UNIVERSITY OF EDUCATION, WINNEBA

THE USE OF SMARTPHONE MATHEMATICS APPLICATIONS AMONG PRE-SERVICE MATHEMATICS TEACHERS AT TEACHER UNIVERSITIES IN GHANA

ANTHONY GYIMAH

MASTER OF PHILOSOPHY

2019

UNIVERSITY OF EDUCATION, WINNEBA

THE USE OF SMARTPHONE MATHEMATICS APPLICATIONS AMONG PRE-SERVICE MATHEMATICS TEACHERS AT TEACHER UNIVERSITIES IN GHANA

ANTHONY GYIMAH

8150110022

A Thesis in the Department of Mathematics Education, Faculty of Science Education, submitted to the School of Graduate Studies in partial fulfilment

of the requirements for the award of the degree of
Master of Philosophy
(Mathematics Education)
in the University of Education, Winneba

JUNE, 2019

DECLARATION

STUDENT'S DECLARATION

I, ANTHONY GYIMAH, declare that this thesis, with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE: …………………………………...

DATE: ……………………………......................

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of thesis as laid down by the University of Education, Winneba.

NAME OF SUPERVISOR: JONES APAWU

Signature: …………………………………...

Date: ……………………………......................

DEDICATION

This thesis is dedicated to my mentor, Prof. Samuel Kwesi Asiedu-Addo for his support, encouragement and financial assistance that propelled me to pursue this postgraduate study.

ACKNOWLEDGEMENTS

First of all, I wish to thank my supervisor, Mr. Apawu Jones for his numerous insightful comments, encouragement which helped me improve the quality of the thesis and for his motivation and support. God richly bless you.

I also owe profound gratitude to Professor C. K. Assuah, Professor D. K. Mereku, Mr. Edward M. Ampiah, Mr. Robert Benjamin Armah, Ebenezer Pascal Ghunney, Benedict Peter Simpson and to all the Lecturers at the Mathematics Education Department, University of Education, Winneba (UEW) especially Professor C. A. Okpoti, Dr. Gloria Armah, Dr. Peter Akayuure, Mr. Ali Mohammed, and Madam Akosua Owusu-Ansah for their valuable comments, encouragement and tremendous support which improved my thesis significantly.

The Pre-service Mathematics Teachers at the two major teacher universities in Ghana cannot be forgotten. Without their interest, fervent commitment, and involvement, this study would not have been possible.

My sincere thanks also go to my family and friends for their prayers and support to make this work a success. Thank you all.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The purpose of the study was to find out the use of Smartphone Mathematics Applications (SMAs) among Pre-Service Mathematics Teachers (PMTs) in learning Mathematics at teacher universities in Ghana. It further investigated the factors that influence PMTs' use of SMAs in learning mathematics and their perceptions about the use of SMAs in learning mathematics. The study utilized a cross-sectional survey design. The targeted population for the study was made up of 1,840 PMTs at the two teacher universities in Ghana. Purposive sampling was used to select the two teacher universities in Ghana and PMTs owning mobile phones. Moreover, a stratified sampling technique was employed to select a PMTs for the study. The sample comprised of 320 PMTs, 160 from Teacher University A and the other 160 from Teacher University B. The instrument employed in this study was a questionnaire. The results indicated that GeoGebra among other types of SMAs was commonly used among most of the PMTs in learning mathematics and could be effective when integrated in learning mathematics. However, the PMTs perceived that the use of SMAs fascinate and make learning of mathematics more interesting and also enable the accomplishment of mathematics tasks more easily and faster. Furthermore, the PMTs have positive perceptions about the use of SMAs in learning mathematics. Results from the Ordinal Logistics Regression Model (OLRM) revealed that among other factors, awareness of the various SMAs influence PMTs' use of SMAs in learning mathematics. Based on the findings, recommendations were consequently made.

CHAPTER 1

INTRODUCTION

1.0 Overview

This chapter presents the background to the study, statement of the problem, the purpose of the study, objectives of the study, research questions, significance of the study, delimitations, limitations of the study, the operational definition of terms, and organization of the study.

1.1 Background to the Study

Over the past two decades, technology devices have become mobile portable to the point that they have become pervasive in everyday life. The evolution of handheld portable devices and wireless technologies have transformed the social and economic lifestyles of modern people (Vyas & Nirban, 2014). According to Cumaoğlu (2015), mobile devices are among the most commonly used and observable technologies of the modern day. Today, many technological devices such as the mobile phones are produced in portable form and people have become accustomed to them. These devices are reshaping user behaviour in daily lives in different ways. With the growing portability and functional convergence of technologies, as well as with cost reduction of products and services, mobile devices are increasingly present in everyday life. Today, mobile phones have become an almost essential part of daily life since their rapid growth in popularity in the late 1990s (Ling, 2004) and are very popular among young people and in our educational institutions (Haruna, Muhammed, Umaru & Ahmed, 2016). The use of these mobile devices has become common among a wide range of age groups due to affordability and availability (Newhouse, Williams, & Pearson, 2006). A study by Meek (2006) as cited in Haruna, et al. (2016) revealed that mobile phone is popular since the late 1990s and today, they are highly used all over the world with over 7 billion mobile connections worldwide and unique mobile subscriptions of over 3.5 billion (Twum, 2011). For instance, in Hong Kong, the mobile phone penetration rate is 98.2% as of August 2003, and analysts predict that by the end of 2004, every Hong Kong person will own one mobile phone on the average (Wong & Csete, 2004). However, in Ghana, according to a report released by Ghana's telecommunications regulator, National Communication Authority (NCA), mobile phone users rose from 25.62 million in 2013 to 26.09 million at the end of January 2014 (NCA, 2014). In 2018, a report stated again by National Communication Authority (NCA) indicates that in Ghana, as at 2018, 29 million Ghanaians use about 34 million mobile phones (NCA, 2018). This indicates how mobile phones have become popular and an essential part of our daily lives especially in Ghana.

Mobile phones are the most necessary medium of communication for adolescents and are very popular with young people and are common in our educational institutions (Haruna, et al., 2016). The earliest generation of mobile phones released to the public in 1982 could only make and receive calls. However, today's mobile phones known as Smartphones are packed with many additional features, such as web browsers, games, cameras, video players and even navigational systems. They could perform functions like the computer, typically having a touchscreen interface, internet access, allow users to access email and an operating system capable of running downloaded and installed applications due to the availability of various easy-to-use mobile applications (Johnson, Levine, Smith, & Stone, 2010). The smartphone ownership rate has been gaining popularity vastly and are prevalent globally in recent years. For example, in Netherlands, a statistical press released by Central Bureau of Statistics in June 28, 2013, revealed that the rate of smartphone ownership was around 70% in the general population. In Switzerland, the rate in adolescents increased from around 50% to nearly

80% from 2010 to 2012 (Willemse, Waller, Süss, Genner, & Huber, 2012). Also, in the United States, the rate in the general population increased from 35% to 56% from 2011 to 2013 (Smith, 2013). Thus, nearly three-quarters of teenagers in the United States have access to a smartphone (Lenhart, 2015). In Asia, the smartphone ownership rate among adolescents is around 85%; in South Korea, around 65%; in Japan and the Philippines, over 55%; and in China over 40% (Mak, Lai, Watanabe, Kim, Bahar, & Ramos, 2014). In Ghana, smartphones such as iPhones (Apple), Blackberry, Android, Windows phones, among others are becoming increasingly popular especially among students.

Smartphones have capacious memories that help users to store huge amount of records digitally and are built on a mobile operating system that allows the user to perform functions like browsing the internet, sending and receiving emails, downloading music, reading and editing documents, using maps and satellite navigation and so on (Boulos, Wheeler, Tavares, & Jones, 2011). They could be used to download and transfer documents easily as well as make teaching and learning more fun and interactive in the classroom as they share ideas (Avugbey, 2013). Also, the features in mobile phones help to integrate third-party applications known as 'apps' which are now being used in a wide number of sectors such as business, travelling, lodging, education, media, medical and health fitness and many more (Shah, Haq, Bashir, & Shah, 2016). These mobile applications have revolutionised the mathematics field by integrating the mathematics tools with these mobile phones. By the end of 2012, there were over 75,000 mathematics applications for the Android and iPhone market (Ensley & Kaskosz, 2012).

Some of the Smartphone Mathematics Applications (SMAs) which have been developed for learning as well as teaching mathematics include Math4Mobile, Mathway, Photomath, Symbolab, Math Tricks, Mathematics Dictionary, Mathematics *fx*, Malmath, Limits-step-by-step, All-in-One Calculator, Math Expert, Graphing Calculator or Algeo Graphing Calculator, iMathematics, GeoGebra, Geometry Pad, FreeGeo Mathematica, Wolfram Alpha, Scientific Calculator, MATLAB, Math Ref, etc. These Smartphone Mathematics Applications give students the opportunity to explore new way of learning mathematics and can be used in the classrooms to promote effective teaching and learning interaction. Thus, these applications can be integrated into the educational curriculum for successful teaching and learning and could students to learn on their own and also interact with the global community on the various social networking sites such as Facebook, Twitter, among others (Avugbey, 2013). However, despite the proposed advantages of using smartphones for increasing computer accessibility, diverse teaching styles, and academic performance, researchers have found different results regarding the effects of mobile devices. For instance, Warschauer, Zheng, Niiya, Cotten, and Farkas (2014), have addressed effectiveness of using such devices. As a result, it must be available to students in the classroom because every student considers mobile phone as a part of the after-school activities, but students have restricted access to mobile phones because school managers and teachers do not encourage their students to use mobile phones during classroom instruction (Dounay, 2004). A report issued in the Daily Graphic on August 23, 2017, by an educationist and Founder of Gifted and Talented Education (GATE), Mr. Anis Haffar, at the fifth quadrennial regional delegates conference of the Greater Accra branch of the Ghana National Association of Teachers (GNAT), advocated the use of mobile phones by students, stressing that it was a backward tendency for students to be restricted from using smartphones in a world that was dominated by technology. According to Haffar (2017), there was the urgent need for holistic structures to be put in place by policy makers in education to allow mobile phones to be efficiently used by students because smartphones can provide more information for students than any teacher can. Teachers themselves need to be taught to use smartphones so that they can, in turn, use them to teach students appropriately and take away the monotony of teachers always being at the center of the learning process (Haffar, 2017).

Integrating Smartphone Mathematics Applications in mathematics education will have the potential to change pedagogical approaches and improve students' learning outcome by transforming the classroom social practices (Lam & Duan, 2012). Students have positive emotions and different learning roles, from which they can choose their own when they have the opportunity to explore more with Smartphone Mathematics Applications (Daher, 2011).

However, today's mobile technology has provided flexibilities for teachers and students to engage in academic discourse irrespective of their location (Kolog, Tweneboah, Devine & Adusei, 2018). While many countries have accepted to incorporate the use mobile devices in schools for learning, others like Ghana are reluctant to pay attention to use mobile devices in education. This is because many scholars and stakeholders of education hold different perspectives on the use mobile devices in schools. For several years, this has been the subject of debate without much empirical studies to ascertain the rationale of this decision. The ongoing debate on this subject is centered on whether the use of mobile device usage in school influences students' academic engagement and performance. Following this debate, we empirically sought to find out the use of

Smartphone Mathematics Applications (SMAs) among Pre-service Mathematics Teachers (PMTs) in learning mathematics at teacher universities in Ghana.

1.2 Statement of the Problem

There has been a growing concern about the use of technology to support teaching and learning in educational institutions in Ghana. According to Agyeman and Mereku (2015), the call to integrate ICTs tools in education has become a major concern to Education stakeholders and policymakers across the world. These could be as a result from the lack of ICT tools in our schools especially those in the rural areas. Meanwhile, there is evidence according to a 2013 United Nations Educational, Scientific and Cultural Organization (UNESCO) report that many students in Ghana even in impoverished areas, can afford and know how to use mobile devices and are commonly found nowadays even in areas where computers are scarce due to the fall in prices of these mobile devices (UNESCO, 2013). In an attempt to find viable solutions to these problems, much hope has been placed in new technologies such as mobile phones. It is believed that technology can empower teachers and learners by facilitating communication and interaction, offering new modes of delivery, and generally transform teaching and learning processes (Valk, Rashid, & Elder, 2010).

According to Moursund and Bielefeldt, (1999), most teachers neither use technology as learning tool nor integrate mobile technology into the delivery system in their field of work because these teachers develop their career with little or no ideas about how the use of mobile technology can support their teaching and learning interactions (Moursund & Bielefeldt, 1999). Mobile technology is a suitable tool for advancing education and can act as a supplement to computers in our education system in providing tools for teaching and learning purposes. Integration of mobile technologies such as Smartphone Mathematics Applications have the potential to make learning effective and interesting towards improving student learning outcomes and could provide opportunities for students to develop skills that will empower them in this modern society (Haffar, 2017).

Despite, the advantages of mobile technology especially in mathematics, the literature on mobile phone use in education today have not been given much attention as a new phenomenon for ICT in education (Madden, 2010). Likewise, in Ghana, the literature appears to suggest that there has been little or no investigation involving the use of mobile technologies for educational purposes (Intsiful, Okyere, & Osae, 2003). Mereku, Yidana, Hodzi, Tete-Mensah, Tete-Mensah, and Williams (2009) asserted that for Ghana, and Africa as a whole, to be able to fully integrate ICT into teaching and learning there is the need for frequent collection and analysis of data on ICT usage. It was therefore essential to conduct an empirical study the use of Smartphone Mathematics Applications (SMAs) among Pre-Service Mathematics Teachers (PMTs) in learning Mathematics at teacher universities in Ghana. Besides, the researcher also intended to investigate the factors that influence PMTs' use of SMAs in learning mathematics and their perceptions about the use of SMAs in learning mathematics.

1.3 Purpose of the Study

The purpose of the study was to find out the use of Smartphone Mathematics Applications (SMAs) among Pre-Service Mathematics Teachers (PMTs) in learning Mathematics at teacher universities in Ghana. It further investigated the factors that influence PMTs' use of SMAs in learning mathematics and their perceptions about the use of SMAs in learning mathematics.

1.4 Objectives of the Study

This study was guided by the following objectives:

1. To find out the SMAs that are commonly used among the PMTs and could be effective when integrated in learning mathematics at teacher universities in Ghana.
2. To examine the perceptions of PMTs towards the use of SMAs in learning mathematics.
3. To investigate the factors (gender, age, academic level, type of smartphone, and awareness) that influence PMTs' use of SMAs in learning mathematics.

1.5 Research Questions

Based on the objectives stated, this study sought answers to the following research questions:

1. What SMAs are commonly used among the PMTs and could be effective when integrated in learning mathematics at teacher universities in Ghana?
2. What are the perceptions of PMTs towards the use of SMAs in learning mathematics?
3. Which factors (gender, age, academic level, type of smartphone, and awareness) influence PMTs' SMAs use learning mathematics?

In answering the third research question, the following hypotheses below was formulated for the study;

Null hypothesis: There is no significant relationship between the factors (gender, age, academic level, type of smartphone, and awareness) and PMTs' SMAs use learning mathematics.

Alternative hypothesis: There is no significant relationship between the factors (gender, age, academic level, type of smartphone, and awareness) and PMTs' SMAs use learning mathematics.

1.6 Significance of the Study

The findings from the study could:

- provide insights into PMTs use of SMAs in learning mathematics that could be sustainable and transferable to other educational institutions.
- could enable policy or decision makers and curriculum developers in education such as the National Council for Tertiary Education in structuring and introducing mobile technology integration policies in all teacher universities in Ghana.
- add to existing knowledge by providing new evidence about the factors that influence technology use in mathematics.
- benefit mathematics students especially PMTs by knowing the various SMAs that could be effective when integrated into the learning of mathematics.
- serve as a baseline documents for future studies in this area and could also make a significant contribution to existing literature.

1.7 Delimitation of the Study

The study was delimited to only two teacher universities in Ghana because of the fact that these were the only teacher universities with a special mandate to train graduate professional in mathematics to become first time professional teachers for all levels of education in Ghana. Moreover, for the purpose of the study, emphasis was laid on only PMTs using or owning mobile phones and the outcome might be different from participants in other teacher universities in Ghana.

1.8 Limitations of the Study

Among the teacher universities in Ghana, only two teacher universities were selected for this study and this has limited the scope of the research. The consequence of this was that, generalization of the research findings was limited. Also, a study of this kind should have covered a wide sampling of data, but due to time constraint and limited financial resources produce an obvious limitation. Therefore, the findings from this study place a limitation on the generalization that could be made on the findings of this study, and the findings are not transferable to other teacher universities in Ghana.

1.9 Operational Definition of Terms

Application Store (App Store): An app store (or app marketplace) is a type of digital distribution platform or online portal through which mobile software programs or mobile applications are made available for procurement and download.

Globalization: Globalization is a process of interaction and integration among the people, companies, and governments of different nations, a process driven by international trade and investment and aided by information technology.

Learning: Learning is the acquisition of knowledge or skills through study, experience, or being taught through a mobile technological device.

