context in which the current study was conducted. In short, the study was conducted at an elite historically white university that is currently undergoing transformation in terms of student enrolment and staff recruitment from historically disadvantaged backgrounds.

The university's population is largely drawn from different parts of S.A. including some remote, rural communities and most of them are second or third English language speakers. Prior to entering higher education, students were taught by teachers who used code-switching to teach them. Thus, most of them struggle to converse effectively in English, which is the language of learning and teaching (LoLT) in institutions of higher learning in S.A. WIM was adopted as a mathematics education cluster's initiative to provide extra support in mathematics and also to increase participation of pre-service teachers in mathematics activities, with an ultimate goal of improving their knowledge of FET mathematics before they exit their training programme.

4.11.3 Dependability

Trochim (2010) contends that dependability parallels reliability in traditional criteria for judging quantitative research approach. The general way of approaching the reliability of the qualitative approach, is to make as many operational steps as possible and to conduct research as if someone were always looking over your shoulder (Yin, 2004). In the current study, the steps of research design, population and research context, research participants' selection criteria, data collection and analysis techniques, validity and reliability issues and ethical considerations were elaborately explained so that readers can establish how the research findings were arrived at and the conditions under which they were investigated.

Additionally, in the current study I engaged in the process of epoché before conducting each interview to minimise my biases. The concept of epoché is the bracketing of the researcher's biases, prejudices, and any preconceived ideas about the phenomenon being studied (Field & Morse, 1985). This process helped me to bracket my own biases about participants.

4.12 A conceptual model of data collection and analysis process

Figure 11 below illustrates a conceptual model of data collection and analysis process. The fact that complex socio-cultural and historical factors (mathematics competence, communicative competence, language, academic backgrounds) influence tutor-pre-service teachers mathematics interactions and pre-service teachers' participation in mediated mathematics learning activities using WIM, made the use of Cultural Historical Activity Theory (CHAT) as a theoretical framework and analytical lenses to unpack these interactions appropriate.

The investigation in this study was driven by research questions that required both quantitative and qualitative data to address them. This decision was not based on my own methodological preferences as a researcher. To this end, the paradigmatic stance of this study is pragmatism. As a philosophical foundation for mixed methods research approach, pragmatism is appropriate in that it focuses on the problem and then utilises numerous approaches to solve the problem (Patton, 2010).

Data collection and analysis process constituted two phases as illustrated below. Phase I involved the quantitative process while Phase II involved the qualitative process. The quantitative data was analysed through the use of statistical techniques while the qualitative data was analysed using both Russell and Schneiderheinze (2005) CHAT analytical framework and the narrative analytic framework. The use of mixed methods research approach enabled me to probe meanings, practice corroboration and triangulate data where paradoxes between two sources of data were found. In this way, the critical research questions were and the objectives of the current study were addressed comprehensively.

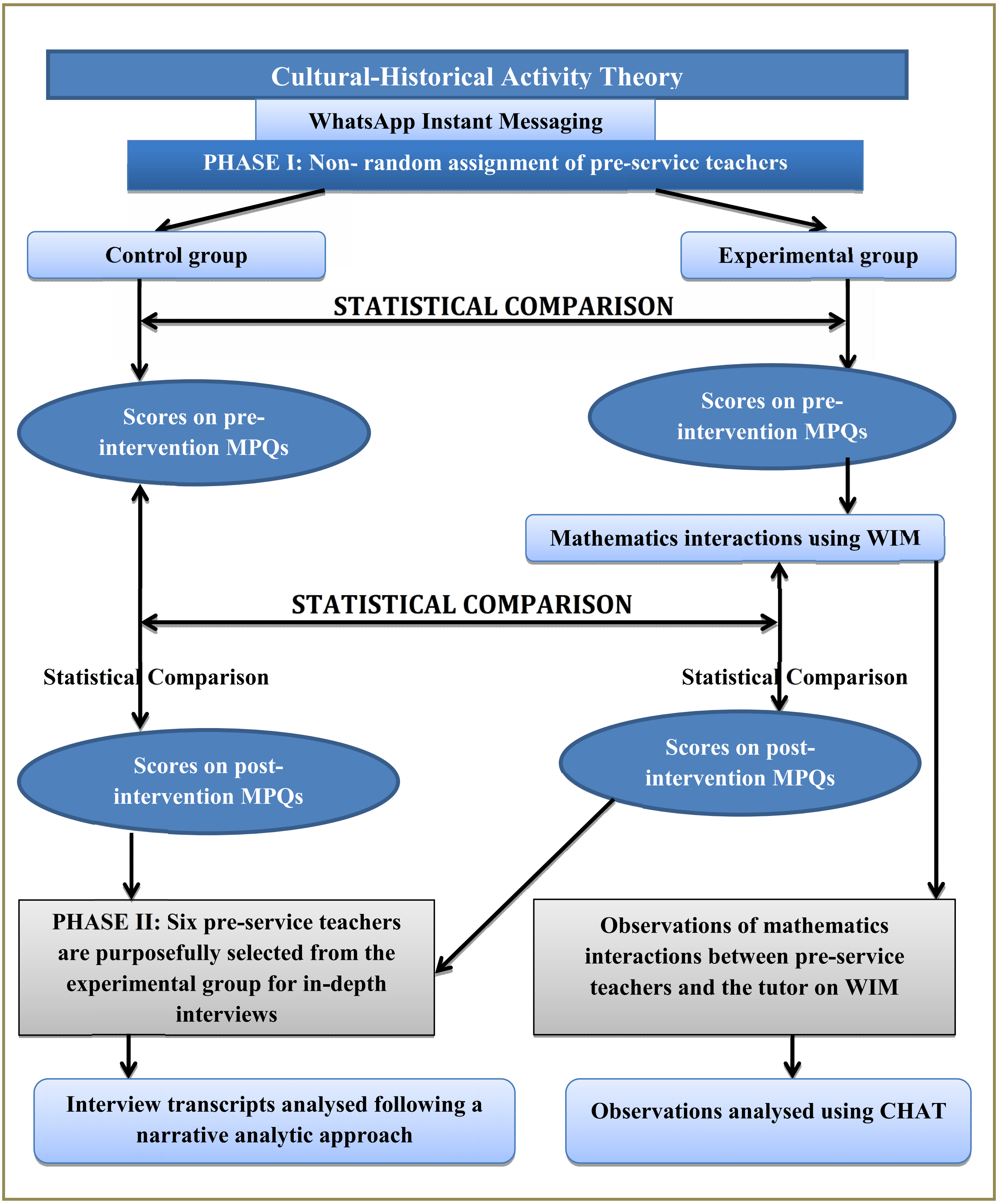

Figure 11: A conceptual model of data collection and analysis process
(Adopted from Amry, 2014, p. 125)

4.13 Ethical considerations

The key ethical question that any experimental research has to deal directly with revolves around the fact that the control group is disadvantaged in the research in the sense that the group is denied access to the treatment which could have been beneficial to it. In the current study, this ethical dilemma was dealt with by making provision for the implementation of WIM intervention to the control group after the post-intervention MPQ had been accomplished. The control group was also offered face-to-face extra mathematical support.

I was a registered student at the university where participants were recruited from therefore; I applied for an ethical clearance certificate from the same university. One of the requirements for ethical clearance certificate was to submit the proposal in which all the details of the study were outlined. Included in the proposal were, among other things, the topic, statement of the problem, research questions, participants, location and context, and the research methodology. Again, copies of both pre-intervention and post-intervention MPQs were required by the authorities at the university where the research would be conducted. The authorities of the university wanted to ascertain the nature and the appropriateness of the questionnaires to be administered to the intended study participants before they granted permission.

Having submitted all the documents that were required by the gatekeepers of the university, I was issued with an ethical clearance certificate. The ethical clearance certificate confirmed that I had been granted permission to conduct the study. I was further required to explain in writing the procedures for the informed consent to the participants. The participants were assured of anonymity and that they would be allowed to discontinue the process should they feel uncomfortable. Furthermore, the participants were required to sign the informed consent form. This served as confirmation that each participant takes part in this research voluntarily.

Finally, there was no monetary compensation for participation in the study, and there were no foreseen or unforeseen risks for participants. However, participants may have felt self-conscious about their mathematical knowledge and competences in the quantitative portion of the study, and were therefore advised that their performance was not going to be judged and was going to remain strictly confidential. Confidentiality was ensured by allocating pseudonyms to participants and no real names were used. The data gathered from this study were kept strictly confidential in the researcher’s computer protected by a dual password.

4.14 Conclusion

In this chapter, I discussed the philosophical underpinning of the current study together with ontological and epistemological assumptions within the pragmatist paradigm. I also gave a detailed description of the mixed methods research approach, including its philosophical and historical foundations, the rationale for the choice of mixed methods research approach, the sequential explanatory design and the challenges posed by the mixed methods research approach to the researcher. Then, data collection and analysis procedures for both phases of the study, the issues of validity and reliability in both phases and ethical considerations were discussed. In the next chapter, I present statistical results of the quantitative data analysis. These are the results of the quantitative data which was collected from pre-service teachers through mathematics proficiency questionnaires (MPQs).

CHAPTER 5: QUANTITATIVE DATA ANALYSIS

5.1 Introduction

As mentioned in chapter one, the purpose of this mixed methods research was to explore the use of WhatsApp instant messaging (WIM) as a platform for pre-service teachers' learning of mathematics. To this end, an explanatory sequential mixed method was utilised. Explanatory sequential mixed methods is characterised by the collection and analysis of quantitative data followed by the collection and analysis of qualitative data. In this chapter, I present the results of the quantitative data analysis which was aimed at providing the answer to the following critical research question: *How does the use of WhatsApp instant messaging as a platform for teaching and learning influence pre-service teachers' knowledge of mathematics*?

5.2 Pre-service teacher scores in pre-intervention MPQ

One of the challenges of a quasi-experimental research design is to match the experimental and the control group. In this study, the pre-intervention results were used to compare the mathematical ability of pre-service teachers in the experimental and the control group in order to find out if there was any significant difference in ability between the two groups. Of the 45 pre-service teachers in the experimental group, 44 of them responded to the pre-intervention MPQ while all 48 pre-service teachers in the control group responded to the pre-intervention MPQ. None of the pre-service teachers in both groups obtained marks above 40% in the pre-intervention MPQ. The marks in the experimental group ranged from 5.7% to 31.4% while that in the control group ranged from 2.9% to 25.7%. The table below presents a summary of pre-service teachers' performance in pre-intervention MPQ for both groups:

Table 5: Group statistics of control and experimental group in pre-intervention MPQ

GROUP	N	MEAN	Std. Deviation	Std. Error Mean
Experimental	44	5.4318	1.9813	.2987
Control	48	4.9583	2.2874	.3302

In the above table, it can be seen that the mean score for the experimental group is 5.4318 while that for the control group is 4.9583. The standard deviation from the mean is 1.9813 and 2.2874 for the experimental and the control group respectively. The pre-intervention results for both the control and the experimental group were also matched using the *p*-value. The probability (*p*) commonly referred to as the *p*-value of the test, is associated with an attained statistical result that could have been induced by chance (random error). The smaller the number (that is, the smaller this chance is), the greater the likelihood that the results expatiated were not due to chance (McMillan & Schumacher, 2010; Leedy & Ormrod, 2013).

The convention is to draw a line at 5% and if $p < 5\%$ (that is, $p < 0.05$), then the results (difference between the experimental and the control group), are statistically significant. If $p >$ 0.05, it is tenable that both the experimental and the control group are equal. In other words, there is no significant difference between the two groups, and so we fail to reject the null hypothesis. Null hypothesis is H_0: $u = u_1$, where u is the control group mean, u_1, is the experimental group mean and H_0 is the Null hypothesis. The table below presents the summary data (pre-intervention MPQ) of the *t*-test for the experimental and the control group.

Table 6: Two-sample *t*-test results for experimental and control in pre-intervention MPQ

	***t*-test for equality of means**						
	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence interval of the difference	
						Lower	Upper
Equal variance assumed	-1.057	90	.293	-.4735	.4480	-1.3636	-4166
Equal variance not assumed	-1.063	89.724	.290	-.4735	.4452	-1.3580	-4111

Even though there was a difference in the mean scores and standard deviation of both groups, (the mean for the experimental group was 5.4318, standard deviation is 1.9813 and the mean for the control group was 4.9583, standard deviation is 2.2874), there was a difference of .9559 points in favour of the experimental group, as can be observed from table 6, the *p*-value is .293. A nonparametric test indicates a *p*-value of .292. Since the *p*-value is > .05, there is no significant difference between the experimental and the control group in terms of scores of the pre-intervention MPQ. This decision, however, is susceptible to type II error (accepting *Ho* when it is false) since, in reality, it is possible that there is a significant difference between the two groups.

5.3 Scores in pre-intervention and post-intervention MPQs

Having analysed the achievement in the pre-intervention MPQ for both groups, I turn to the achievement of pre-service teachers in the control group in both pre-intervention and post-intervention MPQ. All pre-service teachers in the control group responded to the pre-intervention MPQ and 42 of them responded to the post-intervention MPQ. Pre-service teacher performance in the post-intervention MPQ, as in the pre-intervention, was low in the control group. Just as in the pre-intervention MPQ, achievement in the post-intervention MPQ ranged from 2.9% (1 mark out of 35) to 25.7% (9 marks out of 35).

The overall results in post-intervention MPQ were; however, lower than the results in the pre-intervention MPQ. As indicated in Table 7 below, the means of these pre-service teachers were 4.9583 and 4.9286 for the pre-intervention MPQ and post-intervention MPQ respectively, a difference of .0297 in favour of performance in the pre-intervention MPQ. The achievement in the post-intervention MPQ was more consistent than in the pre-intervention MPQ as indicated by the standard deviation in the table below.

Table 7: Paired samples statistics for the control group

	Mean	**N**	**Std. Deviation**	**Std. Error Mean**	**Correlation**
Pre-intervention	4.9583	48	2.2874	.3302	-.368
Post-intervention	4.9286	42	1.9555	.3017	

The correlation between pre-intervention MPQ and post-intervention MPQ is -0.368. It is difficult to understand why pre-service teachers in the control group achieved lower in the post-intervention MPQ given the fact that the same questions were used in both pre-intervention and post-intervention MPQs, but the more important question is whether the difference is statistically significant.