Mobile Learning: Mobile learning (m-learning) refers to learning through mobile computational such as Personal Digital Assistants (PDAs), Digital Cameras, Mobile Phones, Tablets, etc.

Mobile Phone: Mobile phone is a wireless handheld device that allows users to make calls and send text messages, among other features.

Mobile Technology: Mobile technology is the technology used for cellular communication.

Smartphones: Smartphones are mobile devices that are built on a mobile operating system that allows the user to perform functions like browse the internet, send and receive emails, download music and other applications, read and edit documents, use maps and satellite navigation and so on.

Smartphone Applications: A mobile app is a computer program designed to run on a mobile device such as smartphones, tablets, iPads, Personal Digital Assistants (PDAs), also known as a handheld Personal Computers (PC).

Smartphone Mathematics Application (SMAs): Smartphone Mathematics Applications or simply Mobile Maths Apps, are applications design for mathematics to assist users in performing single or various related tasks in mathematics.

Technology: Technology is the machinery and devices developed from scientific knowledge.

1.10 Organization of the Study

The study was organized systematically into five (5) different chapters. In Chapter 1, the background of the study, statement of the problem, purpose of the study, objectives of the study, research questions, significance of the study, delimitation, limitations of the study, operational definition of terms, and the organizational plan were presented. The theoretical framework and the review of related literature pertinent to the study were presented in Chapter 2. The researcher described the research design and methodology in Chapter 3. Chapter 4 presents the results and discussion of findings. Chapter 5 comprises a summary of key findings, conclusion, recommendations and areas for further research.

CHAPTER 2

LITERATURE REVIEW

2.0 Overview

This chapter is primarily focused on varied views on what other authors have written concerning the topic under study. The literature review was discussed under the following themes:

- Theoretical framework
- Mobile technology integration in Education
- SMAs that could be effective when integrated in learning mathematics
- Use of mobile technology in Education and its impact on students' performance
- Factors influencing the use of mobile technology in mathematics Education
- Perception of students towards the use of SMAs in learning mathematics
- Summary

2.1 Theoretical framework

Technology Acceptance Model (TAM) developed by Davis (1989) is one of the most popular research models to predict the use and acceptance of information systems and technology by individual users (Venkatesh, 2000). The model describes how users come to accept and use a technology. Thus, TAM models how users come to accept and use a new technology. Recently, TAM has become an important research model for assessing the factors of information technology acceptance and utilization among users and it was the most adopted model (Davis, 1989). However, Venkatesh (2000) was of the view that TAM is the most widely applied model of users' acceptance and usage of technology and is one of the most influential extensions of Fishbein and Ajzen's (1975) Theory of Reasoned Action (TRA) in the literature. According to Davis

(1989), when consumers or users are ready with a new software package, a number of factors influence their decision about how and when they will use it.

TAM has been identified as a factor that guides future behaviour and as an intentional cause that ultimately leads to a particular behaviour. According to Davis, Bagozzi, and Warshaw (1989) and Nov and Ye (2008), the model is a user's perceptions of a system's usefulness and ease-of-use that results in a behavioural intention to use (BIU), or not to use, the system. TAM has received empirical support for robustly predicting technology adoption in various contexts and with a variety of technologies (Gao, 2005; McKinnon & Igonor, 2008; Park, 2009; Sugar, Crawley, & Fine, 2004; Teo, 2009) as cited in (Ng, Shroff, & Lim, 2013). The model replaces many of TRA's attitude measures with the two technology acceptance measures, such as Perceived Usefulness (PU) and Perceived Ease of Use (PEU). TAM defines an individual adoption of information technology as dependent on their perceived usefulness (PU) and perceived ease of use (PEOU) of the technology. A number of external variables could affect PU and PEOU. The key factors in the Technology Acceptance Model are illustrated in Figure 1.

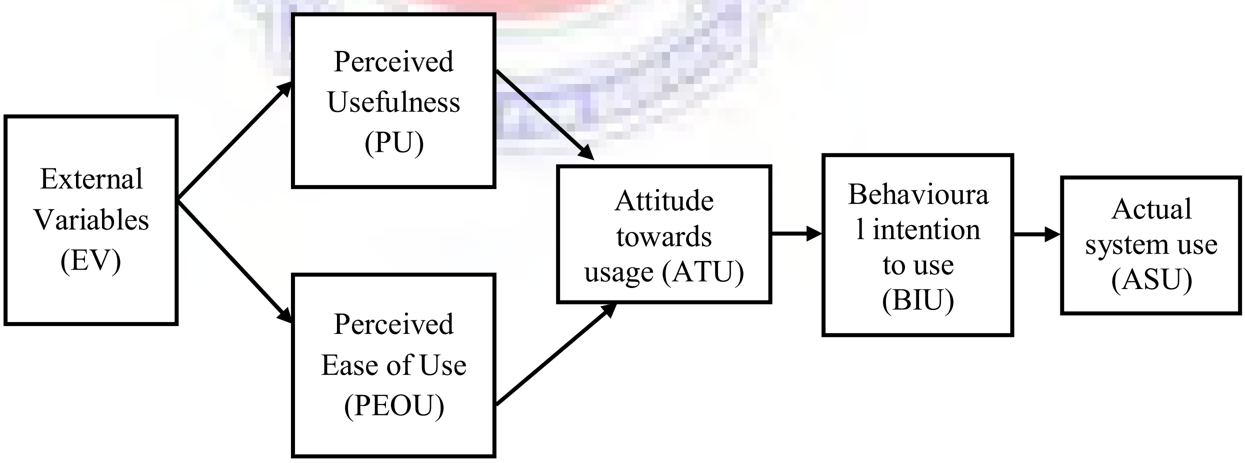

Figure 1: Technology Acceptance Model (TAM) (Source: Davis, 1989).

From Figure 1, the Actual System Use (ASU) is the end-point where we actually want everyone to be able to do with technology and its influenced by Behavioural Intention to Use (BIU), which refers to the individual's intention to perform a particular behaviour. And Behavioural Intention to Use (BIU), is influenced by the Attitude Towards Usage (ATU) which is the general impression of the technology. That is, ATU refers to individual's positive or negative evaluation of the behaviour. Based on the ATU, a number of factors influence their decision about how and when they will use the technology and these are their Perceived usefulness (PU) and Perceived Ease-Of-Use (PEOU). Perceived usefulness (PU) is defined as the degree to which a person believes that using a particular system would enhance his or her performance, whereas Perceived Ease-Of-Use (PEOU) is the degree to which a person believes that using a particular system would be easy to use. These two main factors are been influence by the External Variables (EV) such as a person's demographic variables like age, gender and so on. The PU and PEOU mediate the effect of external variables on user's attitude and behavioural intention, and therefore the actual system use. When all these things are in place, people will have the attitude and intention to use the technology.

According to TAM, a positive perception result leads to a positive attitude and good use of technology and vice versa. Positive perceptions of technology acceptance lead to positive attitudes towards technology use. Allport (1935) indicated that "an attitude is a mental and neural state of readiness, organized through experience, exerting a directive or dynamic influence upon the individual's response to all objects and situations with which it is related" (p. 810). Davis (1989) defined perceived usefulness as "the prospective user's subjective probability that using a specific application system will increase his or her job performance within an organizational context" (p. 985) and perceived ease of use as “the degree to which the prospective user expects the target system to be free of effort” (p. 985).

Davis (1989) posits that the attitude of an individual is not the only factor that determines his or her use of new technology but the impact the tool or system will have on his or her performance is also significant. According to Alrafi (2005), TAM helps to investigate or assess how potential users of a particular technology come to accept and use it. The model explains the causal relationships between system design features, perceived usefulness, perceived ease of use, attitude toward using, and actual usage behaviours. It is important for students to find new ways of using technology as a learning tool to improve learning outcome. Some researchers hold that technology acceptance is more complicated than initially supposed and have scrutinized other variables that stimulate acceptance (Taylor & Todd, 1995; Thompson, Compeau, & Higgins, 2006). These major premises have provided the technology acceptance stream well, perceived ease of use and perceived usefulness are not the only valid determinants related to technology adoption, particularly with newer technologies (Thompson, et al., 2006).

Several researchers have replicated Davis's original study (Davis, 1989) to provide empirical evidence on the relationships that exist between usefulness, ease of use and system use (Adams, Nelson, & Todd, 1992; Davis, 1989; Hendrickson, Massey, & Cronan, 1993; Segars & Grover, 1993; Subramanian, 1994; Szajna, 1994). Legris, Ingham, and Collerette (2003) suggest that TAM must be extended to include variables that account for change processes and that this could be achieved through adoption of the innovation model into TAM. On the contrary, other studies were also conducted by dropping a few factors from the original TAM (Wang, Lin, & Luarn, 2006; Zejno &

Islam, 2012). In view of this, the study adapted the Technology Acceptance Model (TAM) by dropping attitude towards usage (ATU) and actual system use (ASU) to find out PMTs intention or readiness to integrate the SMAs in learning mathematics where PMTs' perceptions is treated to be similar to behavioural intention to use.

2.2 Mobile Technology Integration in Education

The creation of mobile technology for educational instructions is on the ascendancy and currently influenced by many science and technology groups. On daily basis, several mobile technologies, portable and networked such as laptop computers, personal digital assistants (PDAs), tablets, personal computers (PCs), cell phones, and e-book readers are being gradually developed and frequently advertised on the internet to support learning. UNESCO (2013) acknowledged that mobile technologies are commonly found these days even in areas where schools, books, and computers are uncommon. This according to Newhouse et al. (2006) may be due to affordability and availability of such technologies as mobile phones in particular. Many people, even in deprived areas, can afford and know how to use mobile technologies.

Mobile technology has led to most people carrying their own individual small computers that contain exceptional computing power. This large amount of computing power and portability, combined with the wireless communication and context sensitivity tools, makes one-to-one computing a learning tool of great potential in both traditional classrooms and outdoor informal learning. The presence and relevance of such devices in everyday life have motivated research in the educational field. The popularization and development of mobile technologies have given prominence to these devices in formal education so far as teaching and learning are concerned (Buck, McInnis, & Randolph, 2013; Gibson, Taylor, Seymour, Smith, & Fries, 2012). Due to their popularity, mobile technologies can contribute to increasing access to digital educational content. As portable equipment, they can promote learning both inside and beyond the physical space of educational institutions (UNESCO, 2013). Use of such devices can also contribute to more attractive teaching and learning processes, thus catering, with their applications, to different learning styles (Buck, et al., 2013). Mobile technologies, therefore have the potential to make learning more accessible, collaborative and relevant (UNESCO, 2013).

Seabra (2013) recognised that mobile technologies such as mobile phones can be responsible for distractions and that they enable, with their embedded technology, transfer of answers in tests and examinations in more efficient ways than traditional ones. In the view of Machado (2012), ringtones in the classroom, with their variety of musical genres and styles may significantly disturb pedagogical activities as planned by the teacher. Machado (2012) is of the view that a silent practice, texting can also draw attention away from the lesson, as well as be used to send answers to tests or exams. In addition, use of mobile technologies to play games, music, videos, photos and access the internet may compromise student performance in class.

The use of mobile technology in education is, therefore, a complex theme which presents positive aspects and difficulties that must be taken into consideration. However, it is widely recognized in the literature that mobile technology support teaching and learning to a large extent. In terms of promoting innovation in education through information technology, not only does mobile technology support traditional lecture-style teaching, but it can also promote innovative teaching methods such as cooperative learning (Lan, Sung & Chang, 2007), exploratory learning outside the classroom (Liu, Lin, Tsai, & Paas, 2012), and game-based Learning (Klopfer, Sheldon, Perry, & Chen, 2012). Given the fact that teacher support and teacher training have been the least explored topics in mobile technology research (Ekanayake & Wishart, 2014) it is important to explore variables that can be manipulated for educational gains so far as mobile technology in education is concerned.

2.2.1 *The Emergence of Smartphones in Education*

Over the past decades, smartphones have become more advanced and pervasive in everyday life. This advancement and pervasiveness of smartphones have given them significant consideration in education. According to Okolie (2016), smartphones types such as Blackberries, iPhones, and Androids began to flood the market and educators (especially middle and high school teachers) attempted to discourage their students from using them in class as a result of a number of significant challenges. In as much as many studies show that smartphones are a distraction to college students and their use yields poorer results in the classroom, students are still going to be using their smartphones even if they might pose a challenge (Okolie, 2016). For example, a student could easily text a friend during a lesson or worse, students could access the internet during examination resulting in examination malpractice. However, due to the incredible adaptability and capabilities of smartphones currently, educators are beginning to emphasize their benefits and take steps to minimize their shortcomings (Hennessy, 2016).

After an exploratory research it was indicated by Batista (2011), that the use of smartphones in education, depends on: i) students' ability to use the keypad; ii) practicability; iii) the students' receptiveness regarding the educational use of mobile phones. The study also identifies these drawbacks: i) variety of models and resources in the phones; ii) size of the screen; iii) cost of internet access. These drawbacks are not exclusive to a specific area of the curriculum. Similarly, the potential of these devices is quite sufficient, as they support pedagogical actions in different areas.

With the advent of smartphones, researchers (Lam & Duan, 2012; Vavoula & Karagiannidis, 2005) have proposed their use for learning and also indicated the use of such devices in the learning process including stimulus, motivation, ease of use, availability, etc. In the view of Klopfer, Squire, and Jenkins (2002) smartphones are becoming highly valuable tools in the educational process because of their attractive features.

Mobile technologies such as smartphones play an increasingly prominent role in the lives of students worldwide. Shuler (2009) remarked that applications on smartphones have the potential to become the new means of providing educational content to students. As a result, various national ministries and schools are experimenting with the use of these popular devices for a wide range of alternative methods of teaching and learning objectives. According to Johnson, Smith, Willis, Levine, and Haywood (2011), smartphones and tablets are among the six new emerging technologies that may have a major impact on teaching, learning, and research in education.

2.2.2 *Readiness for the Integration of Smartphones in Education*

The readiness for integration of smartphone in education is highly dependent on the various perceptions that teachers and students have towards the use of mobile technologies in general. According to West (2012), teachers are vital in order to assemble an educational process that embraces mobile learning, which is required to effectively teach educators as well as recruit their own support. Also, educators play an important role in promoting quality education through mobile technology (Attewell, 2005; Daniel, 2008; Ferry, 2009). According to Yusof, Daniel, Low, and Aziz (2014), for adopting and implementing mobile learning, teachers' willingness and preparedness are a critical success factor. Ferry (2009) posited that teachers must have the need to establish a dissimilar and innovative set of skills and knowledge for applying this technology (mobile technology) in their classrooms. Mobile learning can facilitate improved interaction among teachers, administrators and students.

A study was conducted by, Uzunboylu and Ozdamli (2011) in Cyprus on teachers' perception of mobile learning and found that teachers showed above moderate levels of awareness of mobile learning. Kafyulilo (2012) also conducted a study in Tanzania to explore the access, practice and insights of teachers and students toward mobile phones as a device for facilitating teaching and learning beyond the classroom. From the findings, it is seen that all pre-service and in- service teachers, college instructors and students owned mobile phones. Recent research by Serin (2012) showed that prospective teachers' (teachers at a university in Turkish Republic of Northern Cyprus) mobile learning perception levels were low. The author also found misconception of the prospective teachers who claimed to have knowledge regarding mobile learning and also their wrong insight that effective communication environment will be continued by using mobile learning. It was determined that prospective teachers' mobile learning perception does not differ significantly (Serin, 2012).

In the United Kingdom, Wishart (2009) conducted a study on the use of Mobile Technology for teacher training which aimed at constructing mobile learning and mobile teaching aptitude, to facilitate school-based associate teachers to join the e-learning municipal interrelated to the indigenous initial teacher preparation course, and to inspire reflective training among trainee teachers. Mobile learning using a mobile device is still incomprehensible to the teachers and remains in an initial stage to them.

Mobile learning using smartphones is due to limited research on educators' concerns and preferences of utilizing the innovative mobile technologies in their teaching and learning (Ferry, 2009; Litchfield, Dyson, Lawrence, & Zmijewska, 2007). The objective of Litchfield et al. (2007) was to assess the lecturers' readiness of mobile learning in Saudi Arabian higher education in terms of perceived usefulness and perceived ease of use. Cruz, Assar, and Boughzala (2012) also investigated the usage and acceptance of mobile technologies by instructors in a business school in France. Furthermore, the authors claimed that they identified technological, institutional, pedagogical and individual obstacles that threaten Mobile learning practices. Educator readiness is based on how educators perceive the mobile technology as a new medium for their teaching and learning (Zulkafly, Koo & Shariman, 2011).

Yusof et al. (2014) investigated teachers' insight on mobile learning application in typical education classes and the benefits and challenges of applying combined learning for special education. Teachers used different teaching strategies to meet different students' requirements and possess imperfect knowledge in integrating mobile learning technologies in their teaching and they have inadequate resources of equipment (Yusof et al., 2014). Thus, the teachers' willingness and preparedness to adopt and implement mobile learning is a more critical success factor. To adopt mobile technologies as an added value on the educators' existing teaching, readiness should be considered and studied in the learning environment (Buckenmayer, 2008; Ferry, 2009). Mobile learning helps teachers to apprehend and analyse students' learning performance. To examine the preferences and intention of educators to implement mobile learning in higher education, Zulkafly, et al. (2011) conducted a study at Multimedia University in Malaysia. The investigators observed that Multimedia University is one of the adopters of mobile learning. Consequently, the educators preferred to use mobile devices for managing learning activities such as taking attendance, delivering announcement and scheduling class events and assessment activities (Zulkafly, et al., 2011). However, Ferry (2009) viewed that educators had lower proficiency of mobile learning than the students in terms of using technology.

2.3 Smartphone Mathematics Applications (SMAs) that could be effective when integrated in Learning Mathematics

Mobile phone usage is rapidly increasing due to the design of mobile applications. The most popular smartphone Operating Systems (OS) that support mobile apps today are Android, iOS, Microsoft Windows Phone and BlackBerry (Viswanathan, 2016). These Operating Systems (OS) can be preloaded on the handheld device as well as can be downloaded by users for free and paid from app stores ("Apple Store" for iOS or iPhones, "Play store" for Android Phone, "BlackBerry App World" for Blackberry Phone as well as "Windows Phone Store" for Microsoft Windows Phone or the Internet by downloading its file extension or package file format. Thus, Android users can download its Android Package Kit (APK) file extension, iOS (Apple) users can download its iPhone application (IPA) file extension, Blackberry users can also download its Java Application Descriptor (JAD) or Java ARchive (JAR) file extension as well as Microsoft Windows users can download Silverlight Application Package (XAP) from the internet. Of these mobile applications, Smartphone Mathematics Applications (SMAs) give users the easiest means to solve mathematics problems. Smartphone Mathematics Applications (SMAs) such as Math4Mobile, Mathway, Photomath, Math Tricks, Mathematics Dictionary, Mathematics f(x), Malmath, Limits-step-by-step, All-in-One Calculator, Math Expert, Symbolab, Graphing Calculator or Algeo Graphing Calculator, iMathematics, GeoGebra, Geometry Pad, FreeGeo Mathematica, Wolfram Alpha, Scientific Calculator, MATLAB, and Math Ref are some of mobile technological tools that have been developed for learning as well as teaching Mathematics. Study experts in mathematics education suggested that the use of these tools can encourage discovery and experimentation in classrooms and that their visualization features can be effectively employed in teaching to generate conjectures (Hohenwarter, Hohenwarter, Kreis, & Lavicza, 2008).

2.3.1 *Mathway*

Mathway, developed by Mathway LLC, is a mathematics mobile application (Smartphone Mathematics Application) that can help users solve problems in mathematics like algebra, trigonometry, calculus, statistics, and chemistry that require a more complex tool than your device's built-in calculator (Uptodown, 2017). Mathway allow users create graphs that help give them a more visual idea of the problem, helping the user to better understand problems that require diagrams. With hundreds of millions of problems already solved, Mathway is a number one problem-solving resource available for users to solve complex math problems on their mobile devices that require no network access (Educational Appstore, n.d.). Mathway is one of the most useful calculator apps in App Store that offers instant answers to users' basic maths problem and complex math equations (Educational Appstore, n.d.). The app practically solves anything from basic mathematics problems, geometry, algebra to more complex calculus equations and trigonometry. Moreover, Mathway (see Figure 2) gives instant answers to your math problems for free but must be paid or subscribed to include step-by-step work and explanations.

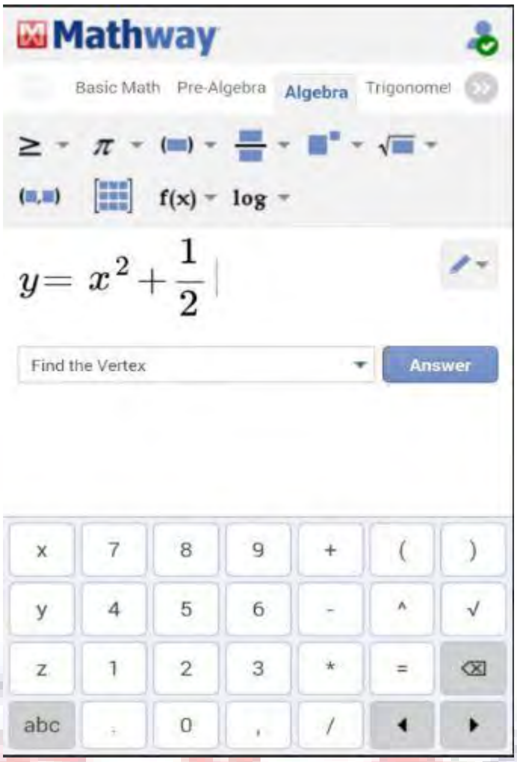

Figure 2. A View of Mathway Screen (Source: Uptodown, 2017)

2.3.2 *Photomath*

Photomath, developed by MicroBlink technology, is an application that can solve mathematics problems by just pointing your camera to the mathematics problem (Uptodown, 2017). The app is the world's smartest camera calculator and math assistant which works similarly to Quick Response (QR) readers and shows you a solution for the problem in seconds. Photomath (see Figure 3) is the world's first camera calculator. When the mobile camera is pointed toward mathematics expressions, the application solves the problem instantly in real time with detailed solving steps.

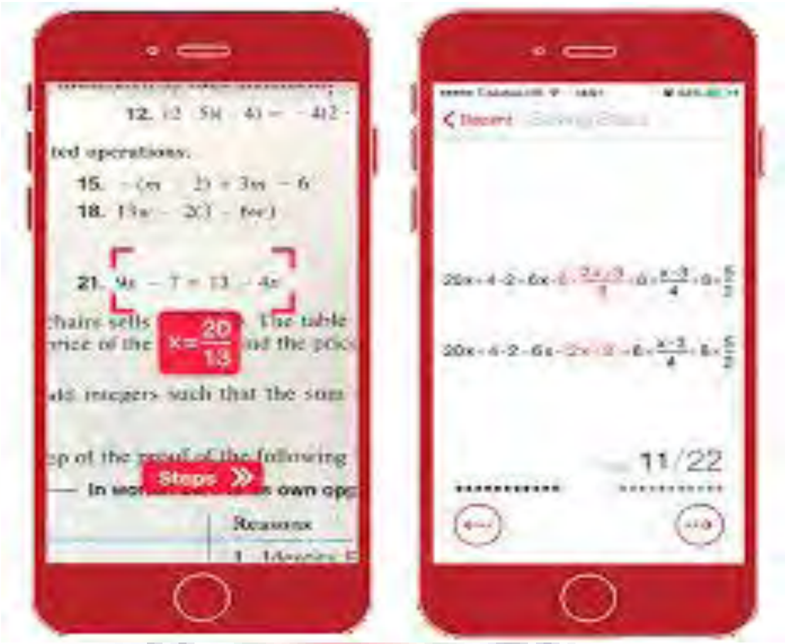

Figure 3. A View of Photomath Screen (Source: Photomath, 2017)

To use Photomath, simply point your camera toward a math problem and it will magically show the result with a detailed step-by-step solution. Photomath supports Arithmetic, fractions, decimal numbers, linear equations, equation systems and several functions like logarithms, more complex problems like integrals, trigonometry and derivatives are also supported but currently work without detailed solving steps (Google Play, 2017).

2.3.3 *Malmath*

Malmath is a math problem solving app developed by three computer science students of the University of Prishtina (Prishtina Insight, 2016). It is a free and offline working mathematics problem solver engine which solves series of mathematical problems including integrals, derivative, Algebra, Equation, Logarithm, Limits, Trigonometry, Statistics, Finite Math, Linear Algebra, and Chemistry questions (Google Play, 2017). Malmath (see Figure 4) helps users to understand the solving process and others who have problems with their home works.

Figure 4. A View of Malmath Screen (Source: Google Play, 2017)

Malmath gives description with detailed explanation for each step, easier to understand step using highlights, graph analysis, generate mathematics problems with several categories and difficulty levels which is capable of giving users the answers to all types of complex mathematical operations and at the same time can show you step-by-step how to get results (Uptodown, 2017).

2.3.4 *GeoGebra*

According to Hohenwarter and Preiner (2007), GeoGebra is a dynamic Mathematics software which is a blend of Computer Algebra Systems and Dynamic Geometry System intended for Mathematics instructions at senior high school and college levels, thereby bridging the gap between Algebra, Geometry and even Calculus (Hohenwarter & Preiner, 2007). Thus, GeoGebra is dynamic mathematics software for all levels of education that brings together geometry, algebra, spreadsheets, graphing, statistics and calculus in one easy-to-use package. GeoGebra has become the leading provider of dynamic mathematics software, supporting Science, Technology, Engineering and Mathematics (STEM) education and innovations in teaching and learning worldwide

(International GeoGebra Institute, 2017). GeoGebra (see Figure 5) is also an intelligent graphing software that allows the user to interactively explore in 2- and 3-dimensional Euclidean geometry.

Figure 5. A View of GeoGebra Screen (Source: Google Play, 2017)

Zulnaidi and Zakaria (2012) claim that due to the combined nature of the visual capabilities of Computer Algebra Systems and dynamic changeability of the Dynamic Geometry System, it enables GeoGebra to examine multiple representations of geometric objects, equations, graphs, tables and effective tool for teaching algebra. It also gives users the chance to manipulate objects on the screen by controlling principally. A study conducted by Healy and Hoyles (2001) indicated that GeoGebra gives access to various geometric objects and relations with which learners can interface in order to build and explore new objects and relations. GeoGebra is the most popular and effective tools used for mathematics education and it is rapidly expanding the community of millions of users located in every country. It easily solves math problems, graph functions and equations, do statistics and calculus, combine with interactive geometry, saves and shares your results (Google Play, 2017). Putting the world's leading dynamic mathematics software and materials in the hands of students and teachers everywhere.

2.4 Use of Mobile Technology in Mathematics Education and its Impact on Students' Performance

In spite of the fact that mobile phones and its usage has become very common in most of our daily lives, the utilization of these devices in education is still new and in its early stages (Kinshuk & Chen, 2005). Mobile devices like smartphones, PDAs, and tablets, could be used to benefit students' learning in or out of the classroom that is propounding software developers to design more applications (apps) to enhance students' learning. The innovation in mobile apps has raised interests among educators because it facilitates teaching and learning (Johnson, Adams, & Cummins, 2012). Mobile applications for mathematics become more known year after year and are used today by millions of students and educators in all over the world (Athanasios & Marios, 2015). Naismith, Lonsdale, Vavoula, and Sharples (2004) suggested a pedagogy-model based classification of mobile learning with six categories: 1) behaviourist, 2) constructivist, 3) situated, 4) collaborative, 5) informal and lifelong learning and 6) support for learning and teaching. Athanasios and Marios (2015) opined that:

> "In recent years, researchers developed online and mobile applications to support teaching in Algebra, Geometry, Mathematical Analysis, Statistics and other areas of mathematics. Mobile math applications allow users to explore functions, providing graphical capabilities and offer many kinds of specific calculators. There are apps designed to handle measurement tasks and educational apps for practicing on numerical and mathematical skills" (p. 34).

Nguyen and Kulm (2005) conducted a study to investigate how mobile technologies provide support for mathematics. Findings from their study revealed that mobile technologies have been increasing over the last decade and the mobile educational tools for mathematics can assist students' problem solving, enhance comprehension of mathematical concepts, provide dynamically representations of ideas and encourage general metacognitive abilities.

The frequent use of mobile technologies in the course of mathematics would help students to improve their skills on one hand, and on the other hand would encourage the improvement of mobile learning applications. For instance, Botzer and Yerushalmy (2007) conducted a pilot case study on four female mathematics students studying for a teaching certificate. Also, Zhao and Okamoto (2009) from the University of Electro-Communications in Japan, introduced a Mobile Mathematics Tutoring (MoMT) system for primary school students, based on individual learner's abilities. The system analyses the user's learning profile, in order to provide personalized mathematics tutoring and exercises. The system also allows discussion between students, so they can exchange ideas, experiences, and questions, via email, text messaging, photos, audio recordings and videos. This mobile tutoring system can improve arithmetic skills and student interest in learning mathematics concepts. In 2013, Zaranis, Kalogiannakis, and Papadakis developed sixteen different activities for mobile teaching realistic mathematics in kindergarten education. Wijers, Jonker, and Kerstens (2008) created an interesting mobile gaming learning environment, based on geographical reality, maps and location technologies, to support 12-14-year-old students. MobileMath is played on a mobile phone with a GPS receiver. The basic goal of the experiment was to help students experience mathematical concepts in the physical world. Users, playing in teams, gain points by creating virtually constructed mathematical shapes (squares, rectangles, or parallelograms). The construction process was done by physically walking and clicking on the location for each vertex. To answer the research questions, they made a pilot study with 60 students in three different schools. After the game, 54 of the players completed a questionnaire. The students understood easily the goal and the rules of MobileMath. The collaboration within teams went well and there was no problem with using the phone.

Furthermore, at the University of Salzburg in 2004, Hohenwarter and Fuchs presented GeoGebra, a project designed to combine features of interactive geometry software and computer algebra systems and might be used in teaching for demonstration and visualization, as a construction tool, for preparing teaching materials and a helpful tool for discovering mathematics. In parallel, they designed GeoGebraTube, a website which supports direct uploading of constructions and allows users to rate tag and comment on the materials. The upcoming version of GeoGebra (version 5), will include a fully dynamic 3D for three-dimensional geometry and graphics (Hohenwarter, 2013). However, Kaufmann, Schmalstieg, and Wagner (2000) introduced Construct 3D, a three-dimensional geometry construction tool, designed for mathematics and geometry education at high school and university. The construct 3D uses augmented reality (AR) to allow users to share a virtual space. AR allows users to see their own body and hand, as well as the results of their movements while they work.

2.5 Factors Influencing the Use of Mobile Technology in Mathematics Education

Mobile technologies are often employed to supplement traditional classroom pedagogy and have not been fully integrated into classroom learning activities (Ginsberg & McCormick, 1998). A wide variety of factors have strong direct and indirect influence on mobile technology usage. Out of all the factors examined, multiple studies concluded that the level of preparedness to use technology had the most direct, significant effect on classroom mobile technology integration (Inan & Lowther, 2010; Ritzhaupt, Dawson, & Cavanaugh, 2012; Tondeur, van Keer, Van Braak, & Valcke, 2008).

Inan and Lowther (2010) found that teacher beliefs and computer availability had significant impacts on technology integration. Moreover, in a longitudinal collective case study, Levin and Wadmany (2008) examined teachers' beliefs about what factors are related to technology integration. Levin and Wadmany interviewed, surveyed, and observed six teachers in grades four to six, and found that while teaching in a technology-rich environment, teacher's views of what influences integration shifted significantly over three years. Initially, teachers focused on organizational aspects, such as product design, alignment with curriculum, and administrator support. Over time, their views shifted to factors related to classroom practices and their own need for additional learning. The most significant finding was that teacher belief is constructed through school experiences, such as teaching and administrator support (Levin & Wadmany, 2008). Anderson and Maninger (2007) also conducted a study to investigate pre-service teachers' abilities, beliefs, and intentions regarding technology integration. Their findings revealed that students' self-efficacy beliefs significantly influence their intentions to use the software in their future classrooms. They further revealed that Students' self-efficacy and intentions were moderately correlated with each other. However, they argued that the best predictors of intentions were self-efficacy beliefs, gender, and value beliefs.

Almekhlafi and Almeqdadi (2010) conducted a study to investigate teachers' perceptions of technology integration in the United Arab Emirates (UAE). Out of 100 teachers sampled, the findings showed that the means scores for female teachers on technologies used were all above 4.4 but that of male teachers ranged from 2.5 to 3.5. A One-way ANOVA statistical test further revealed that there was a significant difference in technology use between male and female teachers. This also implies that gender has an influence on the teachers' technology use. Besides, Goos and Bennison

(2008) surveyed 485 mathematics teachers in Australia to investigate the factors influencing technology use in mathematics teaching. Their findings revealed that pedagogical knowledge and beliefs, access to hardware and software and participation in professional development course were factors influencing technology use in teaching and learning mathematics. Similarly, Mereku, et al. (2009) conducted a study to investigate the pedagogical integration of ICT. Their findings revealed that availability of ICT syllabuses/manual, computers and computer laboratories that can be accessed periodically were factors that influence technology use at the SHS level in Ghana. Agyei and Voogt (2012) proposed for the need to develop technological pedagogical content knowledge for pre-service teachers so that they can be able to integrate Mathematics and technology in practice.

Another factor that came up with great frequency in the literature reviewed was student motivation and student engagement. Researchers (An & Reigeluth, 2011; Freeman et al., 2014; Proctor, Daley, Louick, Leider, & Gardner, 2014) have shown a strong correlation between increased motivation and increased student achievement. Dweck (2008) found that what a student believes about the potential for their brain to grow and develop through additional effort was linked to increased motivation, engagement, and achievement in math and science. Students' beliefs about their brains are significantly affected through direct instruction about neuroplasticity or the brain's ability to grow and change (Dweck, 2008).