In the table below, the *t*-test results of both pre-intervention and post-intervention MPQs for the control group indicates that the *p*-value is .849 and a nonparametric test provides a *p*-value of .809. Since $p > .05$, the results show that even though there is a difference in performance from pre-intervention to post-intervention MPQ, this difference is not statistically significant.

Table 8: Paired-sample *t*-test results for the control group

				Paired differences		
	t	df	Sig.(2-tailed)	Std. Error mean	95% Confidence interval of the difference	
					Lower	Upper
Pre-intervention-post-intervention	.192	41	.849	.3724	-.6806	.8235

5.3.1 Scores in pre-intervention and post-intervention MPQs for experimental group

A total of 44 pre-service teachers in the experimental group responded to the pre-intervention MPQ while a total of 45 responded to the post-intervention MPQ. The results from the post-intervention MPQ for the experimental group were also poor with the scores ranging from 2.9% to 37.1%. In general, most of the scores in the pre-intervention MPQ ranged from 4 to 7 (32 pre-service teachers in total), with the majority of these 32 pre-service teachers scoring 7 out of 35 and in the post-intervention MPQ, the highest frequencies ranged from 5 to 9 (33 pre-service teachers in total). Pre-service teachers, however, improved from a mean score of 5.4318 in the pre-intervention MPQ to 6.3556 in the post-intervention MPQ, a positive difference of .9238 in performance on the post-intervention MPQ. The standard deviation shows that the performance in the pre-intervention MPQ was more consistent than the performance in the post-intervention MPQ.

Table 9: Paired sample statistics for the experimental group

	Mean	N	Std. Deviation	Std. Error Mean	Correlation
Pre-intervention	5.4318	44	1.9813	.2987	.328
Post-intervention	6.3556	45	2.6897	.4010	

As shown in table 9 above, the correlation coefficient is 0.328 pointing to a moderate positive relationship between scores in the pre-intervention MPQ and scores in the post-intervention MPQ. The two-tailed test of difference at .05 significance shows that the intervention had some effect on the MPQ results. The *p*-value (0.032) of the tests in the table below indicates that the difference between the scores is statistically significant (since the *p*-value < .05). A nonparametric test also indicates a *p*-value (.030) that is statistically significant.

Table 10: Paired-sample *t*-test results for the experimental group

				Paired Difference		
	t	df	Sig. (2-tailed)	Std. Error Mean	95% Confidence interval of the difference	
					Lower	Upper
Pre-intervention Post-intervention	2.215	43	.032	.4207	-1.7802	-.8083

5.3.2 Scores in post-intervention for experimental and control group

The 45 and 42 pre-service teachers in the experimental and control group respectively, who responded to the post-intervention MPQ were compared in order to ascertain if there was any difference in achievement between pre-service teachers who used WIM as a platform for mathematics teaching and learning (experimental group) and those who did not (control group). Tables 11 and 12 present a summary data for both groups.

Table 11: Group statistics of control and experimental group in post-intervention MPQ

GROUP	MEAN	N	Std. Deviation	Std. Error Mean
Experimental	6.3556	45	2.6897	.4010
Control	4.9286	42	1.9555	.3017

The mean score for the experimental group was 6.3556 (Standard Deviation is 2.6897) and the mean score for the control group was 4.9286 (Standard Deviation is 1.9555), a difference of 1.427 in favour of the experimental group.

Table 12: Two-sample *t*-test results for experimental and control in post-intervention MPQ

	***t*-test for equality of means**						
	t	df	Sig. (2-tailed)	Mean difference	Std. Error Difference	95% confidence interval of difference	
						Low	Upper
Equal variance assumed	2.813	85	.006	1.4270	1.4270	.4185	2.4355
Equal variance not assumed	2.844	80.308	.006	1.4270	.5018	.4284	2.4256

As indicated in the *t*-test results above, the *p*-value is .006. The *p*-value for the nonparametric test is .008. Since $p < .05$, the means of the post-intervention MPQ scores are considered to be statistically unequal. That is, there is a significant difference between the scores of the experimental group's post-intervention MPQ and that of the control group in the population.

5.4 Pre-intervention and post-intervention scores for experimental group based on gender

After the first level analysis above, it was necessary to disentangle the genders in order to comprehend whether or not the greater beneficiary of WIM programme were male pre-service teachers or female pre-service teachers. It was, thus, necessary to analyse the data based on gender to see if there was any significant difference between the performance of male pre-service teachers and the performance of female pre-service teachers in both the experimental and the control group.

Out of the 44 pre-service teachers who responded to the pre-intervention MPQ in the experimental group, 25 of them were males while 19 of them were females. The table below gives descriptive statistics of the performance of both groups (male pre-service teachers and female pre-service teachers) in the pre-intervention MPQ.

Table 13: Gender statistics for pre-intervention MPQ

	MALE	FEMALE
Minimum score	2	2
Maximum score	11	8
Mean	5.28	5.6316
Std. deviation	2.2642	1.5709

From table 13 above, it can be observed that while the scores for male pre-service teachers range from 2 to 11 that for female pre-service teachers range from 2 to 8. Even though the performance of male pre-service teachers was higher in terms of marks, that of the females pre-service teachers was more consistent (Standard Deviation is 1.5709) than the performance of male pre-service teachers (Standard Deviation is 2.2642) as there were extreme scores amongst the male pre-service teachers. A *t*-test for both groups indicates a *p*-value of .566 and a nonparametric test indicates a *p*-value of .471, indicating that these differences between both groups were not statistically significant before the intervention with WIM.

All 45 pre-service teachers responded to the post-intervention MPQ in the experimental group. The performance in the post-intervention MPQ was better than that of the pre-intervention MPQ even though the minimum mark of (1) was lower in the post-intervention MPQ. The maximum mark of (13) was higher in the post-intervention MPQ compared to that of the pre-intervention MPQ (11). Scores from 5 to 9 had the highest frequency in the scores of the 33 pre-service teachers out of 45 pre-service teachers' scores in total.

For descriptive analysis based on gender, even though both groups (male pre-service teachers and female pre-service teachers) had a range of 12, female pre-service teachers not only performed better but also the performance of female pre-service teachers was more consistent as indicated by the standard deviation in the table below.

Table 14: Gender statistics for post-intervention MPQ

	MALE	**FEMALE**
Minimum score	1	1
Maximum score	13	13
Mean	6.16	6.60
Std. deviation	2.8089	2.5833

A *t*-test for both groups indicates a *p*-value of .588 and a nonparametric test indicates a *p*-value of .381, indicating that the differences between the achievement of male pre-service teachers and the achievement of female pre-service teachers was still not statistically significant after the intervention. A comparative analysis of performance from pre-intervention MPQ to post-intervention MPQ based on gender indicates that there was an improvement in achievement in both groups. While the mean scores for the pre-intervention MPQ for male pre-service teachers and females pre-service teachers are 5.28 and 5.6316 respectively, the mean scores in the post-intervention MPQ are 6.16 and 6.60 respectively, indicating a difference of .88 for male pre-service teachers and .9684 for female pre-service teachers.

Even though the correlation coefficient is .386 for achievement from pre-intervention MPQ to post-intervention MPQ for male pre-service teachers, the *t*-test and nonparametric test for scores in both pre-intervention and post-intervention MPQ for male pre-service teachers indicate a *p*-value of .135 and .129 respectively. This indicates that there was no statistically significant difference between the scores of male pre-service teachers in the experimental group's pre-intervention and post-intervention MPQ scores. There was also no statistically significant difference between achievement by female pre-service teachers from pre-intervention MPQ to post-intervention MPQ as the *p*-value is also .135 for the *t*-test and .127 for the nonparametric test. The correlation coefficient for female pre-service teachers between pre-intervention MPQ scores and post-intervention MPQ scores was .206.

5.5 Pre-intervention and post-intervention scores for control group based on gender

A total of 22 male pre-service teachers and 26 female pre-service teachers responded to the pre-intervention MPQ in the control group.

Table 15: Statistics based on gender for the control group

	PRE-INTERVENTION		POST-INTERVENTION	
	MALE	FEMALE	MALE	FEMALE
Minimum score	2	1	1	1
Maximum score	9	9	9	9
Mean	4.9545	4.9615	5.0526	4.8261
Std. deviation	2.0113	2.5374	1.9571	1.9921

There was no difference in achievement between male pre-service teachers and female pre-service teachers in the pre-intervention MPQ as can be observed in the mean score and the Standard Deviation above (*p*-value is .992). Neither was there any statistically significant difference between achievement of male pre-service teachers and that of female pre-service teachers in the post-intervention MPQ.

5.6 Paired-sample analysis for gender

There was no statistically significant difference in achievement of male pre-service teachers in both control and experimental groups in both pre-intervention and post-intervention MPQs. The pre-intervention MPQ results for male pre-service teachers in both the control and experimental groups indicate a *p*-value of .607 for the *t*-test and .637 for the nonparametric test while the post-intervention MPQ results for male pre-service teachers in the control and experimental group indicate a *p*-value of .131 and .217 for *t*-test and nonparametric tests respectively. There was also no statistically significant difference in achievement of female pre-service teachers between groups in the pre-intervention MPQ as the *t*-test and nonparametric test indicate a *p*-value of .315 and .217 respectively. There was, however, a statistically significant difference in achievement of female pre-service teachers between groups in the post-intervention MPQ. The *t*-test and nonparametric test indicate a *p*-value of .015 and .013 respectively.

5.7 Analysis of scores based on question categories

The preceding analysis has highlighted pre-service teachers' general performance in the MPQ items. In what follows, I provide an analysis of pre-service teachers' performance based on the question categories that were discussed in chapter four. This I do in order to ascertain whether or not the use of WIM as a platform for learning mathematics either improved or constrained performance in the various question categories. The analysis is, thus, limited to the performance in the experimental group. The table below indicates how pre-service teachers performed in questions on number, algebra, measurement, geometry and data.

Table 16: Scores based on question categories

NUMBER			**ALGEBRA**			**TRIGONOMETRY**		
QUESTION	PRE-	POST-	QUESTION	PRE-	POST-	QUESTION	PRE-	POST-
1.	5	8	**8.**	4	12	**2.**	7	8
4.	24	20	**9.**	4	4	**5.**	18	25
7.	8	12	**13.**	8	7	**16.**	10	6
10.	14	21	**15.**	10	15	**23.**	1	5
11.	11	12	**21.**	2	1	**30.**	0	6
17.	10	15	**24.**	5	2	TOTAL	36	44
18.	11	14	**25.**	5	4	**GEOMETRY**		
19.	10	7	**26.**	3	4	**3.**	8	14
20.	16	18	**32.**	0	0	**6.**	5	8
27.	17	24	**TOTAL**	**37**	**49**	**12.**	0	1
28.	10	0				**22.**	1	6
29.	0	0	**MODELLING**			**31.**	3	1
33.	2	0	**14.**	11	16	**TOTAL**	**17**	**30**
34.	3	3						
35.	0	0						
TOTAL	139	154						

Out of 15 questions in the category of number, there was improvement in the experimental group in all but three questions and no change in five questions. The correlation coefficient from pre-intervention to post-intervention shows a value of .939 indicating a high correlation. The *t*-test gives a *p*-value of .203 indicating that the difference is not statistically significant. This is also true for the algebra questions which have a correlation of .811 and a *p*-value of .231. In general, there was improvement in the post-intervention results in all content domains as can be seen in the total number of questions correctly answered in each domain.

In a nutshell, the statistical analysis of data revealed a moderate correlation (0.328) between the performance of pre-service teachers who participated in WIM mathematics teaching and learning initiative (experimental group) and that of those who did not participate (control group). This means that learning mathematics using WIM led to improvement in pre-service teachers' mathematics performance. Given the fact that there was a highly significant difference between the post-intervention MPQ scores in the experimental group and those of the control group, and that the experimental group showed statistically significant higher gains from pre-intervention MPQ scores to post-intervention MPQ scores, it can be concluded that the improvement of the performance in mathematics from pre-intervention MPQ scores to post-intervention MPQ scores, was not due to chance. It can be ascribed to the fact of having learnt mathematics using WIM.

5.8 Conclusion

In this chapter, I discussed the statistical results for the quantitative phase of the current study. These are the results from quantitative data collected through the use of MPQs. The quantitative data was intended to investigate the influence of learning mathematics using WIM on pre-service teachers' knowledge of mathematics. In the next chapter, I present the results of the qualitative data analysis from observations of mathematics interactions using WIM between pre-service teachers and the tutor. The chapter also presents results from semi-structured interviews of purposefully selected pre-service teachers.

CHAPTER SIX: QUALITATIVE DATA ANALYSIS

6.1 Introduction

In this chapter, I present the results of the qualitative data analysis which was aimed at addressing the following critical research questions: *What are pre-service teachers' experiences of using WhatsApp instant messaging for mathematics learning*? *Why do pre-service teachers experience the learning of mathematics using WhatsApp instant messaging in the way that they do*? For this purpose, I used Russell and Schneiderheinze's (2005) Cultural-Historical Activity Theory (CHAT) analytical framework to analyse the transcripts of the observations of WIM-mediated mathematics interactions. For the analysis of the interviews from purposefully selected pre-service teaches, I used a narrative analytical approach.

6.2 Observations of interactions on WhatsApp instant messaging

In this section, I examine mathematics interactions between the tutor and pre-service teachers using WIM in order to unravel how the interactions unfolded and also to explore the experiences of pre-service teachers. To do this, I use Russell and Schneiderheinze's (2005) CHAT analytical framework activity systems to interrogate elements of mathematics interactions on WIM as forces for change in pre-service teachers' mathematics learning.

6.2.1 Mathematics teaching and learning as an activity of interest

The term activity "denotes societal and cultural-historically developed forms of contributing to the satisfaction of collective needs" (Roth, 2007, p.88). In addition, activity involves goal-oriented actions and behaviour in context, often mediated by tools, rules and division of labour (Rambe, 2009). In the current study, the teaching and learning of mathematics using WIM was conceived as an activity of interest. For the tutor, the activity of interest was the design and delivery of an effective mathematic teaching and learning model, meaningful mathematical interactions with pre-service teachers, and pre-service teachers' mastery of conceptual understanding, procedural fluency, strategic competence, adaptive reasoning and productive disposition in mathematics.

For pre-service teachers, the activity of interest was the engagement in mathematics dialogic interactions with peers and the tutor, and the sharing of mathematics skill and strategies for finding solutions. The focus then shifted from exploring rote participation in mundane mathematics tasks to understanding the structural and cultural-historical forces that either enable or constrain the subject's goal-directed activity of mathematics teaching and learning.

6.2.2 The objects of mathematics teaching and learning activity

Roth (2007) asserts that the object of activity demonstrates the goal-directed nature of human consciousness. Roth and Lee (2006) contend that the object or motive of an activity is realised through a series of goal-directed actions and that this characteristic underscores that goals are formulated precisely with the intention of realising these activities. In the current study, I interpreted the objects of teaching and learning of mathematics using WIM (the activity of interest) as:

- ❖ Effective design of mathematics teaching and learning (interaction style, pedagogical mode, structure of content) by the tutor.
- ❖ Meaningful mathematics interactions using WIM that familiarise or equip pre-service teachers with mathematics subject matter knowledge.
- ❖ The mastery of conceptual understanding, procedural fluency, strategic competence, adaptive reasoning and productive disposition of mathematics.
- ❖ Engaging pre-service teachers in mathematical discourses that immerse them in mathematics knowledge construction and knowledge communities.

Each mathematics interaction using WIM contributed to any one or a combination of these objects. Furthermore, the objects highlighted above are affected by the interplay of individual and collective mediating factors (rules, community and roles) and the structural and cultural-historical factors that are at play in WIM mathematics interactions.

The ability of the tutor to articulate the teaching and learning objects clearly is very significant for pre-service teachers' mathematics learning in light of these confounding factors (mediating, structural and cultural-historical), since students with limited "prior mediated learning experiences"[2] (MLE) often have a tendency to conflate the object of teaching and learning with the materials used to achieve it, thereby leading to learning goal displacement (Feuerstein et al., 1980). Hence, "intentionality" in MLE is critical to pre-service teachers' mediated learning using WIM.

Table 17: The object of activity

Element of activity	**Extracts of observation transcripts**	**Researcher's comments**
Object of activity	***We are trying to solve an absolute value inequality, which has the following information… When you are given a problem like this in a test or exam […]***	1. Absolute value inequality is the object of the interaction. 2. Application of WIM interaction content as a basis for a test or examination preparation.

In the extract above, the tutor cites solving an absolute value inequality as the main object of the tutorial. It is very significant for the tutor to define the object of his tutorial to avoid confusing pre-service teachers. As a prerequisite for evaluation (exam or tests), pre-service teachers were required to master mathematics concepts (such as the aforementioned solving an absolute value inequality). Therefore, informing pre-service teachers about future tasks recruited their attention and activated their mental preparation, thus constituting scaffolding.

6.2.3 Pre-service teachers and the tutor as subjects of activity

The tutor and pre-service teachers who were involved in mathematics teaching and learning using WIM (control group) constituted the subjects of the activity. Pre-service teachers had differing experiences and conceptions about learning mathematics using WIM. These diverse conceptions were products of broad structural factors (cultural and socio-historical) and other immediate contextual factors such as the design of the instruction. For instance, while WIM was utilised as an official mathematics interaction space between the tutor and pre-service

[2] "The purpose of mediated learning experiences (MLE), is to create cognitive prerequisites essential for successful direct learning" (Feuerstein et al., 1980 cited in Kozulin, 2003, p. 26). It involves mediation of meaning, transcendence, and intentionality (ibid.).

teachers, pre-service teachers had differing notions of its academic value in mathematics teaching and learning as illustrated in observation extracts below.

Table 18: The subject of activity

Element of Activity (subject)	**Extracts from observations**	**Researcher's comments**
Pre-service teacher X	***I don't think it's possible to learn maths effectively on this thing (WhatsApp). It is very difficult to write mathematics formulae and it has limited characters.***	1. Find it difficult to learn mathematics on WIM. 2. Does not conceive it as serving any academic purpose.
Pre-service teacher Y	***I used WhatsApp for interacting with tutor. If I didn't understand any concept discussed in class, then I would discuss it with him. […] Other students also commend if I asked a question […] So I got to interact with more people and get more solutions to my problems.***	1. WIM complements face-to-face classroom learning. 2. Supports collaborative learning and academic support.

The different experiences and perceptions pre-service teachers had about using WIM for mathematics teaching and learning potentially affected their mathematics learning capabilities. Those pre-service teachers, who found it challenging to learn mathematics using WIM, such as pre-service teacher X, closed down the possibility for using it productively while those pre-service teachers who perceived it as a productive academic resource, such as pre-service teacher Y, used it for mathematics consultations, collective generation of mathematics knowledge and peer-based mathematics support. The above discussion addresses the questions:

What are pre-service teachers' experiences of using WhatsApp instant messaging for mathematics learning? *Why do pre-service teachers experience the learning of mathematics using WhatsApp instant messaging in the way that they do*?

6.2.4 Rules facilitating interactions on WhatsApp instant messaging

The rules facilitating the teaching and learning of mathematics using WIM were both explicit and implicit norms and values that govern the forms of engagement between students and academics in educational institutions. Implicit rules are culturally ascribed and are premised on teaching as a professional praxis. These rules include respect for lecturers and recognition of the power of lecturers as authoritative voices in the classroom. The explicit rule when using WIM was to limit its utilisation to mathematics discussions only and no personal questions were allowed on WIM.

In fact, the tutor and pre-service teachers signed a code of conduct before engaging in mathematic interactions using WIM. The tutor enforced rules that prohibited social interactions among mathematics learning groups on WIM. These ground rules added value to pre-service teachers' learning of mathematics using WIM because they protected group members from being stuffed with unnecessary and non-academic threads. Additionally, these rules ensured that discussions remained focused since all threads were mathematical in nature.

6.2.5 Tools mediating activity of mathematics teaching and learning

WIM was the only technological tool used by the tutor and pre-service teachers for mathematics teaching and learning. The other tools used by the participants were language and cognitive scaffolding such as direct elaboration of mathematics concepts in the tutor's responses, emphasis and explanations, directing pre-service teachers' attention to critical aspects of mathematics problems, providing background information to the solutions, and giving relevant examples. I infer that WIM regenerated questioning opportunities lost in large face-to-face tutorials, where asymmetrical tutor-student academic relations are more salient.

Table 19: Tools mediating activity

Psychological tools	Extracts of empirical materials	Researcher's comments
Direct questions	***Tutor: How do we factor the trinomial $x^2+7x+10$?*** ***Pre-service teacher Y: We look for integers whose product is 10 and whose sum is 7. These integers are 5 and 2 and the trinomial factors as (x+7) (x+2).***	1. Questions are used by the tutor to diagnose pre-service teachers' current mathematical knowledge.
Prompt questions	***Tutor: Mary inherits $100,000 and she wants to invest it. Which formula do we use to calculate interest on investment?*** ***Pre-service teacher X: We use I=Prt.*** ***Tutor: What does each letter stands for?*** ***Pre-service teacher Y: I = interest, P = principal amount, r = interest rate, and t = time in years.***	1. The question prompts scaffold pre-service teachers' learning by connecting prior knowledge to current complex tasks. 2. The question prompts are also used to gauge pre-service teachers' understanding.

6.2.6 Roles of the subjects of activity on WhatsApp instant messaging

Roles are the division of labour that pre-service teachers and the tutor assumed in order to realise the objects of learning mathematics using WIM. The roles for pre-service teachers included being mathematics information disseminators, mathematics knowledge generators, reflectors, and information acquirers. Pre-service teachers also assumed the roles of mathematics resource persons as they advised their peers during their mathematics interactions using. One typical case involved a pre-service teacher inquiry directed at the tutor, followed by a peer‘s intervention as a resource person, and the tutor’s approval of the advice given. Given the capacity of some high achievers to advise their peers, these practices suggest that multiple layers of roles potentially emerged for pre-service teachers.

Furthermore, tutor-pre-service teacher relations of dominance in face-to-face tutorials would take other forms on WIM such as hierarchical relations at pre-service teacher-peer level. Step two of Salmon’s (2000) five-step model[3] for supporting e-learning process emphasise building trust through online socialisation where the online administrator’s roles are facilitating, familiarising students with the online environment and providing bridges between social and cultural aspects of offline and online learning environments.

I infer that WIM-mediated mathematics interactions reduce social distance and establishes familiarity between the tutor and pre-service teachers, and this in turn lead to them engaging robustly. Again, this breach of social distance potentially subverts academic hierarchy as status barriers were removed with heightened interactivity. Sometimes pre-service teachers were presented with the opportunity to demonstrate concepts to their peers. This opportunity shifted the role of participating pre-service teachers from recipients of tutor-generated content to resource persons and informal assessors of peers’ level of understanding of concepts discussed. Figure 12 below illustrates the whole activity system of mathematics interactions between pre-service teachers and the tutor using WIM.

[3] Salmon‘s (2000) Five Step model of online facilitation involves access and motivation, online socialisation, information exchange, knowledge construction and development. In this model students progressively gain familiarisation, control and responsibility for their knowledge construction and cognitive growth.

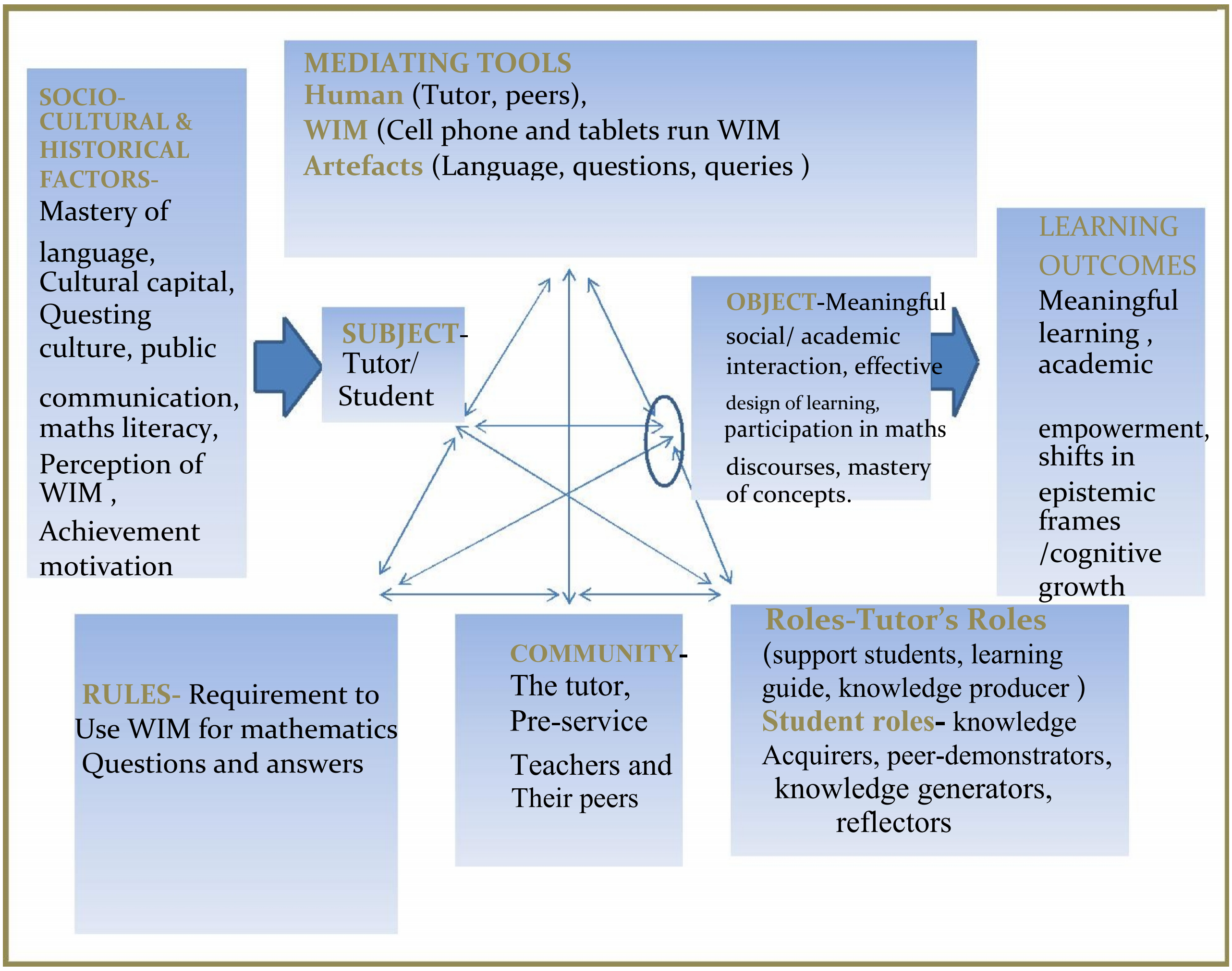

Figure 12: The activity system of teaching and learning mathematics using WIM (Adopted from Russell and Schneiderheinze, 2005, p. 73)

6.2.7 Outcomes of mathematics interactions on WhatsApp instant messaging

Mathematics interactions on WIM were reported to increase pre-service teachers' agency and self-pacing of mathematics learning (academic empowerment). As a technology they have been using for social purposes since high school, pre-service teachers felt they knew WIM better than or as much as the tutor hence, it equalised the academic relations between the tutor and pre-service teachers. In this way, WIM created an environment controlled by pre-service teachers that was empowering and free from administrative controls. Pre-service teachers had a feeling of ownership of mathematics learning using WIM that could not otherwise be felt in face-to-face mathematics tutorials. This answers the research question:

What are pre-service teachers' experiences of using WhatsApp instant messaging for mathematics learning?

6.3 Analysis of interview transcripts

Considering that the crux of the qualitative phase of this study was on exploring pre-service teachers' experiences on a newly introduced mobile learning application (WIM), I used a narrative analytic approach to analyse the data from interview transcripts. As Bryman (2008, p. 559) posits, "The aim of narrative interviews is to elicit participants' reconstructed accounts of connections between events and contexts". Narratives were coded in line with the idea that "at the root of semi-structured interviewing is an interest in understanding the experiences of participants and the meanings they make of those experiences" (Seidman, 1998, p. 3).