2.6 Students' Perceptions towards the use of Smartphone Mathematics Applications (SMAs) in Mathematics Learning

Baya'a and Daher (2009) investigated students' perceptions of Mathematics Learning using mathematics applications on mobile phones which was carried out at Arab middle school in the city of Umelfahm in Israel, and was led by three pre-service teachers who were carrying out their final project in the field of teaching mathematics using some various mathematics applications on mobile phones. In their study, 32 students were selected and their selection was done based on the interest of the students. The learning was done by carrying out outdoor activities using the various features and qualities of the mathematics application on the mobile phone that involved exploring and investigating mathematics concepts and relations of real-life phenomena.

The middle school students worked with mobile phone software (midlets) that support the learning of algebra and geometry. The midlets can be downloaded from Math4Mobile site which belongs to the Institute for Alternatives in Education that operates within the Faculty of Education at the University of Haifa (Yerushalmy & Weizman, 2007). These midlets support the learning of algebra and geometry. In their experiment, the students used the algebraic midlets that enabled them to see the graphs of several templates of linear functions. They could see the change in the corresponding straight line as the result of changing parameters in the algebraic form. The students also had the opportunity to set points in a coordinate system and to check if a straight line could connect all of them; indicating a linear relation in the real-life phenomenon. Carrying out the activities, the students exploited the mobility, dynamics, availability and accessibility properties of the SMAs on the cellular phones. Data were collected using the pre-constructed blog and semi structured interviews. The pre-constructed blog was used in order to suggest the students' ideas regarding the use of mobile phones in the mathematics learning process and to inquire about this use whilst the interviews were conducted for each participant for thirty minutes to find out their mathematics learning using the SMAs on the mobile phones.

2.7 Summary

This study was based on a modified Technology Acceptance Model (TAM) adapted from Davis' (1989) TAM framework to identify PMTs' perceived usefulness and perceived ease of use to accept or reject the use of SMAs in learning mathematics. The TAM framework had been a dominant theoretical model for determining the intention and readiness of pre-service teachers (PTs) to use SMAs in their studies and even in their future instructional practice (Masrom, & Hussein, 2008; Stols, 2007). Some researchers (Shuler, 2009) have noted that applications on smartphones have the potential to become the new means of providing educational content to students.

Also, researchers (Hohenwarter et al., 2008; Johnson et al., 2012) have shown that the use of the SMAs can encourage mathematics discovery and experimentation in classrooms and arouse interests among educators because it facilitates teaching and learning.

Studies (Inan & Lowther, 2010; Ritzhaupt et al., 2012; Tondeur et al., 2008) have concluded that the level of preparedness to use technology had the most direct, significant effect on classroom mobile technology integration. However, understanding students' perceptions is an important step in the effort to attract the best to the profession (Hartwell, Lightle, & Maxwell, 2005).

CHAPTER 3

METHODOLOGY

3.0 Overview

This section looked at the procedures that were employed to carry out the research. This included: research design, population, sample and sampling techniques, research instruments, the validity and reliability of research instruments, data collection procedure, the ethical considerations and also the data analysis procedure.

3.1 Research Design

The study employed a descriptive survey with cross-sectional research design as a strategy of enquiry. A cross-sectional design was deemed most appropriate for this study because it aimed to identify the use of Smartphone Mathematics Applications (SMAs) among Pre-service Mathematics Teachers (PMTs) in learning Mathematics. It also aimed to examine the PMTs' perceptions about the use of SMAs in learning mathematics. The study was cross-sectional as data were collected from two teacher universities in Ghana at a distinct time (Burns & Grove, 2011). According to Bless, Higson-Smith and Kagee (2006), cross-sectional design allows the collection of all data and provides information at a single point in time.

3.2 Population

The population for this research comprised all PMTs at the teacher universities in Ghana. The targeted population was estimated at one thousand, eight hundred and forty (1, 840) PMTs, of which 81% (N = 1, 490) and 19% (N = 350) were males and females respectively.

3.3 Sample and Sampling Technique

In this study, non-probability sampling, particularly purposive sampling was one of the sampling procedures used. This sampling procedure was used to select the two teacher universities in Ghana and PMTs owning mobile phones. Purposive sampling employed based on the basis of the knowledge attained about the population, its elements, and the nature of the research aims (Babbie, 1990)

Stratified random sampling was the second sampling technique that the researcher employed to select the PMTs from the two teacher universities. Firstly, the population was divided into subgroups, called strata (Mason, Lind & Marchal, 1999). That is, the researcher divided the two teacher universities into Teacher University A and Teacher University B and grouped the population for the study into their respective teacher universities. Secondly for each teacher university, the population were further grouped into academic levels (Level 100, Level 200, Level 300, & Level 400). Lastly to select the participants from the selected strata, the Krejcie and Morgan (1970) chart (see Figure 6) was employed and a simple random sampling technique was used to select a sample of three hundred and twenty (320) PMTs of which 265 (82.8%) were males and 55 (17.2%), females were selected for the study. Stratified sampling technique was used in this study to enable the researcher to get equal representatives of PMTs from each teacher university.

Table 1

Stratified Sampling of Participants

Strata	Academic Level				Total
	Level 100	Level 200	Level 300	Level 400	
Teacher University A	40	40	40	40	160
Teacher University B	40	40	40	40	160
Total	**80**	**80**	**80**	**80**	**320**

From Table 1, the distribution of the sample procedure shows that equal number of PMTs were selected from each teacher university.

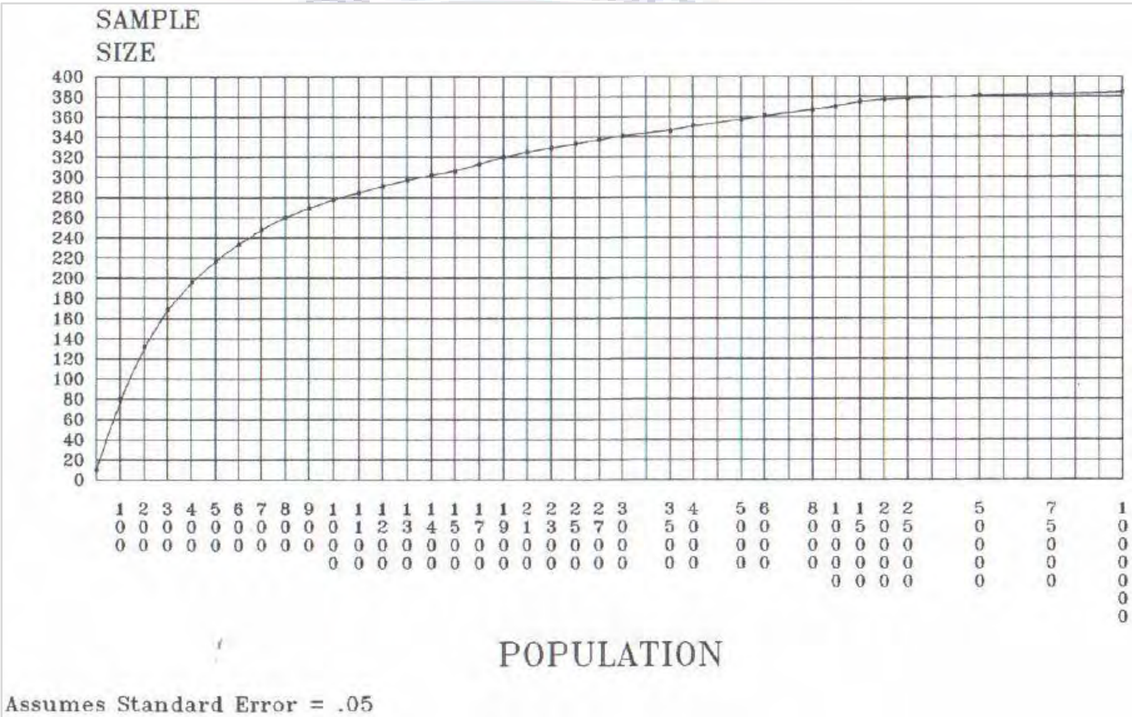

Figure 6. Krejcie and Morgan's sample size determination chart

From Figure 6, since target population was estimated at 1, 840 (approximately 1,900) then its corresponding sample size was 320. Therefore, based on the chart a sample of 320 PMTs were selected for this study.

3.4 Research Instrument

After a careful review of appropriate literature, questionnaire was chosen as the instrument to collect data to answer the questions set for this study. The questionnaire was an efficient tool in collecting data for this study in the sense that, it enabled the researcher to reach the respondents in a short space of time (Oppenheim, 1992). Basically, it took less time to administer them and also ensured the anonymity of respondents (Fraenkel & Wallen, 2000; Muijs, 2004). Questionnaire enabled the researcher to collect potential information about the use of SMAs in learning mathematics, factors that influence the PMTs' use of the SMAs and their perceptions about the use.

3.5 Nature of the Research Instrument

The questionnaire was self-administered questionnaire (SAQ) and consisted of both close and open-ended items. It was structured to be simple and straight to the point in such a way that respondents could answer easily. It was also written in English which is the medium of instruction for the respondents. A sample of the SAQ is presented in Appendix A.

In this study, the SAQ consisted of five (5) sections (A – E). Part A elicited information on the background (demographic data) of the respondents. These included gender, age, and academic level. The second section (Part B) elicited PMTs' information on the use of mobile phones with their specific functions. The third section (Part C) also elicited information on PMTs use of smartphone. The fourth section (Part D) also focused on the information on the use of SMAs in learning mathematics. This was an open-ended item to allow the PMTs to list the various SMAs they use and could be effective in learning mathematics. This section also sought to find out the use of SMAs in learning mathematics which with three options (Little Extent, Some Extent, and Great Extent). A frequency score ranged from 1 (Minimum) to 3 (Maximum), where Little Extent was coded as 1, Some Extent was coded as 2, and Great Extent was coded as 3. The final section (Part E) sought to find out PMTs' perceptions towards the use of SMAs in learning mathematics. This involved a five-point Likert scale, namely, Strongly Disagree (SD), Disagree (D), Uncertain (U), Agree (A) and Strongly Agree (SA) which employed a graded response to each of the statements (Jupp, 2009). The scores were rated from Minimum (1) to Maximum (5), a response intensity of Strongly Agree (SA) which was the highest was rated as 5, Agree (A) rated 4, Uncertain (U) as 3, Disagree (D) scored as 2, whereas Strongly Disagree (SD), the lowest response intensity was scored as 1. Respondents who selected "undecided" were ignored in the analysis; the purpose was to avoid neutral and indeterminate responses altogether (Thobakgale, 2013 p. 60).

3.6 Validity and Reliability

Validity indicates how an instrument measures what it is supposed to measure (Creswell, 2009). Therefore, to ensure validity of the instrument, the researcher presented the SAQ to the study supervisor and specialist researchers from Mathematics and ICT departments for evaluation. The supervisor and specialist researchers evaluated each item on the questionnaire with regard to the degree to which the variables to be tested are represented as well as the instrument's overall suitability for use (Babbie & Mouton, 2003). The specialists were also asked to examine each item and to make judgments whether the items adequately represented hypothetical content in the correct proportions (Polit, Beck, & Hungler, 2010).

Reliability on the other hand is the degree of dependability or consistency of a measuring instrument (Babbie & Mouton, 2003). To ensure reliability, a pilot study was conducted on one hundred (100) randomly selected PMTs owning mobile phones from a teacher university in Ghana aside the two teacher universities. Participants' scores from the pilot study were correlated using Cronbach alpha formula used in reliability testing to ensure the consistency of the instrument specifically on the final section of the SAQ. Cronbach alpha was used because it was "more efficient way of testing reliability" and was less time consuming (Durrheim, 1999, p 90). The value of the reliability coefficient was 0.653. This value indicates a high degree of reliability of the items in the instrument (Fraenkel & Wallen, 2000). The reliability coefficient summary is presented in Appendix B.

3.7 Data Collection Procedure

The researcher collected an introductory letter from the Department of Mathematics Education, University of Education, Winneba (UEW). The Introductory letter was then sent to the Heads of Department (HODs) of Mathematics Education of the two teacher universities. With consent from the HODs, the PMTs were informed about the study and were briefed on the purpose of the study and required for their cooperation for the field work. The researcher later personally administered the questionnaire to the participants (PMTs). The questionnaire was administered personally to help improve the collection and response rate of the questionnaire. The questionnaire was collected as soon as it was completed by the respondents. This enabled the researcher to obtain 100% response rate. The introductory letter is presented in appendix F.

The researcher used a day each for both teacher university in the administration of the questionnaire. A period of 30 - 45 minutes was allotted to respondents to complete the questionnaire. Upon the return, the completed questionnaires were cleansed, and coded for data entry and further analysis.

3.8 Ethical Considerations

The researcher sought permission from the Heads of Department of Mathematics Education of the two teacher universities. Approval was then granted to the researcher to administer the SAQ to the participants. The researcher also sought the consent of the respondents and were thoroughly and truthfully informed about the nature and the purpose of the study. The information provided by the participants (respondents) were not used against them in any way (Polit et al., 2010). Thus, respondents' privacy and confidentiality were maintained throughout the study (Brink, 2006). Therefore, codes were used during data collection and analysis. Additionally, the names of the two teacher universities were concealed during the write up of the study. For this reason, pseudonyms, Teacher University A and Teacher University B were used as references.

3.9 Data Analysis

The responses from the questionnaire items were coded and analysed through the use of International Business Machine Statistical Package for the Social Sciences (IBM-SPSS) version 23. The data entries were done by the researcher in order to check the accuracy of the data. Data were cleaned before running any analysis. Cleaning the data helped the researcher to get rid of errors that could result from coding, recording, missing information, influential cases or outliers.

To find out the SMAs that are commonly used among the PMTs and could be effective when integrated in learning mathematics at teacher universities in Ghana, a descriptive data analysis such as frequency distribution was employed. The descriptive data analysis was used to analyse, describe and compare the quantitative data in this study.

To analyse Research Question 2, which sought to examine the perceptions of PMTs towards the use of SMAs in learning mathematics. Research Question 2 was analysed using descriptive data analysis such as frequency distribution. The descriptive data analysis was used in an attempt to understand, interpret and describe the views or perceptions of the PMTs (Durrheim, 1999). Means and standard deviations were further used to measure the PMTs' perceptions of the use of SMAs in learning mathematics at an interval level using a five-point Likert scale as indicated by Stevens (1946). This is to indicate whether the PMTs held either positive or negative perceptions towards the use of SMAs in learning mathematics.

To analyse Research Question 3, an Ordinal Logistics Regression Model (OLRM) was conducted to investigate the factors (gender, age, academic level, type of smartphone, and awareness) that influence PMTs' use of SMAs in learning mathematics. The null hypothesis that "there is no significant relationship between the factors (gender, age, academic level, type of smartphone, and awareness) and PMTs' SMAs use learning mathematics" was formulated and tested at 0.05 level of significance.

Before the Ordinal Logistics Regression Model was used, the researcher made sure that all the assumptions needed were met.

Ordinal Logistics Regression Model (OLRM) Assumptions

The key assumption of Ordinal Logistics Regression Model (OLRM) assumptions include:

- **Assumption 1:** The dependent variable should be measured on an ordinal level.
- **Assumption 2:** The independent or predictor variables should be categorical in nature (including dichotomous variables).

- **Assumption 3:** There should be no multicollinearity for the Independent variables.
- **Assumption 4:** There should be proportional Odds.

The results of the assumptions are given below:

3.9.1 *The dependent variable should be measured on an ordinal level*

From the study, the dependent variable, "the extent of use of SMAs in learning mathematics", was measured using four ordinal variables or levels: "Not at All coded as 0", "Little Extent coded as 1", "Some Extent coded as 2", and "Great Extent coded as 3". During the data entry, a respondent who do not use any of the SMAs in learning mathematics was automatically transcribed as "Not at All".

3.9.2 *The independent or predictor variables should be categorical in nature*

From the study, the categorical variables that meet this criterion include gender (measured in 2 categories: male and female), age (measured in 4 categories: below 20 years, 20 – 29 years, 30 – 39 years, and above 40 years), academic level (measured in 4 categories: level 100, 200, 300, and 400), type of smartphone (measured in 4 categories: Android, iPhone, Windows Phone, and other OS), and the awareness of SMAs (measured in dichotomous variables: Yes and No).

3.9.3 *No multicollinearity for the Independent variables*

Multicollinearity occurs when there are two or more independent variables highly correlated with each other. From Table 2, the independent variables (gender, age, academic level, type of smartphone, and the awareness of SMAs) are not very strongly intercorrelated and also indistinguishable from each other since the VIF (Variance Inflation Factors) is less than 5 (Ringle, Wende, & Becker, 2015). Therefore, there is no multicollinearity VIF for each IVs (Independent Variables) lies below 5 (VIF < 5).