6.3.1 Participants in interviews

Since the credibility of a qualitative research approach depends less on sample size than on the richness of information gathered and on the analytical abilities of the researcher (Patton, 2010), I selected only six pre-service teachers from the experimental group, based on their levels of achievement in both pre- intervention and post-intervention MPQs. This meant that two pre-service teachers from level 1 (excellent performance), two from level 2 (moderate performance) and two from level 3 (inadequate performance) were selected. Of these six participants, three were female pre-service teachers while the other three were male pre-service teachers. Participants' pseudonyms used in this study in an attempt to avoid exposing them to criticisms were: Chichi, Candice, Getty, Tanya, Amos and Clint.

6.3.2 Main themes from the analysis of interviews

6.3.2.1 Peer collaborative mathematics learning

Collaborative learning is reported to foster the creation of knowledge through group member interactions (Colella, 2008). Previous findings (Rambe, 2009) indicate that collaborative learning potentially enhances the learning process, and increases students' motivational levels to engage in academic activities. This collaborative learning perspective stimulates an increase in self-esteem and also promotes the abilities for cooperative work among students (Hong, Yu, & Chen, 2011). Students can learn from collaborative mobile learning through participating in the process of giving and receiving academic assistance, knowledge sharing and resolving contradictions among themselves (Hong, Yu, & Chen, 2011; Webb & Mastergeorge, 2003).

Interestingly, participants mentioned collaborative learning as an aspect that promoted their effective mathematics learning using WIM in this study. For Chichi, collaborative learning supported by WIM shifted her tendency of private mathematics learning to group learning.

> ***I do not stay on campus, so I do not have anyone to consult after hours. These circumstances made me to develop tendencies of private study. WIM shifted my private mathematics learning habits to collaborative learning since I could interact at any time with my peers.***

Candice also acknowledged that collaborative mathematics learning took place on WIM. She claimed that it taught her to value her peers' opinions and to engage with their views, perspectives and content, rather than her traditional self-study approach which basically consisted of individual mathematics problem solving. She said the following:

> ***The WIM initiative made me realise how much my classmates are worth to me. Small contributions made by my group members significantly contributed to my mathematics learning. I learnt a lot from my peers.***

The collaborative nature of mobile instant messaging learning, according to Sotillo (2012), does not only render interactions that facilitate student awareness of concepts, but it can also improve throughput. Getty had the following to say:

> ***I learn mathematics through showing others what I know and I value peer feedback. My situation is complex in the sense that I stay about 60km away from the university campus, so getting involved in mathematics group discussions after hours is practically impossible, since I need to catch my transport on time. This constraint limits me from sharing knowledge with my peers, since their groups are constrained by time and space. Introduction of WhatsApp perfectly fits my study needs because I can academically interact with my peers at any time of the day, regardless of my location. This initiative has contributed to the improvement of my grades in tests and assignments.***

6.3.2.2 Ubiquitous mathematics learning

Mobile devices that were used by participants in the current study were smartphones, tablets and iPads all of which supported the following applications: SMS, e-mail, internet, Facebook, twitter, Skype and mp3. These mobile devices' portability and ease of use enabled pre-service teachers to ubiquitously utilise WIM for mathematics learning. The majority of the participants interviewed indicated that portability of these mobile learning devices influenced their academic participation in mathematics activities. Tanya in particular had this to say:

> ***The beauty of WhatsApp is that it is an application that runs on a portable mobile device, so my mathematics learning was not limited to one place. Since messages could be read anywhere, even in restricted areas like banks and hospitals, portability of these devices led to flexibility in mathematics learning.***

Amos also had this to say:

> ***I can scroll down and browse through my peers' mathematics questions, queries and comments at any place, because I can carry my phone around. I even get to use WhatsApp for mathematics learning on my lounge suite or my bed, and therefore portability makes mathematics learning accessible anywhere, at any time which is a good idea.***

Additionally, Candice, Chichi and Clint suggest that the adoption of WIM for mathematics teaching and learning gave pre-service teachers and their tutor an opportunity to interact at any time and at any location, hence reducing the time one would spend trying to figure out solutions to mathematics problems alone. The adoption of WIM in mathematics interactions shifted pre-service teachers' traditional learning perception that learning is influenced by time and space. With the mobile devices at hand, pre-service teachers potentially learned mathematics anywhere either in classroom or out of classroom, and any time either on campus or out of campus. Candice, Tanya and Clint had the following to say:

> ***The WhatsApp strategy suited my busy schedule, because it allowed me to multitask so that I could learn mathematics anywhere and at any time. At times I participated in mathematics group discussions while at home. [Clint]***

I like shopping, with WhatsApp I could academically interact with my peers while shopping, since I can learn anywhere and at any time. [Candice]

I stay in a neighbourhood characterised by high criminal activities, thus joining evening mathematics study groups is risky for me, and my only option is to study alone. My self-study strategy relies on nothing other than textbooks since they are my only available study resources. WhatsApp enabled me to learn mathematics anywhere and at any time. Now I can academically interact with my peers at any time of the day. [Chichi]

6.3.2.3 Synchronous and asynchronous mathematics learning

Roberts and Vänskä (2011) postulate that synchronous and asynchronous learning facilitated by mobile learning applications such as WIM, has the potential to enhance students' robust learning. O'Neill, Scott and Conboy (2011) argue that students improve their critical thinking in both synchronous and asynchronous learning through collaboration. On the one hand, synchronous learning significantly involves students in real-time learning, which is an excellent environment for fruitful academic discussion. On the other hand, asynchronous learning is appropriate when students require more time to form their thoughts or research before contributing their views. In a virtual synchronous instructional delivery, these students might be dominated by academically stronger and spontaneous thinkers (Attewell, 2004).

WIM is a flexible instructional delivery method because it is capable of supporting both synchronous and asynchronous learning perspectives. Getty mentioned synchronous and asynchronous mathematics learning enabled by WIM. She had the following to say:

I liked WhatsApp because it allowed me to research and reflect before responding to questions, unlike in face-to-face tutorials or lectures where impromptu responses are expected due to limited time.

Amos alluded to the value of synchronous mathematics learning. He was particularly fascinated by the instant feedback supported by WIM.

I value feedback during mathematics learning, because I don't want to continue studying concepts that I am unsure of, hence I need someone to

confirm that I am on the right track. The face-to-face tutorial was the only place I could ask questions and get feedback on concepts previously discussed. WhatsApp initiative came and extended my mathematics learning. I could get instant feedback from both my peers and the tutor while at home.

Chichi enjoyed the advantages offered by WIM for both synchronous and asynchronous mathematics learning. She declared that blending these two learning contexts enabled her to learn mathematics anytime of the day. She said:

Before the implementation of WhatsApp for mathematics teaching and learning, sharing of ideas was limited to tutorial hall, since my classmates were reluctant to form after-hour study groups. WhatsApp extended my mathematics learning, since ideas could be shared anytime of the day, learning could be done in real time and messages could be responded to later. At least with WhatsApp I could make a decision about when to learn.

6.3.2.4 Anonymous mathematics learning

It is acknowledged in literature that mobile learning applications such as WIM have the potential to raise self-confidence for timid and low self-esteem students (Rambe & Bere, 2013). Further, anonymous learning is reported to facilitate significant improvements in self-esteem and confidence among students in mathematics learning (Attewell, 2004). Candice's views supported these arguments in the following way:

WhatsApp significantly improved my participation in mathematics learning, because nobody could trace my contributions back to me, since WhatsApp hides the name of the sender. Participating freely without fears of being judged by other students enhanced my confidence.

Clint corroborates Candice's claims by declaring,

I am a shy person and I do not feel comfortable participating in face-to-face tutorials because some classmates may judge me. Furthermore, some students randomly pass negative comments against other students' contributions and these students make me hate participating in class. The

> ***introduction of the WhatsApp strategy was a relief to me, because I could comfortably participate in mathematics discussions without fear of victimisation from my classmates, since no one would know that it is my contribution.***

WIM application is engineered in such a way that group members can view each other's phone numbers and not each other's names, hence fostering anonymous learning. Asked why she preferred WIM as compared to face-to-face mathematics consultations, Getty acknowledged that:

> ***I am freer on WhatsApp and comfortable to ask. When I am in a face-to-face tutorial and want to ask something, I have to think twice, is this appropriate, is this not a silly question? But when I am on WhatsApp gee! I can ask any mathematics question I like. However, if it were in face-to-face tutorial classmates would say, "Stop wasting our time".***

The statement "***classmates would say, stop wasting our time***" suggests that more dominant pre-service teachers assume a vertical role of silencing peers who wanted to ask questions in face-to-face tutorials. This challenges the widely held assumption in transmission pedagogy that students are homogenous entities with similar learning needs that require decontextualised content (Rambe, 2009). It seems superior-subordinate academic relations are prevalent even at pre-service teacher-peer levels as some pre-service teachers controlled and marginalised their peers in face-to-face tutorial discourses.

The preference for WIM in mathematics learning by pre-service teachers supports my argument that some pre-service teachers were appropriating WIM as personalised and student-controlled spaces to reclaim academic and psychological power, and learning opportunities lost in hegemonic classroom discourses to more dominant students.

Furthermore, the citation "***But when I am on WhatsApp gee! I can ask any mathematics question I like"*** above, also demonstrates the capacity of WIM interactions to democratise participation by protecting the identities of participants while affording them access to information in ways that would otherwise be impossible for such timid students in face-to-face interactions. WIM thus disrupted the hegemonic voices of academically advantaged pre-service teachers, and democratised mathematics learning at pre-service-peer levels.

6.4 Conclusion

In this chapter, I presented the results from qualitative data analysis for the current study. These are the results from qualitative data collected through the use of semi-structured interviews of purposefully selected pre-service teachers and the observations of mathematics interactions between pre-service teachers and the tutor using WIM. In the next chapter, I draw conclusions on the findings of the whole study and then make recommendations based on the findings. In the same chapter, I conclude by reflecting on the whole research process, shedding light on the limitations of the current study and the possibilities for future research.

CHAPTER 7: CONCLUSION AND RECOMMENDATIONS

7.1 Introduction

The purpose of this study was to explore the use of WhatsApp instant messaging (WIM) as a platform for mathematics teaching and learning at university level involving pre-service teachers and the tutor. For this purpose, an explanatory sequential mixed methods approach was utilised, characterised by the collection and analysis of the quantitative data followed by the collection and analysis of the qualitative data. In chapter five, I presented the results of the quantitative data analysis while in chapter six I presented the results of the qualitative data analysis. In this chapter, I present the review of the entire research process, discussion of finding, recommendations, limitations and the possibilities for future research.

7.2 A review of the entire research process

In S.A, it is reported that most pre-service teachers enter mathematics teacher training programmes with an inadequate knowledge of mathematics (Biyela, 2012). This is due to the fact that the knowledge they have acquired during their high school days, is based mainly on their scanty experiences as students. In addition, the vicissitude of recruiting mathematically competent students into mathematics education programmes leads to the reality that the bulk of those who eventually enter are those who would not have been accepted into mathematically rigorous programmes, due to their low matric mathematics marks (Pournara, 2005). Yet, very often in teacher training institutions more emphasis is put on pedagogical content knowledge at the expense of subject matter knowledge (Benken & Brown, 2008).

Consequently, pre-service mathematics teachers exit their teacher training programmes with substantially the same subject matter knowledge as when they first entered (Biyela, 2012). Unfortunately, the instructional activities of these teachers do not encourage attainment of conceptual understanding and strategic competence in mathematics. Arising out of this is the severe lack of competence which leads to impoverished attainment among S.A students, as evidenced by both national and international assessment reports. However, it is not clear how mathematics programmes at teacher training institutions address this dilemma.

The high infiltration of smartphones into the market, has initiated the growing use of WIM as a communication platform for various student groups, and more recently, for groups of teachers and their students (Tzuk, 2013; Amry, 2014). Motiwalla (2014) suggests that the popularity of WIM within student and teacher population is so great that, ''it would be foolish to ignore it in any learning environment'' (p. 584); and therefore suggested that researchers begin investigating how it can be best utilised in teaching and learning environments. It is against this backdrop that the current study was intended to explore the pedagogical potential of WIM to enhance pre-service teachers' knowledge of mathematics.

CHAT was used as a theoretical framework for the entire study and also as an analytical lens for observations of mathematical interactions between pre-service teachers and the tutor using WIM. Ontologically, I approached the study from a pragmatist perspective. Pragmatists do not recognise the world as an absolute unity and therefore, regard knowledge as both objective and subjective (Jonson & Onwuegbuzie, 2004).

To pragmatists, reality is what works at the time; it is not based on the duality between reality independent of the mind and the reality within the mind (Mertens, 2009). Again, the agreement among pragmatists is that research always occurs in social, historical and political contexts, therefore they believe in an external world independent of the mind as well as that which is harboured within the mind (Creswell, 2014), Hence their preference for mixed methods research.

On the one hand, the quantitative phase of the study was intended to address the following research question: *How does the use of WhatsApp instant messaging as a platform for teaching and learning influence pre-service teachers' knowledge of mathematics*? To this end, a quasi-experimental, non-equivalent comparison group design, which involves the use of both the control and the experimental group, was adopted. The population that constituted the quantitative phase was 1200 pre-service teachers at one of the universities in KwaZulu-Natal.

A total of 93 pre-service mathematics teachers from second year to fourth year who were registered for the Mathematics 110 module were selected as a sample through convenience sampling. There were two tutorial groups for Mathematics 110 module (group A and B). In tutorial group A, there were 45 pre-service teachers while in tutorial group B there were 48 pre-service teachers. Tutorial group A constituted the experimental group while tutorial group B constituted the control group.

The quantitative data was collected utilising the mathematics proficiency questionnaire (MPQ). MPQ is the subtest of the Academic Aptitude Test [AAT] (Minnie & Paul, 1982) which is based on FET mathematics content. The data from both pre-intervention and post-intervention MPQs were analysed using statistical tests (*t*-test), measures of central tendency (means and modes only) and variability (standard deviation and ranges). The magnitude of all relationships reported used the conventions from Davis (in Waldron, 2004).

On the other hand, the qualitative phase of the study was intended to address the following critical research questions: *What are pre-service teachers' experiences of using WhatsApp instant messaging for mathematics learning*? *Why do pre-service teachers experience the learning of mathematics using WhatsApp instant messaging in the way that they do*? To this end, a phenomenological research design which focuses on understanding peoples' experiences, perceptions and understandings of a particular situation was utilised.

The qualitative data was collected through face-to-face semi-structured interviews of purposefully selected pre-service teachers. Six pre-service teachers from the experimental group were selected based on their gender and level of achievement in both pre-intervention and post- intervention MPQs. The interviewing process followed a phenomenological tradition of inquiry focusing on the essence of the phenomenon to be explored.

In this case, the phenomena were pre-service teachers' experiences of mathematics learning using WIM. In addition to interviews, observations of mathematics interactions between pre-service teachers and the tutor using WIM were conducted. The data from interviews were analysed using a narrative analytic approach while the data from observations were analysed through the use of Russell and Schneindeheinze' s (2005) CHAT analytic framework.

7.3 Discussion of findings

7.3.1 Findings from the quantitative phase of the study

A comparison of the control and the experimental group's *t*-test and the nonparametric test before the commencement of the intervention, indicated that there was no statistically significant difference in the questionnaire results between the two groups, even though there was a slight difference in the mean scores in favour of the experimental group. An analysis of the performance in the pre-intervention MPQ and post-intervention MPQ for the control group revealed that there was no statistically significant difference between achievement in both pre-intervention MPQ and post-intervention MPQ; even though achievement of pre-service teachers in this group was lower in the post-intervention MPQ.

An analysis of achievement in pre-intervention MPQ and post-intervention MPQ scores for the experimental group indicated a moderate correlation between achievement in pre-intervention MPQ and achievement in the post-intervention MPQ. A *t*-test and nonparametric test indicated a statistically significant difference between scores in the pre-intervention MPQ and those of the post-intervention MPQ. A comparative analysis of pre-service teacher achievement in both the control and the experimental group in the post-intervention MPQ indicates that there was a highly significant difference between achievements in the experimental group compared to achievement in the control group.

As far as the pre-intervention MPQ analysis by gender is concerned, there was no statistically significant difference between achievements of male pre-service teachers within and between the two groups. This was also true of achievement by female pre-service teachers in the pre-intervention MPQ. In the post-intervention MPQ results for gender, there was no statistically significant difference between achievements by male pre-service teachers as compared to achievement by female pre-service teachers within the two groups.

There was however, a statistically significant difference between achievement of female pre-service teachers in the experimental group and the achievement of female pre-service teachers in the control group. There was no difference in the achievement of male pre-service teachers between the groups in the post-intervention MPQ. As far as the content domains were concerned, there was an improvement in all content domains in the experimental group but none of the domains recorded a statistically significant difference.

In a nutshell, the statistical analysis of data revealed a moderate correlation (0.328) between the performance of pre-service teachers who participated in WIM mathematics teaching and learning initiative (experimental group) and that of those who did not participate (control group). This means that learning mathematics using WIM led to improvement in mathematics performance. Given the fact that there was a highly significant difference between the post-intervention MPQ scores in the experimental group and those of the control group, and that the experimental group showed statistically significant higher gains from pre-intervention MPQ scores to post-intervention MPQ scores, it can be concluded that the improvement of the performance in mathematics from pre-intervention MPQ scores to post-intervention MPQ scores, was not due to chance, instead it can be ascribed to the fact of having learnt mathematics using WIM.

7.3.2 Findings from the qualitative phase of the study

7.3.2.1 Observations of mathematics interactions on WIM

Russell and Schneiderheinze's (2005) analytical framework was adopted for the analysis of observations of mathematics interactions between pre-service teachers and the tutor using WIM. The analysis focused on the subject, the object and outcomes mediated by tools (instruments), rules, roles and the community. During the observations of mathematics interactions, it was noted that the tutor cites solving an absolute value inequality as the object of that particular tutorial. It was very significant for the tutor to define the object of his tutorial in order to avoid confusing pre-service teachers. This is because informing pre-service teachers about future tasks recruited their attention and activated their mental preparation thus constituting scaffolding.

Observations also revealed that pre-service teachers had differing experiences and perceptions about the pedagogical value of WIM in mathematics teaching and learning. Some pre-service teachers perceived WIM as unsuitable for mathematics teaching and learning and therefore denied its productive use. Others perceived it as a productive academic resource and therefore, utilised it for mathematics consultations, collective generation of mathematics knowledge and for peer-based mathematics support. Further, it was observed that the tutor used direct elaboration, emphasis and explanation as cognitive scaffolding tools.

This scaffolding involved the tutor's elaborations of mathematics concepts in his responses, directing pre-service teachers' attention to critical aspects of mathematical problems, providing background information to the solutions and giving relevant examples. Additionally, it was observed that WIM-regenerated questioning opportunities lost in large face-to-face tutorials where asymmetrical tutor-student academic relations are more salient.

Furthermore, observations revealed that there were both implicit and explicit rules (norms and values) that governed the forms of engagement between the tutor and pre-service teachers. Implicit rules included culturally ascribed norms and values premised on teaching as a professional praxis, such as the respect for the tutor as the authoritative voice in mathematics learning. The explicit rule was that the use of WIM must be limited to academic activities only. This meant that no personal discussion between participants was allowed on WIM.

Finally, it was observed that on WIM pre-service teachers assumed numerous roles such as mathematics information disseminators, mathematics knowledge generators, mathematics resource persons and mathematics information inquirers. Again, it was observed that mathematics interactions between pre-service teachers and the tutor using WIM reduced the social distance between them. This removal of social distance resulted in increased familiarity and robust mathematics engagements among participants. Additionally, the breach of social distance potentially subverted academic hierarchy as status barriers were removed with heightened mathematical interactivity. Consequently, pre-service teachers had a feeling of ownership of mathematics learning that could not otherwise be felt in face-to-face tutorials.

7.3.2.2 Interviews with pre-service teachers

The analysis of interview transcripts revealed that academic usage of WIM in mathematics teaching and learning promoted learning through peer-collaboration and sharing of mathematical ideas unbound by time and location. Again, mobile devices' portability and the versatility of WIM promoted an academic transformation from instructive tutor-centred to an active pre-service teacher-centred mathematics teaching and learning approach. Additionally, the mobility of learning devices and the connectivity of WIM application transformed pre-service teachers into active participants rather than passive receivers of knowledge.

Further, WIM transformed the teaching and learning of mathematics since it was no longer defined by presence in the tutorial hall but by collaborative learning, unconstrained by scheduled tutorial hours or specific location. Moreover, WIM's mediation of mathematics teaching and learning profoundly impacted on the ability of the majority of pre-service teachers' ability to engage with peers, resulting in improved collaborative mathematics learning. Collaborative mathematics learning enabled by WIM promoted mathematics knowledge generation through group member interactions and enhanced the distribution of mathematical ideas among group members which subsequently improved their mathematical knowledge.

Furthermore, collaborative mathematics learning using WIM enabled pre-service teachers to externalise their mathematical ideas and to reflect on their mathematical discussions. Again, WIM initiative enhanced pre-service teachers' mathematics participation in diverse ways. Most profoundly, it provided an informal, instantaneous and convenient way of exchanging and sharing mathematical knowledge. Through WIM mathematics interactions, pre-service teachers could consult and get guidance on mathematics concepts. On WIM, pre-service teachers had more time to interact with their peers and the tutor, unlike in face-to-face tutorials where time is limited for each and every academic engagement.

Moreover, discussion threads created during mathematics interactions on WIM were automatically saved on mobile devices. In this way, participants could access these threads for revision purposes at any time, resulting in a useful digital library for the pre-service teachers. These digital libraries contained summaries of mathematics concepts around which pre-service teachers could create robust discussions, resulting in effective and efficient mathematics revision before examinations. In addition, instant feedback given over WIM enhanced pre-service teachers' participation since they wanted to be corrected without continuously having to study concepts whose validity they were not certain of.

Finally, anonymous mathematics learning enabled by WIM enhanced pre-service teachers' learning by recruiting and sustaining their critical questioning and information seeking practices. This was particularly true for those who perceived traditional face-to-face mathematics tutorials as intimidating hegemonic spaces for posing questions and participating. In addition, the ubiquitous mathematics learning promoted by WIM gave pre-service teachers an opportunity to academically consult and contribute to mathematics discussions anywhere, at any time of the day. Furthermore, this ubiquitous mathematics learning supported by WIM encouraged pre-service teachers to take full control of their learning activities by studying at their own space and convenience. Ubiquitous mathematics learning also created more opportunities for learning using both synchronous and asynchronous communication channels.

7.4 Recommendations

Previous research on mathematics education has rendered some invaluable insights into the significance of students' active participation in mathematics activities (Iqbal, Kousar & Ajmal, 2011; Hron & Frriedrich, 2008). Furthermore, a number of studies have reported on the significance of mobile instant messaging in enhancing students' participation in academic activities (Colella, 2008; Roschelle, 2010). The current study's findings inform the following recommendations that have the potential to enhance students' effective learning.

7.4.1 Recommendation to mathematics lecturers or tutors

Lecturers or tutors need to adjust the discussion times after hours, so as to accommodate the academic participation of mature and married students with additional family responsibilities. Further, lecturers should establish a reward mechanism to stimulate student interest in the academic usage of WIM (for example, the most engaging group of the week and weekly prizes for the best contributions). Furthermore, lecturers should identify and summarise interesting student discussions on WIM and post them on the institutionally supplied learner management system to prevent disadvantaging those students without phones enabled for WIM.

7.4.2 Recommendations to university institutional management

The management team of the University should motivate lecturers in other departments to utilise WhatsApp instant messaging in their academic programmes to foster students' participation. The institutional management should also devise a mechanism for subsidising mobile devices for students to promote mobile learning.

7.4.3 Recommendation to software developers

The study reported additional duties that pre-service teachers had to assume, such as mathematics information generation, contribution to peers' thoughts and close reading and interpretation of peers' views before making some contributions. To appreciate these additional responsibilities that WhatsApp instant messaging brings to students, software developers should upgrade WIM by integrating applications that enable sorting discussion threads by topics to diminish the mental load on students during interactions.

7.5 Limitations of the study

The question as to what percentage is representative of the whole will always remain a practical challenge in quantitative research. Certainly, 98 pre-service teachers cannot be judged as an adequate representative of 1200 students enrolled in teacher training programme at the university concerned. Neither can the claim be made that the number of participants in the study is representative of all pre-service teachers enrolled in mathematics education in S.A. The findings therefore, cannot be generalised to other populations.

Akin to the above limitation was the fact that the period for the implementation of WIM programme was not sufficient to conclude that participants' mathematics knowledge was thoroughly improved. The Zone of Proximal Development has implications not only for the mediation of learning but also for the acquisition of new knowledge and skills (Nieman, 2008). Internalising new knowledge and skills no doubt takes time. To this end, a more prolonged mathematics intervention programme using WIM would have been worthwhile.

Furthermore, even when extraneous variables are well controlled it is still possible that some factors be responsible for the statistical difference between the pre-intervention and post-intervention MPQ scores. Like any other experimental research, the current study assumed that all other variables remained constant for both groups during the course of mathematics interventions using WIM. Since MPQs were limited in the number of questions in each category, it was difficult to draw conclusions about the effectiveness of learning mathematics using WIM on pre-service teachers' mathematics knowledge as far as the question categories were concerned.

7.6 Possibilities for future research

Why was there a statistically significant difference in achievement between male and female pre-service teachers from the pre-intervention and post-intervention results? Why mathematics proficiency (knowledge) of female pre-service teachers was greatly improved compared to that of male pre-service teachers? Is the use of WIM in educational environments gender biased? This could be a significant area of research for future studies as it could provide information for those interested in the use of WIM technology in educational environments.

Again, future research could focus solely on two or three content domains and investigate how the use of WIM has either improved or constrained mathematics proficiency of participants in those content domains. Further, the impact of WIM interactions on relations of power in mathematics classrooms is another area that future studies could investigate.

7.7 Conclusion

This research study focused on exploring the potential use of WhatsApp instant messaging (WIM) in improving pre-service teachers' knowledge of mathematics and also in increasing participation of pre-service teachers in mathematics activities. While increased students' participation in mathematics learning does not guarantee a high pass rate, it can make a significant contribution to effective mathematics learning among students. The quantitative results revealed that WhatsApp instant messaging improved pre-service teachers' mathematics knowledge since there was a moderate correlation (0.328) in the scores of pre-service teachers who participated in the programme and the scores of those who did not participate.

The qualitative results suggest that academic appropriation of WhatsApp instant messaging in mathematics teaching and learning has improved pre-service teachers' participation through the following pedagogical means: collaborative mathematics learning, anonymous mathematics learning, ubiquitous mathematics learning and synchronous and asynchronous mathematics learning. Based on both quantitative and qualitative results, it can be concluded that WhatsApp instant messaging has successfully increased participation of pre-service teachers in mathematics teaching and learning which in turn, improved their knowledge of mathematics, hence fulfilling the aims and objectives of the current study.

Finally, these findings concern the introduction of a new form of mathematics teaching and learning in a technology-mediated environment. Mathematics learning itself has become more than an individual activity, as supported by the evidence of collaborative learning evidenced in this study. The study has also broken the traditional face-to-face classroom boundaries in mathematics teaching and learning by promoting ubiquitous mathematics learning. Moreover, WIM peer mentoring was reported to be one of the factors that enhanced participation among participants. However, this type of pedagogical strategy does not only promote participation in mathematics activities, but it also makes use of social constructivism to enable effective mathematics learning.

REFERENCES

Adams, T. L. (2008). Prospective elementary teachers' mathematics subject matter knowledge: The real number system. *Action in Teacher Education*, *20*(2), 35-48.

Adler, J., Ball, D., Krainer, K., Lin, F., & Novotna, L. (2006). Reflections on an emerging field: Researching mathematics teacher education. *Educational Studies in Mathematics,* 60, 4-9.

Ander, K., & Leinhardt, J.T. (2006). *Mathematics activities for elementary school teachers: A problem-solving approach* (6th Ed.). Boston: Pearson Addison-Wesley.