Table 2 presents the result from the Collinearity Statistics.

Table 2

Results from the Collinearity Statistics

Independent Variables	Collinearity Statistics	
	Tolerance	VIF
Sex	0.954	1.048
Age	0.908	1.101
Academic Level	0.906	1.104
Smartphone Type	0.945	1.058
Aware of SMAs	0.954	1.048

3.9.4 *There are proportional Odds*

Proportional odds occur when each independent variable has an identical effect at each cumulative split of the ordinal dependent variable. Here, the researcher used the test of parallel lines to test the assumption of proportional odds. That is, to test whether the relationship between each pair of outcome groups is the same.

The null hypothesis set was that the location parameters (slope coefficients) are the same across response categories. Table 3 shows the results from the test of parallel lines.

Table 3

Results from the Test of Parallel Lines

Model	-2 Log Likelihood	Chi-Square	df	p-value
Null Hypothesis	201.911			
General	143.742	58.169	26	0.067

Table 3 shows the parallel line test for general model with chi-square value 143.742 and p-value of 0.067 which is greater than the 0.05 level of significance ($p > 0.05$). This indicates that we fail to reject the null hypothesis that the location parameters (slope coefficients) are the same across response categories, and conclude that the proportional odds assumption holds (Ringle, Wende, & Becker, 2015).

CHAPTER 4

RESULTS AND DISCUSSION

4.0 Overview

The study sought to find out the use of SMAs among PMTs in learning Mathematics at teacher universities in Ghana. It further investigated the factors that influence PMTs' use of SMAs in learning mathematics and their perceptions about the use of SMAs in learning mathematics. A self-administered questionnaire (SAQ) were administered to 320 PMTs for the purpose of data collection and the data were analysed by using a descriptive and inferential statistics. The results are therefore presented and discussed in this chapter. The chapter is organized into three sections. The first section deals with the presentation of the background information of the PMTs (respondents) while the second section attempts to delve into the respondents' information on use of smartphones and use of SMAs. Finally, the third section focuses on the presentation and discussion of the main results of the study.

4.1 Background Information of Respondents

The background information of respondents featured in this section include: gender of respondents, age of respondents, and the academic level respondents. For the study, 160 respondents were sampled from each teacher university, thus in total 320 respondents participated in this study. Table 4 presents the distribution of the demographic information of the respondents.

Table 4

Distribution of Respondents' Demographic Information

Demographics	Category	Teacher University				Total	
		A		B			
		N	%	N	%	N	%
Gender	Male	132	41.3	133	41.6	265	82.8
	Female	28	8.8	27	8.4	55	17.2
	Total	**160**	**50.0**	**160**	**50.0**	**320**	**100.0**
Age Group	Below 20	5	1.6	4.0	1.3	9	2.8
	20 – 29	142	44.4	129.0	40.3	271	84.7
	30 – 39	13	4.1	24.0	7.5	37	11.6
	40 and Above	0	0.0	3.0	0.9	3	0.9
	Total	**160**	**50**	**160**	**50**	**320**	**100**
Academic Level	Level 100	40	12.5	40	12.5	80	25.0
	Level 200	40	12.5	40	12.5	80	25.0
	Level 300	40	12.5	40	12.5	80	25.0
	Level 400	40	12.5	40	12.5	80	25.0
	Total	**160**	**50**	**160**	**50**	**320**	**100**

Source: Field Work, 2018

4.1.1 *Gender Distribution*

In encouraging diversity of gender equality, the researcher ensured that both male and female respondents were used for the study. As can be seen in Table 4, out of the 320 respondents who were sampled for the study, 82.8% (N=265) were males whereas 17.2% (N=55) were females.

4.1.2 *Age Distribution*

Age is one of the most significant characteristics that helps to examine the responses of the respondents (Andrews & Herzog, 1986). From Table 4, 2.8% (N=9) were below 20 years, 84.7% (N=271) were between the ages of 20 – 29 years. Moreover, 11.6% (N=37) and 0.9% (N=3) were between the ages of 30 – 39 years and more than 39 years respectively.

4.1.3 *Academic Level Distribution*

From Table 4, the academic level distribution of respondents shows that equal number (N=80, 25.0%) of respondents were selected from both Teacher University A and Teacher University B.

4.2 Information of Respondents' use of Smartphones and use of SMAs

The information of respondents' use and use of SMAs featured in this section include: respondents' ownership of smartphone, type of smartphone, awareness and use of SMAs in learning mathematics. For the study, 160 respondents were sampled from each teacher university, thus in total 320 respondents participated in this study. Table 5 presents the distribution of the demographic information of the respondents.

Table 5

Distribution of Respondents' use of Smartphone and use SMAs

	Response	Teacher University				Total	
		A		B			
		N	%	N	%	N	%
Use Smartphone	Yes	160	50.0	155	48.4	315	98.4
	No	0	0.0	5	1.6	5	1.6
	Total	**160**	**50.0**	**160**	**50.0**	**320**	**100.0**
Type of Smartphone	Android	146	45.6	127	39.7	273	85.3
	iPhone	11	3.4	17	5.3	28	8.8
	Windows Phone	3	0.9	9	2.8	12	3.8
	Blackberry	0	0.0	2	0.6	2	0.6
	Total	**160**	**50**	**155**	**48.4375**	**315**	**98.4**
Aware of SMAs	Yes	70	21.9	90	28.1	160	50.0
	No	90	28.1	65	20.3	155	48.4
	Total	**160**	**50.0**	**155**	**48.4**	**315**	**98.4**
Use the SMAs	Yes	43	13.4	49	15.3	92	28.8
	No	28	8.8	41	12.8	69	21.6
	Total	**71**	**22.2**	**90**	**28.1**	**161**	**50.3**

Source: Field Work, 2018

4.2.1 *Distribution of Respondents Use of Smartphones*

As evident from Table 5, out of the 320 respondents who were using mobile phones and were sampled for the study, 98.4% (N=315) were using smartphones whilst the rest (N=5, 1.6%) were not using smartphones.

4.2.2 *Distribution of Respondents' Type of Smartphones*

From Table 5, of the 315 respondents who were using smartphones, 85.3% (N=273) were using Android phones and 8.8% (N=28) were using iPhones (iOS). 3.8% (N=12) out of the 315 respondents owning smartphones were using Windows phones. Moreover, 0.6% (N=2) were using Blackberry) of Operating System (OS) on their smartphone. Figure 7 gives a visual representation of the type of smartphone commonly used by the respondents.

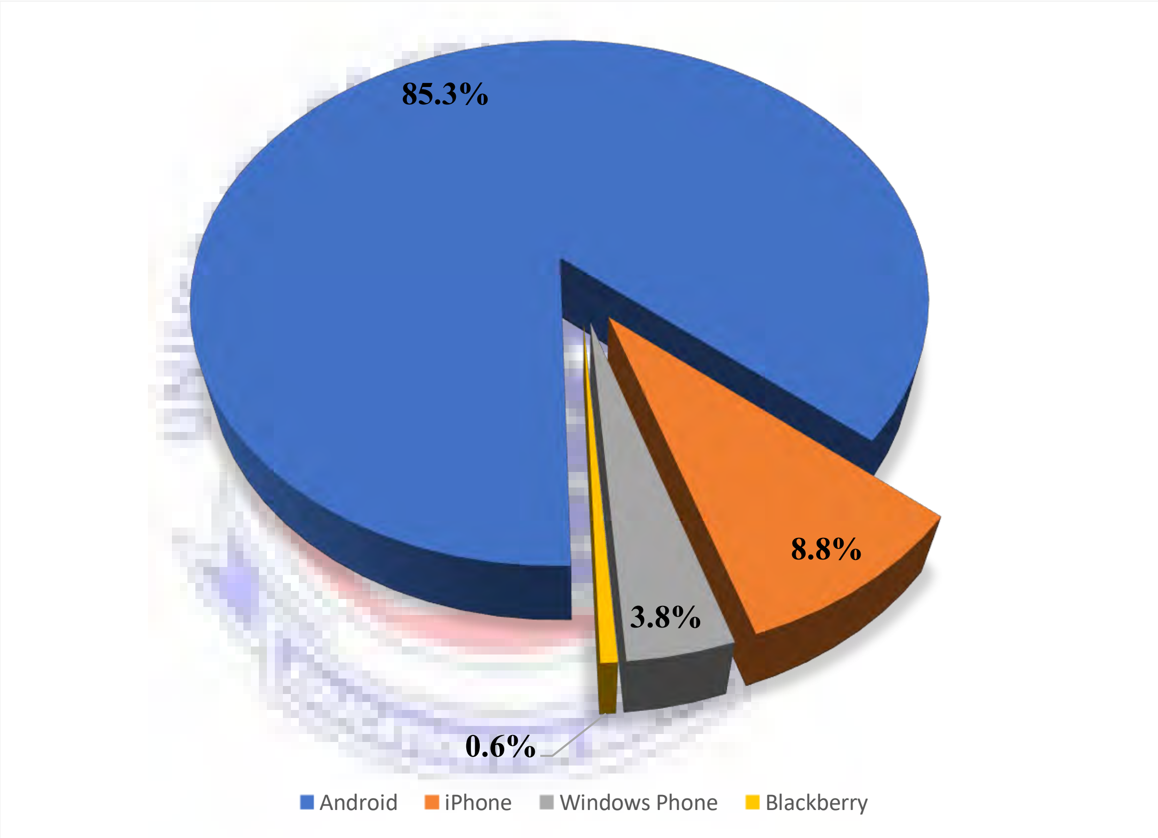

Figure 7: Pie Chart of the Respondents' type of Smartphones.

From Figure 7, of the 315 respondents using smartphones, 85.3% and 8.8% were using Android phones and iPhones (Apple phones) respectively. However, 3.8% and 0.6% were using Windows phones and Blackberry phones respectively. As evident from Figure 7, majority of the respondents were using Android phones.

4.2.3 *Distribution of Respondents' Awareness of SMAs in learning Mathematics*

As indicated in Table 5, when the 315 respondents who were using smartphone were asked whether they were aware of any SMAs in learning mathematics or not, 50.8% (N=160) indicated that they were aware of SMAs in learning mathematics whilst 49.2% (N=155) were not actually aware.

4.2.4 *Distribution of Respondents' Awareness of SMAs in learning Mathematics*

From Table 5, of the 160 respondents who were aware of the SMAs in learning mathematics, 92 representing 57.5% of the respondents were using the SMAs in learning mathematics whereas 68 representing 42.5% were not using the SMAs in learning mathematics.

4.3 Discussion of the Main Results of the Study

The results and discussions based on the analysis of the data for each research question are presented in this chapter under the following sub-headings:

- SMAs that are commonly used among the PMTs and could be effective when integrated in learning mathematics.
- Perceptions of PMTs towards the use of SMAs in learning mathematics.
- Factors that influence PMTs' use of SMAs in learning mathematics.

4.3.1.1 SMAs that are commonly used among the PMTs and could be effective when integrated in learning mathematics.

Research Question 1: What SMAs are commonly used among the PMTs and could be effective when integrated in learning mathematics at teacher universities in Ghana?

In order to address research question one, the 92 respondents (PMTs) who were aware and however using the SMAs in learning mathematics (see Table 5) were asked to list the SMAs they use in learning mathematics and and could be effective when integrated in learning mathematics. The SMAs commonly recorded by the 92 PMTs were GeoGebra, Malmath, Mathematics fx, Maths tricks, Maths Formulae, Mathway, Maths Dictionary, Scientific Calculator, MATLAB, All-in-One Calculator, Pocket Maths, Photomath, Calculus Solver, Cymath and Wolfram Alpha, and so on. Table 6 presents the top ten (10) SMAs that are commonly used among the PMTs and could be effective when integrated in learning mathematics.

Table 6

Distribution of the Top Ten (10) SMAs commonly used by the PMTs and could be effective when integrated in learning mathematics

Type of SMA	N=92*	%
GeoGebra	63	68.5
Malmath	54	58.7
Mathematics fx	31	33.7
Photomath	27	29.3
Graphing Calculator	24	26.1
Mathway	18	19.6
Maths Tricks	13	14.1
Scientific Calculator	13	14.1
MATLAB	12	13.0
Calculus Solver	9	9.8

* *Multiple Responses*

As can be seen from Table 6, 68.5% (N=63) PMTs use GeoGebra in learning mathematics and could be effective when integrated in learning mathematics. Malmath, another type of SMA was used by 58.7% (N=54) of the PMTs. Similarly, 33.7% (N=31) and 29.3% (N=27) of the PMTs use Mathematics *fx* and Photomath respectively. Additionally, 26.1 (N=24) of the PMTs use Graphing Calculator in learning mathematics and could be effective when integrated in learning mathematics. However, 19.6% (N=18) of the PMTs use Mathway in learning mathematics and could be effective when integrated in learning mathematics. Same number (N=13, 14.1%) of the PMTs use Maths Tricks and Scientific Calculator in learning mathematics and could be effective when integrated in learning mathematics. Meanwhile, 13.0% (N=12) and 9.8% (N=9) of the PMTs respectively use Maths Tricks and Scientific Calculator in learning mathematics and could be effective when integrated in learning mathematics

4.2.1.2 Discussion of Findings for Research Question 1

This research question sought to find out the SMAs that are commonly used among the PMTs and could be effective when integrated in learning mathematics. It was found out that GeoGebra among other types of SMAs was commonly used among most (68.5%, N=63) of the 92 respondents (PMTs) using SMAs in learning mathematics. It was not surprising that GeoGebra was used by most of the PMTs in learning mathematics because GeoGebra has a large international user and developer community with users from 190 countries and currently translated into 55 languages and attracts close to 300,000 downloads per month (Hohenwarter, Hohenwarter, & Lavicza, 2009). However, GeoGebra, a dynamic mathematics software was preferably used by most of the PMTs in learning mathematics in particular because of the interest that this software has attracted amongst every user (Ruthven, 2009). Millions of people around the world use GeoGebra to learn mathematics and science (Google Play, 2017). Escuder and Furner (2012) hold the view that, GeoGebra combines dynamic geometry, algebra, calculus, and spreadsheet features (which other packages treat separately) into a single easy-to-use package making it suitable for learning and teaching mathematics from elementary through university. According to Hohenwarter and Preiner (2007), GeoGebra is a free and open-source educational software package, which provides dynamic mathematical representations. Thus, because of its free and open-source nature, there are no licensing issues associated with its use, allowing students or teachers freedom to use it both within the classroom and also at home (Escuder & Furner, 2012).

4.3.2.1 Perceptions of PMTs towards the use of SMAs in learning mathematics.

Research Question 2: What are the perceptions of PMTs towards the use of SMAs in learning mathematics?

To address research question two, the 92 PMTs who were using the SMAs in learning mathematics were asked to indicate the level on their perception of the use of SMAs in learning mathematics. Furthermore, a descriptive data analysis (mean and standard deviation) was further used to examine whether the PMTs' perceptions were either positive or negative. Considering a mean value of 3.0 is to be a middle point. A mean score below 3.0 indicates a negative perception and a mean score above 3.0 indicates positive perception. Table 7 presents the perceptions of PMTs towards the use of SMAs in learning mathematics.