Ahn, S., & Choi, J. (2008). *Teachers' subject matter knowledge as a teacher qualification: A synthesis of the quantitative literature on students' mathematics achievement*. Paper presented at the Annual Conference of the American Educational Research Association, San Diego, CA.

Amry, A. B., (2014). The impact of WhatsApp mobile social learning on the achievement and attitudes of female students compared with face-to-face learning in the classroom. *European Scientific Journal, 22*(10), 116-136.

Attewell, J. (2004). *Mobile technologies and learning.* London: Learning and Skills Development Agency.

Ball, D. L. (2009). *Unknown title*. Paper presented at Learning Network Conference, Washington DC on 16th of October, 2009.

Ball, D.L., & Bass, M. (2000). Interweaving content and pedagogy in teaching and learning to teach: Knowing and using mathematics. In J. Boaler (Ed.), *Multiple perspectives on mathematics teaching and learning* (pp.83-104). Westport, CT: Ablex Publishing.

Ball, D.L., Thames, M.H. & Phelps, G. (2005). Content knowledge for teaching: What makes it special? *Journal of Teacher Education, 59*, 389-407.

Ball, D. L., & Wilson, S. M. (2009). *Knowing the subject and learning to teach it: Examining assumptions about becoming a mathematics teacher* (Research Report 90-7). East Lansing, MI: Michigan State University, NCRTE.

Barab, S., Hay, K., & Yamagata-Lynch, L. (2001). Constructing networks of action- relevant episodes: An in situ research methodology. *The Journal of the Learning Sciences*, *10*(1&2), 63-112.

Barnes, H. (2005). Realistic mathematics education: Eliciting alternative mathematical conceptions of learners. *African Journal of Research in SMT Education, 8*(1), 53-64.

Bass, M., Blume, L., & Common, B. (1996). Teacher beliefs and the reform movement in mathematics education. *Phi Delta Kappan, 75*(6), 462-470.

Benken, B.M. & Brown, N. (2008). Integrating teacher candidates' conceptions of mathematics teaching and learning: A cross university collaboration. *The Journal of Higher Education*, *6*(4), 132-1145.

Bere, A. (2012). *A comparative study of student experiences of ubiquitous learning via mobile devices and learner management systems at a South African university.* Paper presented at the 14th Annual Conference on World Wide Web Applications in November 2012, Durban, South Africa.

Biyela, K.B. (2012). *Professional training in mathematics education: A study of programmes, practices and prospects*. (Unpublished doctoral dissertation). University of Zululand, Zululand.

Blaikie, N. (2007). *Approaches to social inquiry*. Cambridge: Polity press.

Bødker, S. (1996). Applying activity theory to video analysis: how to make sense of video data in HCI. In B. Nardi (Ed.), *Context and Consciousness: Activity theory and human-computer interaction* (pp.147–174). Cambridge, MA: MIT Press.

Bouhnik, D., & Deshen, M. (2014). WhatsApp goes to school: Mobile instant messaging between teachers and students. *Journal of Information Technology Education: Research,* 13, 217-231.

Bryan, T. J. (1997). *The knowledge and beliefs of prospective secondary mathematics teachers: An analysis on five levels*. (Unpublished doctoral dissertation). University of Texas, Austin.

Bryman, A. (1988). Effective leadership in higher education: A literature review. *Studies in Higher Education, 32*, 693-710.

Bryman, A. (2008). *Social research methods* (3rd ed.). Oxford: Oxford University Press.

Campbell, D., & Stanley, J. (1963). *Experimental and Quasi-experimental designs for research.* Boston: Houghton Mifflin.

Carnoy, M., & Arends, F. (2014). Explaining mathematics achievement gains in Botswana and South Africa, *Prospects* (18 October 2012), 1-16. doi: 10.1007/s11125-0129246-6.

Chandler, D. (2009). *Semiotics for beginners*. Retrieved on 20th of October 2015 from http// www.aber.ac.uk/ media/ documents/ S4B/sem2-html.

Chipunza, P. R. C. (2013). *Using mobile devices to leverage student access to collaboratively-generated re-sources: A case of WhatsApp instant messaging at a South African university*. Paper presented at the International Conference on Advanced Information and Communication Technology for Education in Cape Town on the 25th of March, 2013.

Church, K., & de Oliveira, R. (2013). What's up with WhatsApp? Comparing mobile instant messaging behaviors with traditional SMS. *Proceedings of the 15th International Conference on Human-computer Interaction with Mobile Devices and Services* (pp. 352-361). ACM.

Cohavi, A. (2013). *How did WhatsApp became the strongest social network?* Calcalist. Retrieved on 09th of March, 2015 from http://www.calcalist.co.il/local/articles/0,7340,L-3593840,00.html.

Colella, V. (2000). Participatory simulations: building collaborative understanding through immersive dynamic modelling. *Journal of the Learning Sciences, 9*(4), 471-500.

Conference Board of the Mathematical Sciences. (2007). *The mathematical education of teachers.* Retrieved on 17th of April, 2015 from http://www.cbmsweb.org/METDocument/index.htm.

Coyle, J., & Williams, B. (2000). An exploration of the epistemological intricacies of using qualitative data to develop a quantitative measure of user views of health care. *Journal of Advanced Nursing, 31*, 1235 – 1243.

Creswell, J.W. (2014). *Research design: Quantitative, qualitative and mixed methods approach*. Thousand Oaks, CA: Sage Publications.

Creswell, J.W., & Plano Clark, V.L. (2011). *Designing and conducting mixed methods research*. Thousand Oaks, CA: Sage.

Daniels, H., & Cole, T. (2002). The provision for development of young people with emotional and behavioural difficulties: Activity theory analysis. *Oxford Review of Education*, *28,* 311-329.

Denzin, N.K., & Lincoln, Y.S. (2011). *Strategies of qualitative inquiry*. Thousand Oaks: Sage.

Department of Basic Education. (2012). *National education policy act: The national policy framework for teacher education and development in South Africa*. Pretoria; Government Printer.

Department of Basic Education. (2014). *National strategy for mathematics, science and technology education: Creating tomorrow's stars today*: *Implementation plan 2015-20120*. Pretoria: Government Printer.

DeVries, R. (2000). Vygotsky, Piaget, and education: A reciprocal assimilation of theories and educational practices. *New Ideas in Psychology*, *18*, 187-213.

Dorfler, W. (2006). Mathematics and mathematics education content and people, relation and difference. *Educational Studies in Mathematics, 54*(2/3), 147-170.

Dwyer, D. (2008). Apple classrooms of tomorrow: What we've learned. *Education Leadership*, *1*, 4-7.

Eric, J. (2012). *Why selling WhatsApp to Facebook would be the biggest mistake of Jan Koum's and Brian Acton's lives*. Forbes magazine.

Engeström, Y. (1987). *Learning by expanding: An activity theoretical approach to developmental research*. Helsinki: Orienta-Konsultit Oy.

Engeström, Y. (1996). *Perspectives on activity theory*. Cambridge: Cambridge University Press.

Engeström, Y. (2001). Expansive learning at work: towards an activity theoretical reconceptualisation. *Journal of Education and Work,* 14, 133-156.

Ernest, P. (1994). *An introduction to the research methodology and paradigms*. RSU, School of education: University of Exeter.

Fennema, E., & Franke, M. (2009). Teachers' knowledge and its impact. In D.A.Grouws (Ed.) *Handbook of research on mathematics teaching and learning (pp55-78)*. New York: Macmillan.

Feuerstein, R., Rand, Y., Hoffman, M., & Miller, R. (1980). *Instrumental enrichment*. Baltimore, MD: University Park Press.

Field, P. A., & Morse, J. A. (1985). *Nursing research: The application of qualitative research*. London: Croom Helm.

Furner, J., & Robison, S. (2008). Using TIMSS to improve the undergraduate preparation of mathematics teachers. *The Journal of Issues in the Undergraduate Mathematics of School Teachers, 4,* 1-2.

Gates, P. (2001). Mathematics teacher belief systems: Exploring the social foundations. *Psychology of Mathematics Education (PME), 25*(3), 17-24.

Gelo, O., Braakmann, D., & Benetka, G. (2008). Quantitative and qualitative research: Beyond the debate. *Integrative Psychological and Behavioral Science, 42*, 266 – 290.

Goulding, M., Chiayang, C.D., & Miller, D, H. (2007). Pre-service elementary teachers' views of pedagogical and mathematical content knowledge. *Teaching and Teacher Education, 12,* 4-9.

Goulding, M., Rowland, T., & Barber, P. (2006). Does it matter? Primary teacher trainees' subject knowledge in mathematics. *British Educational Research Journal*, *28*(5), 689-704.

Graeber, A. O. (2007). Forms of knowing mathematics: What pre-service teachers should learn. *Educational Studies in Mathematics, 38,* 189-208.

Graneheim, U.H., & Lundman, B. (2008). Qualitative content analysis in nursing research: Concepts, procedures and measures to achieve trustworthiness. *Nurse Education Today, 24,* 105–112.

Greene, J. C., Caracelli, V. J., & Graham, W. F. (1989). Toward a conceptual framework for mixed-method evaluation designs. *Educational Evaluation and Policy Analysis, 11*, 255 – 274.

Greenwald, R., Hedges, L. V., & Laine, R. D. (2006). The effect of school resources on student achievement. *Review of Educational Research, 66,* 361-96.

Gutierrez, K., & Larson, J. (2007). Discussing expanded spaces for learning: Profiles and perspectives. *Language Arts, 85*, 69-77.

Hasan, H. (1998). Activity theory: A basis for the contextual study of information systems in organisations. In H. Hasan, E. Gould & P.N. Hyland (Eds.), *Information systems and activity theory: Tools in context*. Wollongong, Australia: University of Wollongong Press.

Hashim, N.H., & Jones, M.L. (2007). *Activity theory: A framework for qualitative analysis*. Paper presented at the Fourth International Qualitative Research Convention on the 10th of February, 2007 in California, USA.

Hardman, J. (2005). Activity theory as a framework for understanding teachers' perceptions of computer usage at a primary school level in South Africa. *Journal of Education, 25,* 258-265.

Heaton, R. (2010). *Teaching mathematics to the new standards: Relearning the dance*. New York: Teachers College Press.

Herzig, A. H. (2008). Becoming mathematicians: Women students of color choosing and leaving doctoral mathematics. *Review of educational research, 74*(2), 171-214.

Hettinga, M. (1998). Towards a theoretical foundation of EVOLVE. In P.N. Hyland (Ed.). *Report of an inventory of theories relevant for a conceptual model of evolving use of groupware* (pp. 1-43): Telematica Instituut.

Hill, H. C., & Ball, D. L. (2008). Learning mathematics for teaching: Results from California's mathematics professional development institutes. *Journal of Research in Mathematics Education*, 35(5), 330-51.

Hill, H.C., Rowan, B., & Ball, D.L. (2005). Effects of teachers' mathematical knowledge for teaching on student achievement. *American Educational Research Journal,* 42 (2), 371-406.

Hong, J., Yu, K., & Chen, M. (2011). Collaborative learning in technological project design. *Int J Technol Des Educ*, *21* (3), 335-347.

Hristovitch, S., & Mitcheltree, M. (2008). *Exploring middle school teachers' pedagogical content knowledge of fractions and decimals*. Paper presented at the Annual meeting of the North American Chapter of the International group for the Psychology of Mathematics Education*,* 21 October 2004.

Hron, A., & Frriedrich, H. F. (2008). A review of web-based collaborative learning: Factors beyond technology. *Journal of Computer Assisted Learning, 19* (1), 70-79.

Iqbal, M. J., Kousar, N., & Ajmal, M. (2011). Collaborative learning: Myth for distance learning? *International Journal of Academic Research, 3* (4), 604-608.

Jaworski, B., & Gellert, U. (2003). Educating new mathematics teachers. In A. Bishop, M.Clements, C. Kietel, J. Kilpatrick, & F. Leung (Eds.), *Second international handbook of mathematics education*, (pp. 823-876). The Netherlands: Kluwer Academic Publishers.

Johnson, R.B., & Onwuegbuzie, A.J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational Researcher*, *33*(7), 14-26.

Johnson, R. B., & Turner, L. A. (2003). Data collection strategies in mixed methods. In A. Tashakkori, & C. Teddlie (Eds.), *Handbook of mixed methods in the social and behavioral research* (pp. 297-319). Thousand Oaks, CA: Sage.

Kazima, M. (2008). Mother tongue policies and mathematical terminology in the teaching of mathematics. *Pythagoras, 67,* 56-63.

Keegan, D. (2010). *The incorporation of mobile learning into mainstream education and training*. Paper Presented at the World Conference on Mobile Learning, Cape Town, South Africa.

Keijzer, D., & Terwel, J. (2007). Audrey's acquisition of fractions: A case study into the learning of formal mathematics. *Educational Studies in Mathematics,* 47 (1), 53-73.

Kilpatrick, Swafford & Findell (Eds.). (2011). *Adding it up: Helping children learn mathematics*. Washington, DC: National Academy Press.

Kozulin, A. (2003). *Psychological tools: A sociocultural approach to education*. Cambridge, MA: Harvard University Press.

Kuutti, K. (1996). Activity theory as a potential framework for human–computer interaction research. In B.A. Nardi (Ed.), *Context and consciousness: Activity theory and human–computer interaction* (pp.17–44). Cambridge, MA: MIT press.

Kyle, J. (2008). Key aspects of teaching and learning in mathematics and statistics. In H. Fry, S. Ketteridge & S. Marshall (Eds.). A *handbook for teaching and learning in higher education: Enhancing academic practice*, (pp. 413-431). Oxford: Blackwell Publishers.

Lauricella, S., & Robin, K. (2013). Exploring the use of text and instant messaging in higher education classrooms. *Research in Learning Technology, 21*(40), 142-175.

Leedy, P.D., & Ormrod, J.E. (2013). *Practical research: Planning and design* (10th ed.). Upper Saddle River, New Jersey: Pearson Education.

Lee, J., Meadows, M., & Lee, J. (2006). *What causes teachers to implement high-quality mathematics education more frequently: Focusing on teachers' pedagogical content knowledge*. Phoenix, AZ: ERIC Document Reproduction Service No. ED 472 327.