Table 7

PMTs Perceptions towards the Use of SMAs in Learning Mathematics (N=92)

Perceptions	Ratings of PMTs' Perception towards the use of SMAs in learning mathematics					
	Disagree		Agree			
	SD (%)	D (%)	A (%)	SA (%)	M	SD
1. SMAs fascinate and make learning mathematics more interesting.	2 (2.2)	4 (4.3)	48 (52.2)	34 (37.0)	4.17	0.872
2. SMAs aid in learning mathematics towards achieving academic excellence.	3 (3.3)	7 (7.6)	41 (44.6)	39 (42.4)	4.21	0.920
3. SMAs discourage academic laziness in mathematics.	3 (3.3)	19 (20.7)	31 (33.7)	22 (23.9)	3.67	1.256
4. SMAs aid the learning of mathematics independently	13 (14.1)	29 (31.5)	31 (33.7)	14 (15.2)	3.05	1.397
5. SMAs improve learning techniques to enhance computational skills and logical reasoning.	8 (8.7)	29 (31.5)	30 (32.6)	10 (10.9)	3.05	1.199
6. SMAs help in the understanding of most mathematics concepts to enhance the rate of assimilation in mathematics.	4 (4.3)	8 (8.7)	39 (42.4)	21 (22.8)	3.71	1.054
7. SMAs enable the accomplishment of mathematics tasks more easily and faster.	3 (3.3)	11 (12.0)	46 (50.0)	24 (26.1)	3.84	1.051
Overall Mean					**3.67**	**1.107**

Note: 1 – Strongly Disagree; 2 – Disagree; 4 – Agree; 5 – Strongly Agree

As can be seen from Table 7, 89.1% (N=82) out the 92 PMTs using the SMAs in learning mathematics agree that SMAs fascinate and make learning mathematics more interesting but 6.5% (N=6) of them disagree. However, the PMTs had a positive perception on the view that SMAs fascinate and make learning mathematics more interesting with a mean score of 4.17 (SD = 0.872). Similarly, out of the 92 PMTs using the SMAs in learning, 87.0 (N=80) agree that SMAs aid in learning mathematics towards achieving academic excellence but 10.9% (N=10) disagree. With a mean score of 4.21 (SD = 0.920), the PMTs again had a positive perception on the view that SMAs aid in learning mathematics towards achieving academic excellence. 57.6% (N=53) agree that SMAs discourage academic laziness in mathematics whereas 23.9 (N=22) disagree. With a mean score of 3.67 (SD = 1.256), the PMTs again had a positive perception on the view that SMAs discourage academic laziness in mathematics. Furthermore, out of the 92 PMTs using SMAs in learning mathematics, 48.9% (N=45) agreed that SMAs aid the learning of mathematics independently whilst 45.7% (N=42) do not agree. With a mean score of 3.05 (SD = 1.397), the PMTs had a positive perception on the view that SMAs aid the learning of mathematics independently. Besides, 43.5% (N=40) agree SMAs improve learning techniques to enhance computational skills and logical reasoning whilst 40.2% (N=37) think the use of SMAs do not improve learning techniques to enhance computational skills and logical reasoning. With a mean score of 3.05 (SD = 1.199), the PMTs again had a positive perception on the view that SMAs improve learning techniques to enhance computational skills and logical reasoning. 65.2% (N=60) agree that SMAs help in the understanding of most mathematics concepts enhance the rate of assimilation in mathematics whereas 13.0% (N=12) disagree. With a mean score of 3.71 (SD = 1.054), the PMTs had a positive perception on the view that SMAs help in the understanding of most mathematics concepts enhance the rate of assimilation in mathematics. Nevertheless, 76.1% (N=70) out of the 92 PMTs using SMAs in learning mathematics agree that SMAs enable the accomplishment of mathematics tasks more easily and faster whilst 15.2% (N=14) disagree to the fact that SMAs enable the accomplishment of mathematics tasks more easily and faster. With a mean score of 3.05 (SD = 1.199), the PMTs again had a positive perception on the view that SMAs enable the accomplishment of mathematics tasks more easily and faster.

The overall mean score of 3.67 as indicated in Table 7 reveals that in general, the PMTs mostly agreed to the perceptions towards the use of SMAs in learning mathematics. Thus, the PMTs had positive perceptions about the use of SMAs in learning mathematics. However, the standard deviation of 1.107 also reveals that the PMTs' responses where more standardised and were not far away from the data sets of the responses.

4.3.2.2 Discussion of Findings for Research Question 2

Research Question 2 sought to find out the perceptions of PMTs towards the use of SMAs in learning mathematics. Findings from the result showed most of the PMTs have positive perception about the use of SMAs in learning mathematics. Thus, the majority agreed to the perceptions held by the use of SMAs in learning mathematics. They perceived that the use of SMAs fascinate and make learning mathematics more interesting. This is in agreement with the findings of Slaouti and Barton (2007) which reported that technology can motivate students in their learning by bringing variety into the lessons, and at the same time, sustaining teachers' own interest in teaching. The findings further revealed that majority of the PMTs were of the view that SMAs aid in learning mathematics towards achieving academic excellence. Substantial research has shown that successful integration of technology in K-12 schools have a significant positive impact on student achievement, problem-solving skills, and use of technology as a tool for learning (Drayton, Falk, Stroud, Hobbs, & Hammerman, 2010; Shapley, Sheehan, Maloney, & Caranikas-Walker, 2010; Suhr, Hernandez, Grimes, & Warschauer, 2010).

The findings also revealed that the use of SMAs in learning mathematics dissuade academic laziness in mathematics and improve learning techniques to enhance computational skills and logical reasoning in mathematics. This supports previous findings that participants learning mathematics using cellular phones and applets enhances solving mathematical problems in short time, without much effort and precisely, ensures the correction of their solutions, and makes them more active in their learning (Baya'a & Daher, 2009). Additionally, the findings revealed that the use of SMAs help in the understanding of most mathematics concepts to enhance the rate of assimilation in mathematics. This finding is consistent with the CRA (Concrete, Representational, and Abstract) Model for teaching and learning mathematics currently in better-reaching students as they learn and understand mathematical concepts (Research - Based Education Strategies & Methods, 2012). Similarly, the findings revealed that the use of SMAs enables the accomplishment of mathematics tasks more easily and faster. According to Isernhagen (1999), "Technology is a major catalyst for increasing learning" (p. 30). The findings from the results conclusively indicated that most of the PMTs bear positive perceptions that mathematics apps on their smartphones can be used for enhancing overall learning mathematics process.

4.3.3.1 Factors that influence PMTs' use of SMAs in learning mathematics.

Research Question 2: Which factors (gender, age, academic level, type of smartphone, and awareness) influence PMTs' SMAs use learning mathematics?

To investigate if gender, age, academic level, type of smartphone (OS), and the awareness influence PMTs' use of SMAs in learning mathematics, an Ordinal Logistics Regression Model (OLRM) was conducted to test the null hypothesis that "there is no significant relationship between the factors (gender, age, academic level, type of smartphone, and awareness) and PMTs' SMAs use learning mathematics". Thus, gender, age, academic level, type of smartphone, and the awareness of SMAs statistically have no significant influence on PMTs' use of SMAs in learning mathematics at 0.05 level of significance.

To test the adequacy and the variability of the distributions of the OLRM, a Model Fitting Information, Goodness-of-Fit Statistics, and a Nagelkerke Pseudo R-Square (Nagelkerke R^2) were performed. The Model Fitting Information (see Appendix C) indicates that the model gives better predictions than if we guessed based on the marginal probabilities for the outcome categories since there was a statistically significant improvement over the baseline intercept-only model at $p < 0.05$. Therefore, the full model (with factors that affect the PMTs' use of SMAs in learning mathematics as a predictor) is significantly better than other models. Moreover, the results from the Goodness-of-Fit Statistics analysis (see Appendix D) suggest the model does fit very well at $p > 0.05$ and that the model fits adequately. Furthermore, the Nagelkerke R^2 (see Appendix E) indicates the model accounts for 51.8% of variance in tier entry. This indicates that there is relatively small proportion of the variation. The variability of the distributions (presented in Appendices C, D, & E) suggest the OLRM is highly adequate to be employed to test the null hypothesis (DeCarlo, 2003). Table 8 presents the results from the ordinal logistics regression model.

Table 8

Results from the Ordinal Logistics Regression Model

Factors	Categorical Variables	N	Estimate	Std. Error	Wald	df	p-value
Gender	Male	265	-0.427	0.414	0.919	1	0.338
	Female	55	-0.262				
Age	Below 20	9	-7.089	0.414	0.194	3	0.139
	20 - 29	271	-7.809				
	30 - 39	37	-6.957				
	40 and Above	3	-3.238				
Academic Level	Level 100	80	-0.358	0.130	0.234	3	0.628
	Level 200	80	-0.162				
	Level 300	80	-0.3				
	Level 400	80	-0.25				
Type of Smartphone	Android	273	-17.675	0.320	0.552	3	0.984
	iPhone	28	-12.764				
	Windows Phone	12	-13.91				
	Blackberry	2	-10.01				
Aware of SMAs	Aware	160	25.472	0.000	0.000	1	0.000
	Not Aware	155	11.7				

**Significant ($p < 0.05$), **Highly Significant ($p < 0.001$)*

The Ordinal Logistics Regression Model (OLRM) was performed to ascertain if gender, age, academic level, type of smartphone, and the awareness influence PMTs' use of SMAs in learning mathematics. Table 8 presents the results of the OLRM and as can be seen from this table the test revealed that gender (Wald $X^2(1) = 0.919, p = 0.338$), age (Wald $X^2(3) = 0.194, p = 0.139$), academic level (Wald $X^2(3) = 0.234, p = 0.628$), and type of smartphone (Wald $X^2(3) = 0.552, p = 0.984$) were not found to be statistically significant at 0.05 level of significance. Thus, since $p > 0.05$, likewise the Wald statistics were all greater than 0.05, then gender, age, academic level, and type of smartphone have no statistically significant influence on PMTs' use of SMAs in learning mathematics. Therefore, the null hypothesis that "there is no significant relationship between the factors (gender, age, academic level, and type of smartphone) and PMTs' SMAs use learning mathematics" were accepted at 0.05 level of significance. Hence, gender, age, academic level, and type of smartphone have no statistical influence on PMTs' use of SMAs in learning mathematics.

On the other hand, awareness of the various SMAs (Wald $X^2(1) = 0.000, p = 0.000$) was found to be statistically significant at 0.05 level of significance. As indicated from Table 8, since $p < 0.05$, likewise the Wald statistics was greater than 0.05, then awareness has statistically significant influence on PMTs' use of SMAs in learning mathematics. Therefore, the null hypothesis that "there is no significant relationship between awareness and PMTs' SMAs use learning mathematics was rejected at 0.05 level of significance. In conclusion, awareness of SMAs was found to be statistically significant to influence PMTs' use of SMAs in learning mathematics whereas the other factors (gender, age, academic level, and type of smartphone do not.

4.2.3.2 Discussion of Findings for Research Question 3

Research Question 3 investigated if gender, age, academic level, type of smartphone, and awareness influence PMTs' use of SMAs in learning mathematics. Results from the Ordinal Logistics Regression Model (OLRM) performed revealed that awareness of the various SMAs influence PMTs' use of SMAs in learning mathematics. The finding is in consonance with the findings conducted by Shah, et al. (2016) who found that awareness of the academic use of smartphones and medical apps have a significant influence on the medical students to use their phones for academic purposes.

CHAPTER 5

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.0 Overview

This chapter provides the summary of the study and the key findings. It highlights the conclusion of the study and also outlines some recommendations and areas for future research.

5.1 Summary of Study

The purpose of the study was to investigate the use of Smartphone Mathematics Applications (SMAs) among Pre-Service Mathematics Teachers (PMTs) in learning Mathematics at teacher universities in Ghana. It further investigated the factors that influence PMTs' use of SMAs in learning mathematics and their perceptions about the use of SMAs in learning mathematics.

This study was guided by the following research questions:

1. What SMAs are commonly used among the PMTs and could be effective when integrated in learning mathematics at teacher universities in Ghana?
2. What are the perceptions of PMTs towards the use of SMAs in learning mathematics?
3. Which factors (gender, age, academic level, type of smartphone, and awareness) influence PMTs' SMAs use learning mathematics?

In answering the third research question, the following hypotheses below was formulated for the study;

Null hypothesis: There is no significant relationship between the factors (gender, age, academic level, type of smartphone, and awareness) and PMTs' SMAs use learning mathematics.

Alternative hypothesis: There is no significant relationship between the factors (gender, age, academic level, type of smartphone, and awareness) and PMTs' SMAs use learning mathematics.

The general approach chosen for the study was a survey which employed a cross-sectional survey design as a strategy of enquiry. The targeted population was made up of 1, 840 PMTs at the two teacher universities in Ghana. Purposive sampling was used to select the two teacher universities in Ghana and PMTs owning mobile phones. Secondly, a stratified sampling technique was employed to select a PMTs for the study. The sample comprised of 320 PMTs, 160 from Teacher University A and the other 160 from Teacher University B. A questionnaire was the main instrument used in this study. The responses from the questionnaire were analysed through the use of IBM SPSS version 23. Descriptive data analysis such as frequency distribution, mean and standard deviation were used to analyse, describe and compare the quantitative data in this study. A pie chart was also used to illustrate the visual representation. Inferential data analysis such as Ordinal Logistics Regression Model (OLRM) was employed to find out if gender, age, academic level, type of smartphone, and the awareness influence PMTs' use of SMAs in learning mathematics. In particular, each research question was looked at from all relevant data sources.

5.2 Summary of Key Findings

The key findings of the study are summarized and presented as follows:

In order to find out the SMAs are commonly used among the PMTs and could be effective when integrated in learning mathematics at teacher universities in Ghana, a frequency distribution was used to identify the types of SMAs used by the 92 PMTs using the SMAs in learning mathematics. The top ten (10) types of SMAs commonly used among the PMTs were GeoGebra, Malmath, Mathematics fx, Maths tricks, Maths Formulae, Mathway, Maths Dictionary, Scientific Calculator, MATLAB, All-in-One Calculator, Pocket Maths, Photomath, Calculus Solver, Cymath, and Wolfram Alpha. Findings from the results showed that, GeoGebra among other types of SMAs was commonly used among most (68.5%, N=63) of the PMTs and could be effective when integrated in learning mathematics.

It was also found in this study that of the PMTs using the SMAs in learning mathematics, majority of the PMTs agreed to the perceptions held by the use of SMAs in learning mathematics. They perceived that the use of SMAs fascinate and make learning of mathematics more interesting. The findings also show that among the PMTs using the SMAs in learning mathematics, they perceive that the use of SMAs aid in learning mathematics towards achieving academic excellence, help in understanding most mathematics concepts to enhance the rate of assimilation in mathematics and also enable the accomplishment of mathematics tasks more easily and faster. Moreover, the PMTs have positive perceptions about the use of SMAs in learning mathematics.

Finally, findings from the study indicated that awareness of the various SMAs statistically influence PMTs to use SMAs in learning mathematics. However, sex, age, level, and type of smartphone do not statistically influence PMTs to use SMAs in learning mathematics. Thus, awareness of the various SMAs influence PMTs' use of SMAs in learning mathematics.

5.3 Conclusion

Based on the findings made in this study, it can be concluded that:

- GeoGebra among other types of SMAs was commonly used among most of the PMTs in learning mathematics and could be effective when integrated in learning mathematics.
- The PMTs perceived that the use of SMAs fascinate and make learning of mathematics more interesting and also enable the accomplishment of mathematics tasks more easily and faster. The PMTs have positive perceptions about the use of SMAs in learning mathematics.
- Awareness of the various SMAs influence PMTs' use of SMAs in learning mathematics.

In view of these findings, the researcher has made the following recommendations.

5.4 Recommendations

On the basis of the major findings and the conclusion drawn in this study, it is recommended that:

- PMTs should be encouraged to use SMAs especially, GeoGebra in learning mathematics.
- PMTs should be encouraged to use SMAs in learning mathematics to enhance their computational skills and logical reasoning in mathematics.
- Awareness of the various SMAs in learning mathematics should be raised among PMTs to influence the use of SMAs in learning mathematics.

5.5 Suggestions for Areas of further research

The following are recommended for further research:

- A study in this area can be done to involve more PMTs to obtain the general picture of how the PMTs use SMAs in learning mathematics.
- It is suggested that this study should be replicated to include all PMTs at teacher universities in Ghana.
- Similar study should be conducted in other teacher universities in Ghana and the results compared with this research.

REFERENCES

Adams, D. A., R.R. Nelson, & P.A. Todd (1992). Perceived usefulness, ease of use, and usage of information technology: a replication. *MIS Quarterly*. 16 (2), 227-247.

Agyei, D. & Voogt, J. (2012). Developing technological content knowledge in pre-service mathematics teachers, through Teacher Design Teams. *Australasian Journal of Educational Technology*, *28*(4), 547-564.

Agyemang, M. & Mereku, D. K. (2015). Technology use among Ghanaian Senior High School mathematics teachers and the factors that influence it. *African Journal of Educational Studies in Mathematics and Sciences*, 11, 31 – 42.

Allport, G. W. (1935). Attitudes. In C. M. Murchison. *Handbook of Social Psychology*. Winchester, 798 - 844, MA: Clark University Press.

Almekhlafi, A. G., & Almeqdadi, F. A. (2010). Teachers' perceptions of technology integration in the United Arab Emirates school classrooms. *Educational Technology & Society, 13*(1), 165–175.

Alrafi, A. (2005). Technology acceptance model: Critical analysis with reference to managerial use of information and communication technology. *Innovation North Research Conference*, 18-20, Leeds Metropolitan University, UK. Retrieved 21 November, 2016, fromhttp://www.leedsmet.ac.uk/inn/RIP2005-4.pdf.

An, Y. J., & Reigeluth, C. (2011). Creating technology-enhanced, learner-centered classrooms: K–12 teachers' beliefs, perceptions, barriers, and support needs. *Journal of Digital Learning in Teacher Education*, *28*(2), 54-62.

Anderson, S. E., & Maninger, R. M. (2007). Preservice teachers' abilities, beliefs, and intentions regarding technology integration. *Journal of Educational Computing Research*, *37*(2), 151-172.

Andrews, F. M. & Herzog, A. R. (1986). The quality of survey data as related to age of respondent. *Journal of the American Statistical Association, 81(394),* 403-410. doi: 10.2307/2289229

Athanasios, S. D., & Marios, A. P. (2015). A Review of Mobile Learning Applications for Mathematics. *International Journal of Interactive Mobile Technologies*, *9*(3).doi: http://dx.doi.org/10.3991/ijim.v9i3.4420

Attewell, J. (2005). Mobile technologies and learning: A technology update and m-learning project summary. *Learning and Skills Development Agency*, Argyll Street, London. Retrieved from http://www.m-learning.org/docs/The%20m-learning%20project%20%20technology%20update%20and%20project%20smmary.pdf

Avugbey, F. (2013, August 15). Reverse mobile phone ban in SHSs. *Daily Graphic*. Retrieved from https://www.graphic.com.gh/news/education/reverse-mobile-phone-ban-in-shss-avugbey.html

Babbie, E. (1990). *Survey research methods* (2nd ed.). Belmont, CA: Wadsworth.