Leinhardt, J.T., Ma, L., Simon, R., Smith, T., & Tompson, L. (2002). *Mathematics for elementary teachers: A contemporary approach (*7th ed.). Hoboken, N.J: John Wiley & Sons, Inc.

Leitzel, J. R. (Ed.). (1991). *A call for change: Recommendations for the mathematical preparation of teachers of mathematics.* Washington, DC: Mathematical Association of America.

Leont'ev, A.N. (1981). The problem of activity in psychology. In: JV Wertsch (Ed.). *The concept of activity in Soviet psychology (pp. 16-32)*. Armonk, NY: ME Sharpe.

Lerman, S. (2010). The social turn in mathematics education research. In J. Boaler, (Ed.). *Multiple perspectives on mathematics teaching and learning* (pp. 19-44), London: Ablex Publishing.

Lincoln, Y. S., Lynham, S. A. & Guba, E.G. (2011). Paradigmatic controversies, contradictions and emerging confluences revisited. In N.K. Denzin & Y.S. Lincoln. *The SAGE handbook of qualitative research* (4th ed.) (pp.97-128). Thousand Oaks, CA: Sage.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Beverly Hills, CA: Sage Publications.

Lott, J.W., & Souhrada, T.A. (2008). As the century unfolds: A perspective on secondary school mathematics content. In M. J. Burke & F.R. Curcio, (Eds.). *Learning mathematics for a new century (pp-87-92).* Reston, VA: NCTM.

Ma, L. (2009). *Knowing and teaching elementary mathematics: Teacher's understanding of fundamental mathematics in China and the United States.* Mahwah, NJ: Erlbaum.

Makgato, M., & Mji, A. (2006). Factors associated with high school learners' poor performance: A spotlight on mathematics and physical sciences. *South African Journal of Education*, *26*, 3-6.

Makoe, M. (2010). Exploring the use of Mxit: a cell-phone social network to facilitate learning in distance education, open learning. *The Journal of Open, Distance and e-Learning*, *25*, 2-7.

Mansfield, H. (1985). Points, lines, and their representations. *For the Learning of Mathematics*, *5*, 2-6.

Maschietto, M., & Bartolini Bussi, M.G. (2009). Working with artefacts: Gestures, drawings and speech in the construction of the mathematical meaning of the visual pyramid. *Educational Studies in Mathematics*, 70, 143-157.

Matthews, M., & Seaman, W. (2013). The effects of different undergraduate mathematics courses on the content knowledge and attitude towards mathematics of pre-service elementary teachers: Issues in undergraduate mathematics preparation of school teachers. *The Journal*, 1. Retrieved October 15th, 2014 from http://www.k-12prep.math.ttu.edu/.

McMillan, J.H., & Schumacher, S. (2010). *Research in education: Evidence-based inquiry*. Upper Saddle River, NJ: Pearson Education.

McMorris, L. E. (2002). *Under the influence: A case study of academic practice partnerships in tobacco prevention.* Austin, TX: University of Texas at Austin.

Mendick, H. (2010). A beautiful myth? The gendering of being/doing 'good at math'. *Gender and Education*, 17(2), 203-219.

Menon, R. (2009). Pre-service teachers' subject knowledge of mathematics. *International Journal for Mathematics Teaching and Learning.* Available at: http:// www. limit. plymouth.ac.uk / journal/ menon. Retrieved on 5th of December, 2014.

Mertens, D.M. (2009). *Transformative research and evaluation*. New York: The Guilford Press.

Methews, I., & Rech, D. (2010). Content knowledge transformation: An examination of the relationship between content knowledge and curricula. *Teaching and Teacher Education,* 11 (4), 389-401.

Minnie, R., & Paul, V.H. (1982). *Manual for the academic aptitude test (Standard 10) (AAT).* Human Science Research Council. Pretoria, South Africa: HSRC.

Monk, D. (2005). Subject area preparation of secondary mathematics and science teachers and student achievement. *Economics of Education Review*, *13*(2), 125-145.

Morf, E., & Weber, G. (2000). Psychology and the bridging potential of Leont'ev's activity theory. *The Journal of Educational Psychology, 14*(3), 152-154.

Morse, J. M., & Chung, S. E. (2003). Toward holism: The significance of methodological pluralism. *International Journal of Qualitative Methods, 2*(3), 1–12.

Motiwalla, L. (2014). Mobile learning: A framework and evaluation. *Computers & Education, 4,* 5-8.

Moustakas, C. E. (1994). *Phenomenological research methods*. Thousand Oaks, CA: Sage.

Naidoo, J. (2011). *Exploring master teachers' use of visuals as tools in mathematics classrooms*. (Unpublished doctoral dissertation). University of KwaZulu-Natal, Durban.

Nardi B (Ed.) (1996). *Context and consciousness: Activity theory and human-computer interaction*. Cambridge, MA: MIT Press.

Ng'ambi, D. (2011). Enhancing student interaction in didactic teaching approaches: the right to text during class. In *Proceedings of the 6th International Conference on e-Learning* (pp. 249–257), University of British Columbia, Kelowna, 27–28 June, 2011.

Nieman, M. (2006). Using the language of learning and teaching (LoLT) appropriately during mediation of learning. In Nieman, M., & Monyai, R. (Eds.). *The educator as mediator of learning (pp.122-175)*. Pretoria: Van Schaik Publishers.

O'Neill, S., Scott, M., & Conboy, K. (2011). A Delphi study on collaborative learning in distance education: The faculty perspective. *British Journal of Educational Technology*, *42,* 939-949.

Onwuegbuzie, A.J., & Leech, N.L. (2006). Linking research questions to mixed methods data analysis procedures. *The qualitative report, 11*(3), 474-498.

Opie, C. (2004). *Doing educational research: A guide to first time researchers*. London: Sage.

Otte, M. (2006). Mathematical epistemology from a peircean semiotic point of view. *Educational Studies in Mathematics, 61*(1/2), 11-38.

Patton, M. Q. (2010). Patton, M. Q. (2002). *Qualitative research and evaluation methods: Qualitative research* (3rd ed.). Thousand Oaks, CA: Sage.

Pickreign, J. (2014). Rectangles and rhombi: How well do pre-service teachers know them? *Issues in the Undergraduate Mathematics Preparation of School Teachers*, 1. Retrieved May 12th, 2015 from http://www.k-12prep.math.ttu.edu/.

Polit, D.F., & Hungler, B.P. (2009). *Nursing research: Principles and methods*. New York: J.B. Lippincott Company.

Pournara, C. (2005). *The glass is half-full: Rising to the challenge of pre-service mathematics teacher education in South Africa.* Paper presented at the 15th ICMI study conference in the professional education and development of teachers of mathematics. Johannesburg, South Africa: University of Witwatersrand.

Putnam, H. (1990). *Realism with a human face*. Cambridge, MA: Harvard University Press.

Putnam, R.T., & Borko, H. (2010). What do new views of knowledge and thinking have to say about research on teacher learning? *Educational Researcher, 29*(1), 4-15.

Quinn, J. R. (2007). Effects of mathematics methods courses on the mathematical attitudes and content knowledge of pre-service teachers. *The Journal of Educational Research*, *91*(2), 108-113.

Rajkumar, S. (2005). *Activity theory*. Retrieved on the 12th February 2015 from http:// www.mcs.open.ac.uk/yr258./act theory/.

Rambe, P. (2009). *The impact of using social networking sites on academic relations and student learning in university setting*. (Unpublished doctoral dissertation). University of Cape Town, Cape Town.

Rambe, P., & Bere, A. (2013). *An M-Learning Strategy for leveraging learner participation: Using WhatsApp Mobile messaging at a South African University of Technology*. Paper presented at

Southern African Computer Science Lecturers' Association Conference (SACLA) (pp. 29-36), Black Mountain Leisure & Conference Hotel, Thaba-Nchu, outside Bloemfontein, July 2012.

Rambe, P., & Chipunza, C. (2013). Using mobile devices to leverage student access to collaboratively-generated re-sources: A case of WhatsApp instant messaging at a South African University. *International Conference on Advanced Information and Communication Technology for Education (ICAICTE 2013*), 4 (2), 23-34.

Rech, L., Hartzell, K., & Stephens, P. (2009). Comparisons of mathematical competencies and attitudes of elementary education majors with established norms of a general college population. *School Science and Mathematics, 93*(3), 36-67.

Reddy, V. (2012). *Mathematics and science achievement at South African schools in TIMSS 2011*. Pretoria, South Africa: HSRC Press.

Reichardt, C.S., & Rallis, T. D. (1994). Beyond qualitative versus quantitative methods. In T. D. Cook & C. S. Reichardt (Eds.), *Qualitative and quantitative methods in evaluation research* (pp. 7-32). Beverly Hills, CA: Sage.

Remillard, J.T. (2005). Examining key concepts in research on teachers' use of mathematics curricula. *Review of Educational Research,* 75(2), 211-246.

Reyes, L. H., & Stanic, G.M.A. (2008). Race, sex, socio-economic status and mathematics. *Journal for Research in Mathematics Education, 19*(1), 26-43.

Rine, S. (2008). The role of research and teachers' knowledge base in professional development. *Educational Researcher, 27*(5), 27-31.

Roberts, N., & Vänskä, R. (2011). Challenging assumptions: Mobile learning for mathematics project in South Africa. *Distance Education, 32*(2), 243–259.

Rohrer-Murphy, L., & Jonassen, D.H. (1999). Activity theory as a framework for designing constructivist learning environments. *ETR&D, 47*, 61–79.

Roodt, J., & Conradie, P. (2006). Creating a learning culture in rural schools via educational satellite television broadcasts. *Communicatio, 29*(1/2), 265-279.

Roschelle, J. (2010). Keynote paper: unlocking the learning value of wireless mobile devices. *Journal of Computer Assisted Learning, 19*(3), 260-272.

Roth, W. (2007). The ethico-moral nature of identity: Prolegomena to development of third-generation cultural-historical activity theory. *International Journal of Educational Research, 46,* 7-9.

Roth, W.M., & Lee, Y.J. (2004). Interpreting unfamiliar graphs: Generating activity theoretic model. *Educational Studies in Mathematics, 57,* 264-290.

Roth, W., & Lee, Y. (2006). Vygotsky's neglected legacy: Cultural-historical activity theory. *Review of Educational Research*, *77*(2), 186-232.

Rowan, S. (2005). The mathematical understanding that prospective teachers bring to teacher education. *The Elementary School Journal, 90* (4), 56-87.

Rowan, B., Chiang, F.S., & Miller, R. J. (2007). Using research on employees' performance to study the effects of teachers on students' achievement. *Sociology of Education, 70*(4), 256-284.

Rowan, B., Correnti, R., & Miller, R. J. (2006). *What large-scale survey research tells us about teacher effects on student achievement: Insights from the prospects study of elementary schools*. Philadelphia, PA: Consortium for Policy Research in Education, University of Pennsylvania.

Rowland T.S., Martyn S., Barber P., & Heal, C. (2008). Primary teacher trainees' mathematics subject knowledge and classroom performance. *Research in Mathematics Education, 2*(3), 1-18.

Russell, D., & Schneiderheinze, A. (2005). Understanding innovation in education using activity theory. *Educational Technology & Society, 8*, 38-53.

Salmon, G. (2000). *E-moderating.* Rotterdam: Kogan Page.

Samson, D. (2007). Patterns of visualisation. *Learning and Teaching Mathematics, 5*, 4-9.

Schmidt, W. (2006). The benefit to subject-matter knowledge. *American Educator, 26,* (2), 18-22.

Schoenfeld, A. H., & Kilpatrick, J. (2008). Toward a theory of proficiency in teaching mathematics. In D. Tirosh & T. Wood (Eds.), *The international handbook of mathematics teacher education: Tools and processes in mathematics teacher education (pp. 39-63)*. Rotterdam: Sense Publishers.

Schulze, S. (2003). Views of the combination of quantitative and qualitative research approaches. *Progression, 25*(2), 8-20.

Schunk, D.H. (2008). *Learning theories: An educational perspective.* Columbus, OH: Prentice-Hall.

Seaman, C.E., Szydlik, S.D., Szydlik, J.E., & Beam, J. E. (2006). A comparison of pre-service elementary teachers' beliefs about mathematics and teaching mathematics. *Journal of Science and mathematics*, *105*(4), 179-210.

Seidman, I. E. (1998). *Interviewing as qualitative research: A guide for researchers in education and the social sciences*. London: Teacher College Press.

Setati, M. (2006). *Access to mathematics versus access to the language of power*. Paper presented at the Psychology of Mathematics Education Conference on the 25th of April, 2006, Prague.

Shulman, L. (1986). Paradigms and research programs in the study of teaching: A contemporary perspective. In: M. Wittrock (Ed.). *Handbook of research on teaching (pp. 135-163).* New York: Macmillan.

Sieber, S. D. (1973). The integration of fieldwork and survey methods. *The American Journal of Sociology, 78*, 1335 – 1359.

Singleton, R., Straits, B., Straits, M., & McAllister, R. (1988). *Approaches to social research*. New York: Oxford University Press.

Slay, J. (2002). Human activity systems: A theoretical framework for designing learning for multicultural settings. *Educational Technology and Society, 5*(1), 1-9.

Soman, R. B. (2006). Educators' perceptions of quality assurance in education. (Unpublished doctoral dissertation). University of Zululand, KwaDlangezwa, Zululand.

Sotillo, S. (2012). *Using instant messaging for collaborative learning: A case study*. *Innovate.* Retrieved May 13, 2015, from *http://www.innovateonline.info/index.php? View= article&id=170*

Spaull, N. (2011). *A preliminary analysis of SACMEQ III South Africa*. Working Papers 11/11, Stellenbosch, South Africa: Stellenbosch University, Department of Economics.

Spector, P. (1981). *Research designs*. London: Sage Publications.

Stacey, H., Steinle, B., & Irwin, B. (2010). Pre-service teachers' knowledge of difficulties in decimal numeration. *Journal of Mathematics Teacher Education, 4*(3), 205-225.

Stanghellini, G. (2005). Schizophrenic consciousness, spiritual experience, and the borders between things, images and words. *Transcultural Psychiatry*, *42*(4), 610-629.

Stoddart, T., Connell, M., Stofflett, R., & Peck, D. (2013). Reconstructing elementary teacher candidates' understanding of mathematics and science content. *Teaching and Teacher Education*, *9,* 229-241.