Babbie, E. & Mouton, J. (2003). *The practice of social research*. Cape Town: Oxford University Press.

Batista, S. C. F. (2011). *M-learnmat: pedagogical model for m-learning activities in mathematics*. Unpublished PhD in Education thesis, Federal University of Rio Grande do Sul. Porto Alegre, RS, Brazil. Retrieved June 23, 2018 from http://ijonte.org/FileUpload/ks63207/File/01a.batista.pdf

Baya'a, N., & Daher, W. (2009). Learning mathematics in an authentic mobile environment: The perceptions of students. *International Journal of Interactive Mobile Technologies*, *3,* 6–14.

Bless, C., Higson-Smith, C. & Kagee, A. (2006). *Fundamentals of social research methods. An African perspective* (4th. Ed). Cape Town: Juta.

Botzer, G., & Yerushalmy, M. (2007). Mobile applications for mobile learning. *In the proceedings to the Cognition and Exploratory Learning in the Digital Age (CELDA)*, 313-316, Algarve, Portugal.

Boulos, M. N. K., Wheeler, S., Tavares, C., & Jones, R. (2011). How smartphones are changing the face of mobile and participatory healthcare: an overview, with example from eCAALYX. *Biomedical Engineering Online*, *10* (24). doi: http://doi.org/10.1186/1475-925X-10-24

Brink, H. (2006). *Fundamentals of research methodology for health care professionals*. Cape Town: Juta and Co.

Buck, J. L., McInnis, E., & Randolph, C. (2013). The new frontier of education: the impact of smartphone technology in the classroom. *Proceedings of the ASEE Southeast Section Conference*, Atlanta, GA, United States.

Buckenmayer, J. (2008). Revisiting teacher adoption of technology: Research implications and recommendations for successful full technology integration. *College Teaching Methods & Styles Journal, 4*(6), 7-10.

Burns, N., & Grove, S.K. (2011). Understanding nursing research: Building evidence-based practice. China: Elsevier.

Central Bureau of Statistics (2013). *Government, government balance and debt*. Retrieved from http://statline.cbs.nl/StatWeb/publication/default.aspx?DM=SLNL&PA=81194ned&D1=410%2c1213&D2=a&D3=49%2c53%2c54&HDR=G2%2cG1&STB=T&VW=T

Creswell, J.W. (2009). *Research design: Qualitative, quantitative and mixed methods approach.* London: Sage Publication.

Cruz, Y., Assar, S., & Boughzala, I. (2012). Exploring teacher's perception and potential use of Mobile Learning in a Business School. *18th Americas Conference on Information Systems*, Washington, USA**.**

Cumaoğlu, G. K. (2015). How Mobile Devices Affect Students According to Teachers' Beliefs. *Journal of International Education Research*, *11*(4), 217-230.

Daher, W. (2011). Learning mathematics in the mobile phone environment: students' emotions. *Journal of Interactive Learning Research, 22*(3), 357-378. Chesapeake, VA.

Daniel, E. G. S. (2008). An emergent Scaffolding Model of Tertiary M-learning: A case study of science teacher education. *2nd International Mobile Learning and Edutainment Conference*. Kuala Lumpur, Malaysia.

Davis, F. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, *13*(3), 319-340.

Davis, F., Bagozzi, R. P., & Warshaw, P. R. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science, 35*(8)*,* 982-1003.

DeCarlo, L. T. (2003). An application of signal detection theory with finite mixture distributions to source discrimination. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29*(5), 767–778. https://doi.org/10.1037/0278-7393.29.5.767

Dounay. J. (2004). Pagers and cellular phones on school property. *Education Commission of the States: Safety Notes*. Retrieved from http://www.ecs.org/html/Document.asp?chouseid=5444

Drayton, B., Falk, J. K., Stroud, R., Hobbs, K., & Hammerman, J. (2010). After installation: Ubiquitous computing and high school science in three experienced, high-technology schools. *The Journal of Technology, Learning, and Assessment*, *9*(3).

Durrheim, K. (1999). Quantitative Measurement. In M. Blanch, & K. Durrheim, *Research in Practice: Applied Methods for the Social Sciences,* 72-95. Cape Town: University of Cape Town Press.

Dweck, C. S. (2008). Can personality be changed? The role of beliefs in personality and change. *Association for Psychological Science*, *17*(6), 391-394.

EducationalAppStore (n.d.). *Mathway*. Retrieved on March 5, 2018 from https://www.educational appstore .com/app/mathway

Ekanayake, S. Y., & Wishart, J. (2014). Integrating mobile phones into teaching and learning: A case study of teacher training through professional development workshops. *British Journal of Educational Technology*. doi: 10.1111/bjet.12131

Ensley, D. & Kaskosz, B. (2012). *Mobile math apps: Innovative smartphone technology. International Conference on Technology in Collegiate Mathematics*. Retrieved from http://archives.math.utk.edu/ICTCM /VOL25/S064/paper.pdf.

Escuder, A., & Furner, M. J. (2012). *The impact of GeoGebra in Math Teachers' Professional Development*. Retrieved from archives.math.utk.edu/ICTM/vol23 /s113/paperpdf

Ferry, B. (2009). Using mobile phones to enhance teacher learning in environmental education. In J. Herrington, A. Herrington, J. Mantei, I. Olney & B. Ferry (Eds.), *New technologies, new pedagogies: Mobile learning in higher education*, 45 - 55. University of Wollongong. Retrieved from http://ro.uow.edu.au/cgi/viewcontent .cgi?article=1081&context=edupapers

Fishbein, M., & Ajzen, I. (1995). *Belief, attitude, intention, and behaviour: An introduction to theory and research*. MA: Addison-Wesley.

Fraenkel, J. R. & Wallen, N. E. (2000). *How to design and evaluate research in education*, (5th ed.). New York: McGraw-Hill Publishing Co.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*(23), 8410-8415.

Gibson, J., Taylor, T., Seymour, Z., Smith, D. T., & Fries, T. P. (2012). Educational aspects of Undergraduate research on smartphone application development. *Proceedings of the World Multi-Conference on Systemics, Cybernetics, and Informatics (WMSCI 2012)*, Orlando, FL, USA.

Ginsberg, R., & McCormick, V. (1998) Computer use in effective schools. *Journal of Staff Development*, *19*, 22-26.

Google Play (2017, August 27). *GeoGebra Graphing Calculator*. Retrieved from https://play.google.com/store/apps/details?id=org.geogebra.android

Google Play (2017, July 11). *Photomath - Camera Calculator*. Retrieved from https://play.google.com/store/apps/details?id=com.microblink .photomath

Google Play (2016, October 15). *Malmath: Step by step solver*. Retrieved from https://play.google.com/store/apps/details?id=com.malmath.apps.mm

Goos, M., & Bennison, A. (2008). Surveying the technology landscape: teachers' use of technology in secondary mathematics classrooms. *Mathematics Education Research Journal, 20*(3), 102-130.

Haffar, A. (2017, August 23). Allow SHS students to use mobile phones – Educationist suggests. *Daily Graphic*. Retrieved from https://www.graphic.com.gh/news /general-news/allow-shs-students-to-use-mobile-phones-educationist-suggests .html

Hartwell, C. L. Lightle, S. S., & Maxwell, B. (2005). High School Students' Perceptions of Accounting. *The CPA JOURNAL*, *75*(1), 62-67.

Haruna, R., Muhammed, A. I., Umaru, Y., & Ahmed, H. T. (2016). Impact of Mobile Phone Usage on Academic Performance Among Secondary School Students in Taraba State, Nigeria. *European Scientific Journal*, *12*(1), 466-470. doi:10.19044/esj.2016.v12n1p466

Healy, L., & Hoyles, C. (2001). A Study of Proof Conceptions in Algebra. *Journal for Research in Mathematics Education, 31*(4), 396-428.

Hendrickson, A.R., P.D. Massey, and T.P. Cronan (1993). On the test-retest reliability of perceived usefulness and perceived ease of use scales. *MIS Quarterly.* 17(2), 227-230.

Hennessy, M. A. (2016). *Smartphone Use in the Classroom: More Advantages than Risks?* Retrieved from http://www.lessonplanspage.com/

Hohenwarter, J., Hohenwarter, M., & Lavicza, Z. (2009). Introducing dynamic mathematics software to secondary school teachers: The case of Geogebra. *Journal of Computers in Mathematics and Science Teaching*, *28*(2), 135-146.

Hohenwarter, M. (2013). GeoGebra 4.4 - From desktops to tablets. *Indagatio Didactica*, *5*(1). 8-18.

Hohenwarter, M., & Fuchs, K. (2004). Combination of dynamic geometry, algebra and calculus in the software system GeoGebra. Retrieved from https://archive.geogebra.org/static/publications/pecs_2004.pdf

Hohenwarter, M., & Preiner, Z. (2007). Dynamic mathematics with GeoGebra. *Journal of Online Mathematics and its Applications*. ID 1448*,* vol. 7.

Hohenwarter, M., Hohenwarter, J., Kreis, Y., & Lavicza, Z. (2008). Teaching and learning calculus with free dynamic mathematics software, GeoGebra. *Proceeding of International Conference in Mathematics Education 2008*. Monterrey, Mexico.

Inan, F. A., & Lowther, D. L. (2010). Factors affecting technology integration in K-12 classrooms: a path model. *Educational Technology Research and Development*, *58*(2), 137-154.

International GeoGebra Institute (2017). *Putting the world's leading dynamic mathematics software and materials in the hands of students and teachers everywhere*. Retrieved from https://www.geogebra.org/about?ggbLang=br

Intsiful, J., Okyere, P. F., & Osae, S. (2003). *Use of ICT for education, research and development in Ghana: Challenges, opportunities, and potentials*. Accra: Unimax Publishers Ltd.

Isernhagen, J. C. (1999). *Technology: A Major Catalyst for Increasing Learning. T.H.E. Journal*, *27*(1).

Johnson, L., Adams, S., & Cummins, M. (2012). *Mobile apps. The NMC horizon report: 2012 higher education edition*. Austin, Texas: The New Media Consortium.

Johnson, L., Levine, A., Smith, R. & Stone, S. (2010). *The 2010 horizon report*. Austin, Texas: The New Media Consortium.

Johnson, L., Smith, R., Willis, H., Levine, A., & Haywood, K. (2011). *The 2011 horizon report*. Austin, Texas: The New Media Consortium.

Jupp, V. (2009). *The Sage dictionary of social research methods*. California: Sage Publication.

Kafyulilo, A. (2012). Access, use, and perceptions of teachers and students towards mobile phones as a tool for teaching and learning in Tanzania. *Education and Information Technologies*. doi:10.1007/s10639-012-9207-y.

Kaufmann, H., Schmalstieg, D., & Wagner, M. (2000). Construct3D: a virtual reality application for mathematics and geometry education. *Education and Information Technologies*, *5*, 263–276.

Kinshuk, D. & Chen, J. (2005). Mobile technology in educational services. *Journal of Educational Multimedia and Hypermedia*, *14*(1), 89-107.

Klopfer, E., Sheldon, J., Perry, J., & Chen, V. H. H. (2012). Ubiquitous games for learning (UbiqGames): Weatherlings, a worked example. *Journal of Computer Assisted Learning*, 28, 465-476.

Klopfer, E., Squire, K., & Jenkins, H. (2002). Environmental detectives' PDAs as a Window into a virtual simulated world. *IEEE Interna- national Workshop* on *Wireless and Mobile Technologies in Education, 10,* 95-98.

Kolog, E., Tweneboah, S., Devine, S. & Adusei, A. (2018). Investigating the use of mobile devices in Schools: A case of the Ghanaian Senior High Schools. *Mobile Technologies and Socio-Economic Development in Emerging Nations*, 81-108. doi: 10.4018/978-1-5225-4029-8.ch005.

Krejcie, R.V. and Morgan, D.W. (1970) Determining sample size for research activities. *Educational and Psychological Measurement*, 30, 607-610. Retrieved from https://doi.org/10.1177/001316447003000308

Lam, J. & Duan, G. (2012). A review of mobile learning environment in higher education sector of Hong Kong: Technological and social perspectives. *ICHL,* 165-173.

Lan, Y. J., Sung, Y. T., & Chang, K. E. (2007). *A mobile-device-supported peer-assisted learning system for collaborative early EFL reading*. Retrieved from http://llt.msu.edu/vol11num3/pdf/lansungchang.pdf

Legris, P., J. Ingham, and P. Collerette (2003). Why do people use information technology? A critical review of the technology acceptance model. *Information & Management*. 40, 191-204.

Lenhart, A. (2015). *Teens, Social Media & Technology Overview 2015*. Washington, DC: Pew Internet & American Life Project. Retrieved on January 3, 2019 from http://www .pewinternet.org/2015/04/09/teens-social-media-technology-2015/

Levin, T., & Wadmany, R. (2008). Teachers views on factors affecting effective integration of information technology in the classroom. *Journal of Technology and Teacher Education*, *16*, 233-263.

Ling, R. S. (2004) Mobile connection: *The cell phone's impact on society*. Morgan Kaufmann, San Francisco.

Litchfield, A., Dyson, L., Lawrence, E., & Zmijewska, A. (2007). Directions for m-learning research to enhance active learning. In ICT: Providing choices for learners and learning. *Proceedings ascilite Singapore*. Retrieved from http://www.ascilite.org.au/conferences/singapore07/procs/litchfield.pdf

Liu, T. C., Lin, Y. C., Tsai, M. J., & Paas, F. (2012). Split-attention and redundancy effects in mobile learning in physical environments. *Computers & Education*, *5*(8), 172-180.

Machado, J. L. A. (2012). *Celular na escola: o que fazer?* Retrieved on June 24, 2018 from http://cmais.com.br/educacao/celular-na-escola-o-que-fazer.

Madden, C. (2010). *The use of smartphones among students in relation to their education and social life* [master's thesis]. Retrieved from https://www.academia.edu/27884833/The_use_of_smartphones_among_students_in_relation_to_their_education_and_social_life?auto=download

Mak, K. K., Lai, C. M., Watanabe, H., Kim, D. I., Bahar, N., & Ramos, M. (2014). Epidemiology of Internet behaviours and addiction among adolescents in six Asian countries. *Cyberpsychology, Behaviour, and Social Networking*, *17*(11), 720-728. doi: https://doi.org/10.1089/cyber.2014.0139

Mason, R. D., Lind, D. A. & Marchal, W., G. (1990). *Statistical Techniques in Business and Economics (10th ed).* Boston: McGraw-Hill Companies, Inc.

Masrom, M., & Hussein, R. (2008). *User Acceptance of Information Technology: Understanding Theories and Models*. Selangor, Venton.

Mereku, D. K., Yidana, I., Hodzi, W., Tete-Mensah, I., Tete-Mensah, W., & Williams,J. B. (2009). Pan-African research agenda on the pedagogical integration of ICT: Phase 1 Ghana report. University of Education, Winneba. *International Development Research Center (IDRC)*, Canada.

Moursund, D., & Bielefeldt, T. (1999). *Will new teachers be prepared to teach in digital age? A national survey on information technology in teacher education.* Retrieved on May 6, 2018 from http://www.mff.org/publications/publications. taf?page=154

Muijs, D. (2004). *Doing quantitative research in education with SPSS*. London: SAGE Publishers Ltd

Naismith, L., Lonsdale, P., Vavoula, G., & Sharples, M. (2004). *Literature Review in Mobile Technologies and Learning* (Futurelab Series Report 11). Bristol: Futurelab. Retrieved from https://www.nfer.ac.uk/publications/FUTL15

National Communication Authority (NCA) (2018, March 20). *29 million Ghanaians use 34 million mobile phones*. Retrieved from https://www.ghanaweb.com /GhanaHomePage/NewsArchive/29-million-Ghanaians-use-34-million-mobile -phones636095#:~:text=A%20recent%20report%20on%20the,a%20penetratio n%20rate%20of%20119%25

National Communication Authority (NCA) (2013, March 22). *Ghana has 26.09 million mobile phone users*. Retrieved from https://www.ghanaweb.com /GhanaHomePage/NewsArchive/Ghana-has-26-09-million-mobile-phone users-268640

Newhouse, C. P., Williams, P. J., & Pearson, J. (2006). Supporting mobile education for pre-service teachers. *Australasian Journal of Educational Technology, 22*(3), 289–311.

Ng, E. M. W., Shroff, R. H., & Lim, C. P. (2013). Applying a modified technology acceptance model to qualitatively analyse the factors affecting e-portfolio implementation for student teachers' in field experience placements. *Issues in Informing Science and Information Technology*, *10*, 355-365.