Stylianou, D. A. (2006). On the interaction of visualisation and analysis: The negotiation of a visual representation in expert problem solving. *The Journal of Mathematical Behaviour,* 21, 3-17.

Swain, M., Brooks, L. (2002). Peer-peer dialogue as a means of second language learning. *Annual Review of Applied Linguistics, 22*, 171-185.

Sweeny, S. M. (2010). Writing for the instant messaging and text messaging generation: Using new literacies to support writing instruction. *Journal of Adolescent & Adult Literacy, 54*, 121-130.

Tachie, S.A., & Chireshe, R. (2013). High failure rate in mathematics examinations in rural secondary schools in Mthatha district, Eastern Cape: Learners' attributions. *Study Tribals*, *11*, 70-73.

Tanner, H., & Jones, S. (2010). Becoming a successful teacher of mathematics. London: Routledge Falmer Press.

Tashakkori, A., & Teddlie, C. (2003a). *Handbook of mixed methods in social and behavioral research*. Thousand Oaks, CA: Sage.

Teddie, C., & Tashakkori, A. (2010). *Foundations of mixed methods research: Integrating qualitative and quantitative approaches in the social and behavioural sciences*. California: Thousand Oaks, Sage.

Tella, A. (2008). Teacher variables as predictors of academic achievement of primary school pupils in mathematics. *International Electronic Journal of Elementary Education, 1*(1), 17-33.

Trochim, W.M. (2010). *Research methods knowledge base*. Cincinnati, OH: Atomic Dog Publisher.

Tsao, Y. (2012). The number sense of pre-service elementary school teachers. *College Student Journal*, *39*(4), 647-679.

Turnuklu, E.B., & Yesildere, S. (2007). The pedagogical content knowledge in mathematics: Pre-service primary mathematics teachers' perspectives in Turkey. IUMPST: *The journal.* Retrieved on the 13th of June 2015 from http://www.k-12prep.math.ttu.edu.

Tzuk, A. (2013). WhatsApp has 350 million active users a month. [In Hebrew] *Calcalist.* Retrieved on the 23rd of October, 2014 from http://www.calcalist.co.il/internet/articles/0,7340,L-3615097,00.html.

Uden, L. (2007). Activity theory for designing mobile learning. *International Journal of Mobile Learning and Organisation, 1*(1), 81-102.

Usiskin, Z. (2010). Why elementary algebra can, should and must be an eighth-grade course for average students. *Mathematics Teacher, 80*(25), 428-438.

Van der Berg, S., & Louw, M. (2011). *Lessons learnt from SACMEQII: South African student performance in regional context*. Stellenbosch South Africa: Stellenbosch Economic Working Papers 16/07.

Van Dooren, W., Verschaffel, L., & Onghena, P. (2002). The impact of pre-service teachers' content knowledge on their evaluation of students' strategies for solving arithmetic and algebra word problems. *Journal for Research in Mathematics Education*, *33*(5), 319-351.

Verenikina, I. (2001). Scaffolding numeracy: Pre-service teachers' perspectives: Paper presented at the identities, culture and learning spaces. *Proceedings of the 29th Conference of the Mathematics Education Research Group OF Australasia (MERGA), Adelaide*.

Vidich, A. J., & Shapiro, G. (1955). A comparison of participant observation and survey data. *American Sociological Review, 20*, 28–33.

Vygotsky, L.S. (1978). Mind in society: The development of higher psychological processes. In M. Cole, V. John-Steiner, S. Scribner, & E. Souberman (Eds. & Trans) (pp. 67-93). Cambridge, MA: Harvard University Press.

Vygotsky, L.S. (1997). *Educational psychology*. Boca Raton, FL: Ingram.

Waite, T. (2005). Activity theory. Retrieved 12th February 2014 from http// www.slis. Indiana.edu/ faculty/grogers/act theory2/.

Waldron, W. (2004). *An evaluation of the summer bridge program's delivery of mathematics instruction to career academy students: an urban school district's approach***.** (Unpublished doctoral Dissertation). Ohio State University, USA.

Webb, N. M., & Mastergeorge, A. (2003). Promoting effective helping behavior in peer directed group. *International Journal of Educational Research, 39* (1-2), 73-97.

Welder, R. M. (2007). *Pre-service elementary teachers' mathematical content knowledge for prerequisite algebra concepts*. (Unpublished doctoral dissertation). Montana State University, Montana.

WhatsApp. (2010, November). Retrieved from BlackBerry App World: BlackBerry App World. R.

Wilbourne, J.M., & Long, M. (2010). Secondary pre-service teachers' content knowledge for state assessment: Implications for mathematics education programs. *The Journal, 1*(12), 143-172.

Willis, J. (2007). *The foundations of qualitative research: Interpretative and critical approaches*. Thousand Oaks, CA: Sage.

Wilson, S., & Ball, D.L. (2002). Helping teachers meet the standards: New challenges for teacher educators. *Elementary School Journal, 97*(11), 121 – 138.

Wilson, S. M., Floden, R. E., & Ferrini-Mundy, J. (2001). *Teacher preparation research: Current knowledge, gaps, and recommendations*. East Lansing, MI: Center for the Study of Teaching and Policy, University of Washington.

Wilson, S. M., Shulman, L. S., & Richert, A. E. (1987). 150 different ways of knowing: Representation of knowledge in teaching. In J. Calderhead (Ed.). *Exploring teachers' thinking* (pp. 104-124). London: Cassell.

Wood, D, Bruner, J., & Ross, S. (1976). The role of tutoring in problem solving. *British Journal of Psychology, 66,* 181-191.

Yin. R. (2004). *Case study research: Design and methods*. New Delhi: Sage Publications.

Zevenberger, R. (2010). Language, social class and underachievement in school mathematics. In P. Gates (Ed.), *Issues in mathematics teaching.* (pp. 38-50). London: Routledge Falmer.

Zinchenko, V. (1996). Developing activity theory: The zone of proximal development and beyond. In Nardi, B. (Ed.). *Context and consciousness: Activity theory and human-computer interaction*. Cambridge, MA: MIT Press.

APPENDIX A: RESEARCH INSTRUMENTS

OBSERVATION SCHEDULE FOR MATHEMATICS INTERACTIONS ON WIM

DATE......................................	WHATSAPP GROUP: ....

THE SUBJECTS OF ACTIVITY

....

....

ACTIVITY OF INTEREST

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THE OBJECTS OF ACTIVITY

....

....

THE TOOLS USED FOR MEDIATING ACTIVITY

....

....

THE RULES FACILITATING INTERACTIONS OF SUBJECTS

....

....

THE OUTCOMES OF ACTIVITY

……

……

SOURCES OF CONTRADICTIONS IN ACTIVITY

……

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ANYTHING ELSE OBSERVED

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SEMI-STRUCTURED INTERVIEW SCHEDULE

Pseudonym:

Gender __________________ **Date** _______________

1. What kind of mobile learning technological devices are you currently using for learning in your academic programme?

	IPad	Tablet	Laptop	Desktop	Smartphone	Other
Y/N						

2. What functionalities or application programs does your mobile technological device support?

SMS	Email	WhatsApp	Internet	Facebook	Twitter	Skype	Other
Y/N							

3. Do you consider the portability of your device important for learning?

4. If yes, explain why?

5. Has your participation in WhatsApp instant messaging tutorial programme contributed to your mathematics learning?

6. If yes, can you explain how?

7. What kind of mathematical assistance did you receive on WhatsApp instant messaging?

8. Was it easy for you to access such information?

9. Did you find WhatsApp instant messaging suitable for mathematics learning?

10. Please elaborate on your answer to question 9 above.

11. What are your overall feelings on the use of WhatsApp instant messaging for mathematics learning?

12. Did your participation in mathematics tutoring programme using WhatsApp instant messaging enhance your motivation to learn mathematics?

13. If yes, explain how?

14. What ground rules were laid down for using WhatsApp instant messaging for mathematics learning and how did those rules assist in your mathematics learning?

15. Did you find WhatsApp instant messaging to enhance collaborative mathematics learning?

16. If yes, can you explain how?

17. Did you find WhatsApp instant messaging to be helpful in enhancing any time anywhere mathematics learning?

18. If yes, can you explain how?

19. Do you feel that WhatsApp instant messaging created conducive environment for you to take control of your mathematics learning?

20. If yes, can you explain how?

22. What were the challenges that you experienced during the course of your mathematics learning using WhatsApp instant messaging? And what is your suggestion?

23. What is your reflection of the whole project?

APPENDIX B: LETTERS AND CERTIFICATES

UNIVERSITY OF
KWAZULU-NATAL
INYUVESI
YAKWAZULU-NATALI

A request for students to participate in the research project.

My name is Kabelo Joseph Kopung. I am a Master of Education student in the Department of Science, Mathematics and Technology Education at the University of KwaZulu-Natal, Edgewood campus. The fundamental requirement of this degree is to conduct a research project and thereafter write a disseration. The topic of my study is: **Exploring the use of WhatsApp instant messaging as a platform for pre-service teachers' learning of mathematics.**

If you agree to particiapte in this project, please note that:

- ❖ You will respond to a mathematics proficiency questionnare.
- ❖ You will participate in mathematics tutoring prgramme using WhatsApp.
- ❖ Mathematics tutorials using WhatsApp will be observed.
- ❖ You will be interviewed on your experiences of using WhatsApp for mathematics learning.

CONFIDENTIALITY:

The data from this study will be kept as confidential as possible. No individual identities will be used in any reports or publications resulting from the study. All audiotapes, transcripts and summaries will be given codes and stored seperately from any names or direct identification of partcipants. Research information will be kept in locked files at all times. After the completion of the study and the transcription of data from the tapes, the audio tapes will be kept for a period of five years and thereafter be destroyed. You will receive a copy of the final transcript so that you can confirm that the transcrits reflect your exact views, if necessary suggest changes. Please note that your involvement in this project is purely for academic purpose and that there are no financial benefits involved. Also, note that your partcipation is voluntary therefore, you are at liberty to withdraw from the study at any stage.

If you have any further questions or quries about the study, please contact:

Mr. K.J. Kopung: 0730631365/kkopung@gmail.com

Dr. Jayaluxmi Naidoo: +27312601127/naidooj2@ukzn.ac.za

Ms. P. Ximba (HSREC Research Office): 0312603587/ximbap@ukzn.ac.za

DECLARATION

If you are willing to take part in the project, please indicate (by ticking as applicable) whether you are willing to allow the interview to be recorded by the following equipment or not:

EQUIPMENT	WILLING	NOT WILLING
Audio equipment		
Photographic equipment		
Video equipment		

I ……………………………………………………… (Full names of the participant) hereby confirm that I understand the contents of this document and the nature of the research project and I therefore consent to participating in the research project.

I understand that I am at liberty to withdraw from the project at any stage, should I desire so.

Signature of the participant   Date

……………………………   ………………………..

Signature of the parent/guardian (where a participant is a minor)   Date

…………………………...   ……………………….

G177 Ubophe Road
Ntuzuma
4359

29th April 2014

The Dean of the School of Education
Edgewood Campus
University of KwaZulu-Natal

Dear Sir!

Re: Application for permission to conduct a research project/Ethical clearance certificate.

My name is Kabelo Joseph Kopung. I am a master's degree student in education at the University of KwaZulu-Natal, Edgewood Campus. The tittle of my study is: **Exploring the use of WhatsApp instant messaging as a platform for pre-service teachers' learning of mathematics.** I intend to collect data for a period of six months from July to December 2014.

The study attempts to address the following critical research questions: How does the use of WhatsApp instant messaging as a platform for teaching and learning influence pre-service teachers' knowledge of mathematics? What are pre-service teachers' experiences of using WhatsApp instant messaging for mathematics learning? Why do pre-service teachers experience the learning of mathematics using WhatsApp instant messaging in the way that they do?

Based on the nature of these questions, I therefore ask permission to administer mathematics proficiency questionnaire to students registered for Mathematics 110 module, make observations of their mathematics interaction with the tutor using WhatsApp instant messaging and interview them following their participation in online mathematics tutoring programme.

I appreciate your cooperation and consideration in this regard.

Yours Sincerely

K.J Kopung (Mr.)
Cell phone: 0730631365
Email address: kkopung@gmail.com

My supervisor is Dr Jayaluxmi Naidoo who is located at the School of Education, Edgewood campus of the University of Kwa-Zulu Natal.

Contact details:

Email: naidooj2@ukzn.ac.za

Tel: +27312601127

DR. J. NAIDOO

You may also contact the Research Office through:

Ms P Ximba (HSREC Research Office).

Tel: 031 260 3587

Email: ximbap@ukzn.ac.za

DECLARATION

I ...PROF G H KAMWENDO... (Full names) hereby confirm that I understand the contents of this document and the nature of the research project and I therefore give my assent to the research project.

Signature .... Date ...12/06/2014...

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

19 June 2014

Mr Kabelo Joseph Kopung (213573605)
School of Education
Edgewood Campus

Protocol reference number: HSS/0260/014M
Project title: Exploring the use of whatsApp instant messaging as a platform for pre-service teachers learning of mathematics

Dear Mr Kopung,

Full Approval – Expedited Application

With regards to your response to our letter dated 06 May 2014, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol have been granted **FULL APPROVAL.**

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number.

PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

....

Dr Shenuka Singh (Chair)

/ms

Cc Supervisor: Dr Jaya Naidoo
cc Academic Leader Research: Professor P Morojele
cc School Administrator: Mr Thoba Mthembu

Humanities & Social Sciences Research Ethics Committee
Dr Shenuka Singh (Chair)
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15 Morris Place

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C: 082 926 5333
H: 031 206 1738

9th December 2015

TO WHOM IT MAY CONCERN

This is to record that I have carried out language editing of the article by KJ Kopung, entitled 'Exploring the use of WhatsApp instant messaging as a platform for pre-service teachers' learning of Mathematics; A mixed methods approach'.

Crispin Hemson

Crispin Hemson

EXPLORING THE USE OF WHATSAPP INSTANT MESSAGING AS A PLATFORM FOR PRE-SERVICE TEACHERS' LEARNING OF MATHEMATICS: A MIXED METHODS APPROACH.

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