Nguyen, D. M., & Kulm, G. (2005). Using web-based practice to enhance mathematics learning and achievement. *Journal of Interactive Online Learning*, *3*(3), 1-16.

Nov, O., & Ye, C. (2008). Users' personality and perceived ease of use of digital libraries: The case for resistance to change. *Journal of the American Society for Information Science and Technology, 59*(5), 845-851.

Okolie, T. (2016). How can a smartphone make your studying for competitive exams easy? Retrieved from https://www.quora.com/How-can-a-smartphone-make-your-studying-for-competitive-exams-easy

Oppenheim, A.N. (1992). *Questionnaire Design, Interviewing and Attitude Measurement*. London: Pinter Publishers.

Polit, D. F., Beck, C. T., & Hungler, B. P. (2010). *Essentials of nursing research: Methods, appraisal, and utilization*. New York: Philadelphia.

Prishtina Insight (2016). *Kosovar students create math app hit*. Retrieved from http://prishtinainsight.com/kosovar-students-create-math-app-hit/

Proctor, C. P., Daley, S., Louick, R., Leider, C. M., & Gardner, G. L. (2014). How motivation and engagement predict reading comprehension among native English-speaking and English-learning middle school students with disabilities in a remedial reading curriculum. *Learning and Individual Differences*, *36*, 76-83.

Research - Based Education Strategies & Methods (2012). *Concrete Representational Abstract (CRA)*. Retrieved from https://makingeducationfun .wordpress.com/2012/04/29/concreterepresentationa-abstract-cra/

Ringle, C. M., Wende, S., & Becker, J. M. (2015). *SmartPLS 3*. Bönningstedt: SmartPLS.

Ritzhaupt, A. D., Dawson, K., & Cavanaugh, C. (2012). An investigation of factors influencing student use of technology in K-12 classrooms using path analysis. *Journal of Educational Computing Research*, *46*(3), 229-254.

Ruthven, K. (2009). Towards a naturalistic conceptualisation of technology integration in classroom practice: The example of school mathematics. *Education & Didactique*, *3*(1), 131–159.

Sambamurthy, V., and W.W. Chin (1994). The Effects of Group Attitudes toward Alternative GDSS Designs on the Decision-making Performance of Computer-Supported Groups. *Decision Sciences*. 25(2), pp. 215-241.

Seabra, C. (2013). *O celular na sala de aula*. Retrieved from http://cseabra.wordpress.com/2013/03/03/o-celular-na-sala-de-aula/

Segars, A.H., and V. Grover (1993). Re-examining Perceived Ease of Use and Usefulness: A Confirmatory Factor Analysis. *MIS Quarterly*. 17(4), 517-525.

Serin, O. (2012). Mobile learning perceptions of the prospective teachers (Turkish republic of Northern Cyprus sampling). *The Turkish Online Journal of Educational Technology, 11*(3), 222-233.

Shah, J., Haq, U., Bashir, A., & Shah, S. A. (2016). Awareness of academic use of smartphones and medical apps among medical students in a private medical college? *Journal of Pakistan Medical Association*, 66(2), 184–186.

Shapley, K. S., Sheehan, D., Maloney, C., & Caranikas-Walker, F. (2010). Evaluating the implementation fidelity of technology immersion and its relationship with student achievement. *The Journal of Technology, Learning and Assessment*, *9*(4).

Shuler, C. (2009). *Pockets of potential: Using mobile technologies to promote children's learning*. New York: The Joan Ganz Cooney Center at Sesame Workshop.

Slaouti, D., & Barton, A. (2007). Opportunities for practice and development: newly qualified teachers and the use of information and communication technologies in teaching foreign languages in English secondary school contexts. *Journal of In-service Education*, *33*(4), 405-424. doi: 10.1080/13674580701687807.

Smith, A. (2013). *PEW Research Center Report on Smartphone ownership*. Retrieved June 5, 2017, from http://www.pewinternet.org/files/old-media//Files/Reports/2013/PIP_Smartphone_adoption_2013_PDF.pdf

Stevens, S. S. (1946). *On the Theory of Scales of Measurement.* Science, New Series, 103(2684), 677-680. doi:10.1126/science.103.2684.677. PMID 17750512.

Stols, G. (2007) Designing mathematical technological activities for teachers using the Technology Acceptance Model. *Pythagoras*, *65*, 10–17.

Suhr, K. A., Hernandez, D. A., Grimes, D., & Warschauer, M. (2010). Laptops and fourth grade literacy: Assisting the jump over the fourth-grade slump. *The Journal of Technology, Learning, and Assessment*, *9*(5).

Szajna, B. (1994). Software evaluation and choice predictive validation of the Technology Acceptance Instrument. *MIS Quarterly*. 18(3), 319-324.

Taylor, S., & Todd, P. A. (1995). Assessing IT usage: The role of prior experience. *MIS Quarterly*, *19*(4), 561-670.

Thobakgale, E. M. (2013). *Factors contributing to absenteeism on pupil nurses in the nursing schools of Capricorn District* [master's thesis]. Retrieved from http://ul.netd.ac.za/bitstream/handle/10386/1013/Thobakgale_em_2013.pdf?sequence=1

Thompson, R. L., Compeau, D., & Higgins, C. (2006). Intentions to use information technologies: An integrative model. *Journal of Organisational and End User Computing (OEUC)*, *18*, 25-46.

Tondeur, J., van Keer, H., van Braak, J., & Valcke, M. (2008). ICT integration in the classroom: Challenging the potential of a school policy. *Computers & Education*, *51*, 212–223

Twum, R. (2011). *Students' Questionnaire on Mobile Phone Use in Learning (SQMPUL)*. Kenyatta University, Kenya.

United Nations Educational, Scientific and Cultural Organization (UNESCO) (2013). *Policy guidelines for mobile learning* [Guidelines]. Paris, France. Retrieved from http://unesdoc.unesco.org/images/0021/002196/219641e.pdf

Uptodown (2017, August 8). *Mathway*. Retrieved from http://mathway.en.uptodown.com/android

Uptodown (2017, February 3). *Photomath*. Retrieved from http://photomath.en .uptodown.com/android

Uzunboylu, H., & Ozdamli, F. (2011). Teacher perception for m-learning: scale development and teachers' perceptions. *Journal of Computer assisted learning, 27*(6)*,* 544-556.

Valk, J. H., Rashid, A. T., & Elder, L. (2010). *Using mobile phones to improve educational outcomes: An analysis of evidence from Asia*. Toronto: Pan Asia Networking.

Vavoula, G., & Karagiannidis, C. (2005). Designing mobile learning experiences. In Bozanis, P. & E. N. Houstis (Eds.), *PCI 2005, LNCS 3746*, 534-544. Berlin: Springer-Verlag.

Venkatesh,V. (2000). Determinants of perceived ease of use: integrating control, intrinsicmotivation, and emotion into the technology acceptance model. *Information Systems Research*, 11(4), 342-365.

Viswanathan, P. (2016, Feb 10). *What is a Mobile Application?* Retrieved from https://www.lifewire.com/what-is-a-mobile-application-2373354

Vyas, N., & Nirban, V. S. (2014). Students' Perception of the Effectiveness of Mobile Learning in an Institutional Context. *ELT Research Journal*, *3*(1), 26-36.

Wang, Y. S., Lin, H. H., & Luarn, P. (2006). Predicting consumer intention to use mobile Service. *Information Systems Journal, 16*(2)*,* 157–179.

Warschauer, M., Zheng, B., Niiya, M., Cotten, S., Farkas, G. (2014). Balancing the one-to-one equation: equity and access in three laptop programs. Equity Excellent Education, 47(1), 46–62.

West, M. (2012). Mobile learning for teachers' global themes. *United Nations Educational, Scientific and Cultural Organization (UNESCO)*, Paris, France. Retrieved from http://unesdoc.unesco.org/images/0021/002164/216452e.pdf

Wijers, M., Jonker, V., & Kerstens, K. (2008). MobileMath: The Phone, the Game and the Math. *2nd European Conference on Games Based Learning*. Barcelona, Spain. Retrieved from http://www.fi.uu.nl/publicaties/literatuur /2008_wijers_jonker_kerstens_mobilemath.pdf

Willemse, I., Waller, G., Süss, D., Genner, S., & Huber, A. L. (2012). *Jugend, Aktivitäten, Medien-Erbebung Schweiz (JAMES)*. Zürcher Hochschule für Angewandte Wissenschaften, Zürich.

Wishart, J. (2009). *Use of Mobile Technology for Teacher Training*. Retrieved from http://www.academia.edu/2808648/Use_of_mobile_technologyfor_teacher_training

Wong, Y. H., & Csete, J. (2004). Mobile learning framework: A cross-reference of m-commerce experience. In Cantoni, L. & McLoughlin, C. (Eds.), *Proceedings of ED-MEDIA 2004 - World Conference on Educational Multimedia, Hypermedia & Telecommunications*, 223-230. Lugano, Switzerland: Association for the Advancement of Computing in Education (AACE). Retrieved from https://www.learntechlib.org/p/12936/

Yerushalmy, M., & Weizman, A. (2007). *Math 4 mobile environment*. The University of Haifa. Retrieved from http://www.math4mobile.com

Yusof, A. M., Daniel, E. G. S., Low, W. Y., & Aziz, K. A. (2014). Teachers' Perception on Mobile Learning for Special Needs Learner: The Malaysian case study. *International Journal of Inclusive Education*, 1-10. doi: http://dx.doi.org/10.1080/13603116.2014.885595

Zaranis, N., Kalogiannakis, M., & Papadakis, S. (2013). Using Mobile Devices for Teaching Realistic Mathematics in Kindergarten Education. *Scientific Research*, *4*(7), 1 - 10. doi: http://dx.doi.org/10.4236/ce.2013.47A1001

Zejno, B., & Islam, A. (2012). Development and validation of library ICT sage scale for the IIUM postgraduate students. *OIDA International Journal of Sustainable Development, 3*(10), 11-18.

Zhao, X. Y., & Okamoto, T. (2009). Scalable learning contents for virtual community in a context aware environment. *IEEE Multidisciplinary Engineering Education Magazine*, *4*(1), 37–45.

Zulkafly, N. A., Koo, A. C., Shariman, T. P. N., & Zainuddin, M. N. (2011). Educators' perceptions towards Mobile Learning. *Artificial Intelligence Workshop*, Kuala Lumpur, Malaysia.

Zulnaidi, H., & Zakaria, E. (2012). The Effect of Using GeoGebra on Conceptual and Procedural. *Asian Social Science, 8*(11), 102-106.

APPENDIX A

Questionnaire for Pre-service Mathematics Teachers

UNIVERSITY OF EDUCATION, WINNEBA

FACULTY OF SCIENCE EDUCATION

DEPARTMENT OF MATHEMATICS EDUCATION

Dear student,

I am Anthony Gyimah, a final year MPhil student offering Mathematics Education, and I am conducting research on Pre-service Mathematics Teachers use of *Smartphone Mathematics Applications* in learning Mathematics. Note, this questionnaire is to be answered by students with *mobile phones* only. Please take few minutes of your time to answer this questionnaire.

NB. *You are assured that any information you provide will be treated strictly confidential, and be used only for the purpose of this study. Thank you.*

Instructions: Please tick (✓) where applicable

PART A

Background Information

1. Sex?

   [ ] Male [ ] Female

2. Age?

   [ ] Below 20 years [ ] 20 – 29 years

   [ ] 30 – 39 years [ ] Above 40 years

3. Academic level?

   [ ] 100 [ ] 200

   [ ] 300 [ ] 400

PART B

Information on Mobile Phone Usage

4. What do you normally use your mobile phone for? *(Please you can tick **more than one**).*

   [ ] Make Calls

   [ ] SMS/ Instant Messaging

   [ ] Taking pictures

   [ ] Entertainments *(eg. Music, videos, games, radio, etc.)*

   [ ] E-mails *(Sending and Receiving mails)*

   [ ] Social Media *(eg. Facebook, Twitter, WhatsApp, Instagram, Snap chat, etc.)*

   [ ] Surfing Internet/Browsing

   [ ] Creating or Reading Documents *(like word or pdf)*

   [ ] Business purpose (*eg. Mobile banking, Mobile money, etc.*)

   [ ] Other(s) (*specify:)* ……………………………..

5. Do you use your Mobile Phone for any learning purpose(s)?

   [ ] Yes [ ] No (Please skip to Question 6)

   If yes, which of the areas do you use it for?

   [ ] Mathematics [ ] Other courses [ ] Both

6. How frequently do you use your mobile phone?

   [ ] Not at all [ ] Quite frequent

   [ ] Frequent [ ] Extremely frequent

7. Is your mobile phone a **Smartphone**?

   [ ] Yes (Please continue)

   [ ] No (Please **do not** continue, Thank you for your time)

PART C
Information on Smartphone Usage

8. What is your Smartphone type (OS)?

   [ ] Android

   [ ] iPhone

   [ ] Windows Mobile

   [ ] Other (*Specify*)……………………………….……

9. How many **years** have you been using your Smartphone?

   [ ] Less than a year

   [ ] 1 – 3 years

   [ ] More than 3 years

10. Have you been **using** any Mobile Application(s) on your Smartphone?

    [ ] Yes   [ ] No (Please skip to Question 11)

    (If Yes) Please Specify those you have been using here ……………………………...

    ………………………………………………………………………………………

    ………………………………………………………………………………………

PART D
Information on Use of Smartphone Mathematics Applications (SMAs) in learning Mathematics

11. Are you **aware** of any *Smartphone Mathematics Application*(s) in learning Mathematics?

    [ ] Yes

    [ ] No (Please **do not** continue, Thank you for your time)

    (If Yes) Please Specify those you know about here ……...…………………………..

    ………………………………………………………………………………………

    ………………………………………………………………………………………

12. Have you been **using** any of the *Smartphone Mathematics Application*(s) (SMAs) you listed in 11?

[ ] Yes

[ ] No (Please **do not** continue, Thank you for your time)

13. Which of the SMAs (listed in 11) could be effective when integrated in learning Mathematics?

……………………………………………………………………………………….

……………………………………………………………………………………….

……………………………………………………………………………………….

……………………………………………………………………………………….

14. To what **extent** do you use the *Smartphone Mathematics Application*(s) (SMAs) in learning mathematics

[ ] Little Extent

[ ] Some Extent

[ ] Great Extent

PART E

Perceptions of the use Smartphone Mathematics Applications in Learning Mathematics

The following table shows various perceptions of the use of Smartphone Mathematics Applications (SMAs) in learning mathematics. Please read each statement and circle O *the number which best shows how you feel.*

(SD= Strongly Disagree, D= Disagree, U= Undecided, A= Agree, SA= Strongly Agree)

PERCEPTIONS	SD	D	U	A	SA
15. SMAs fascinate and make learning mathematics more interesting.	1	2	3	4	5
16. SMAs aid in learning mathematics towards achieving academic excellence.	1	2	3	4	5
17. SMAs discourage academic laziness in mathematics.	1	2	3	4	5
18. SMAs aid the learning of mathematics independently.	1	2	3	4	5
19. SMAs improve learning techniques to enhance computational skills and logical reasoning.	1	2	3	4	5
20. SMAs help in the understanding of most mathematics concepts to enhance the rate of assimilation in mathematics.	1	2	3	4	5
21. SMAs enable the accomplishment of mathematics tasks more easily and faster.	1	2	3	4	5

***** Thank you for your Time *****

APPENDIX B

Reliability Test Statistics

Reliability Test Statistics

Cronbach's Alpha	N of Items
0.653	7

APPENDIX C

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	p-value
Intercept Only	375.368			
Final	201.911	173.457	13	0.000

APPENDIX D

Goodness-of-Fit Statistics

	Chi-Square	df	Sig.
Pearson	144.323	248	0.999
Deviance	131.255	248	0.909

APPENDIX E

Pseudo R-Square Analysis

Cox and Snell	0.423
Nagelkerke	0.508
McFadden	0.307

APPENDIX F

Introductory Letter

UNIVERSITY OF EDUCATION, WINNEBA
FACULTY OF SCIENCE EDUCATION
DEPARTMENT OF MATHEMATICS EDUCATION
P. O. Box 25, Winneba, Ghana
+233 (020) 2041076
math@uew.edu.gh

March 12, 2018

Dear Sir/ Madam,

LETTER OF INTRODUCTION

I would be please if you provide the necessary assistance to **MR. ANTHONY GYIMAH,** a second year M.PHL student with index number **8150110022,** to conduct his research in your institution.

He is pursuing Master of Philosophy in Mathematics Education in the Department of Mathematics Education, UEW and wishes to conduct his research on **"INVESTIGATING THE USE OF SMARTPHONE MATHEMATICS APPLICATIONS AMONG PRE-SERVICE MATHEMATICS TEACHERS AT TEACHER UNIVERSITIES IN GHANA"**

I hope your assistance will help him greatly.

I count on your assistance.

Thank you.

Yours faithfully,

Dr. Charles K. Assuah (Ph.D)
Ag. Head of Department

H. O. D
DEPT. OF MATHS EDUCATION
UEW