ABSTRACT

PORTER, SAMANTHA PATRICIA. Introducing Dynamic Geometry to Future Mathematics Teachers in a Caribbean Country: A Case Study (Under the direction of Dr. Karen Keene).

This thesis describes, analyzes data, and reports results from a four day workshop initiative developed and provided for pre-service mathematics teachers at the St. Vincent Community College Division of Teacher Education to introduce the Geogebra, an online mathematics software. The purposes of this study were to evaluate pre-service teachers' (PSTs) engagement during the workshop and their response to the use of the Software and to determine the quality of tasks written by the pre-service teachers using GeoGebra.

The research design was a case study of a group of secondary mathematics education PSTs with a focus on their responses in terms of attitude, curricular issues, pedagogical issues, mathematical content and the different activities completed during the workshop as well as their cognitive, behavioral and emotional engagements and the quality of PSTs tasks using GeoGebra. Data from questionnaires, video and written tasks were collected and analyzed under a conceptual framework based on the work of Bu et al. (2010), Prienner (2008); Fredricks, Blumenfeld, and Paris (2004); the Powell, Francisco, & Maher (2003) and Trocki (2014).

The researcher found that PSTs responded positively to the introduction of GeoGebra, in all aspects. They self-reported that completing tasks using GeoGebra was easy; they demonstrated a positive attitude towards using GeoGebra.

Students were engaged cognitively mainly through explanations and exploration. Behavioral engagements were exhibited in the form of manipulating and dragging of dynamic creations, discussions, active participation and questionings. Emotion engagements

were quite evident in students' expressions of joy, excitement, and uncertainty. Tasks written by PSTs contained both technological action and mathematical depth. Some of the tasks were of better quality than others.

Implications for this study are several. Students that are introduced to technology and tasks as adults, even though they have not had any experience, are responsive to learning and engage quickly and easily. The potential for using GeoGebra to teach and learn mathematics in St. Vincent and the Grenadines and other Caribbean countries is great and far reaching.

Introducing Dynamic Geometry to Future Mathematics Teachers in a Caribbean Country: A Case Study

by
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BIOGRAPHY

Samantha P. Porter was born at the Milton Cato Memorial Hospital in St. Vincent and the Grenadines. She attained her primary Education at the Belair Government School and her secondary education at the St. Vincent Girls High School. She then attended the St. Vincent Grammar School where she completed her Advance level subjects. She began her teaching career at the Emmanuel High school where she taught for several years. She is married to Gilbert Porter and a mother of two children. She is also a very active Christian.

She continued her education at the St. Vincent Teachers' College and graduated top of her Class and was award valedictorian. She continued to forward her studies at the University of the West Indies and complete a Bachelor of Education in Mathematics with honors. Upon completion of her first degree she joined the staff at the St. Vincent Teachers' College (Now St. Vincent Community College: Division of Teacher Education), where she is currently a mathematics education lecturer.

She is a Fulbright scholar and is currently reading for a Master of Science in Mathematics Education.

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CHAPTER ONE - INTRODUCTION

During 2014, the government of St. Vincent and Grenadines embarked on a project to distribute 12,500 Acer laptops to secondary and post-secondary school students and teachers as part of the government's One Laptop per Student initiative (I-Witness News, 2014). Therefore, computer technology for mathematics classrooms has experienced an explosive growth both in terms of development and as well as availability in the country. However, traditional methods of teaching and learning are still dominant in St. Vincent and the Grenadines' mathematics classrooms, so professional development in more modern pedagogical practices is an area deserving close attention. Many teachers are struggling with the task of effectively using technology for everyday teaching.

Considering the vital role teachers play in a technology-supported mathematics classroom, in many countries it may just be a matter of adapting professional development opportunities in order to prepare teachers for this new challenge of effectively integrating technology into their teaching practice (Preiner, 2008). There were previously few opportunities provided to teachers by the government of St. Vincent and the Grenadines for professional development to enable teachers to gain some experience in a digital environment; yet there was a clear, demonstrated need to do this. Given these circumstances, it was deemed necessary to start with pre-service teachers. If pre-service mathematics teachers, who will eventually guide the learning environments for their students, become familiar with the use of GeoGebra, then this may improve their attitudes and skills in the use of technology in mathematics instruction and accordingly encourage them to integrate technology in their future classes. Hence, for this reason it is imperative for the pre-service mathematics teachers to be introduced to current software with which they can easily transfer these competencies into the learning environment.

In order to introduce pre-service teachers (PSTs) to the value of using technology the researcher provided a new professional development, never before provided in the country. The different sessions introduced PSTs to new approaches for teaching with technology which will help them to become better prepared for effectively integrating technology into their own teaching practice. This workshop initiative also has the potential to serve as a catalyst for the redesigning and implementation of a curriculum with the integration of technology in the teaching of mathematics in all primary and secondary schools throughout St. Vincent and the Grenadines.

In this technological explosion in the world, we have experienced rapid changes that have taken place in education. There has been an increase in the use of multimedia technology, especially computers and special software, in the teaching of mathematics. Integrating technology into learning is providing greater learning opportunities for students (Roberts, 2012), and the use of technology can enhance the student abilities. In addition, integrating technology in the classroom will help to produce students who have the potential and expertise in both technology and academics.

Technological advances in mathematics education have paved the way for teachers to use technology to improve the quality of teaching and learning. As a result of the implementation of policies that emphasize the importance of using technology in education, all stakeholders involved in education are faced with the important task of reforming pedagogy tools to improve teaching and learning.

Algebra and geometry are two core strands of mathematics curricula throughout the world and are considered the “two formal pillars” of mathematics (Atiyah, 2001). It is therefore not surprising that they have been specifically targeted by the field of technology (Sangwin, 2007); hence GeoGebra was selected for this research. GeoGebra is dynamic mathematics software (DMS) designed for teaching and learning mathematics for all levels of education. The software combines the ease of use of dynamic geometry software (DGS) with certain features of a computer algebra system (CAS) and therefore is essential in making the necessary connections between geometry, algebra, spreadsheets, graphing, statistics and calculus (Hohenwarter and Preiner, 2007). In addition, GeoGebra can be used to visualize mathematical concepts as well as to create instructional materials.

GeoGebra has the potential to clearly demonstrate to students the close connection between geometry and algebra and is becoming a recognized part of mathematical knowledge (Jones and Edwards, 2006; Hohenwarter and Jones, 2007). Edwards and Jones (2006, p.30) believe that a significant feature of GeoGebra is “its activities which require high-level thinking and enable students to engage with the potential that technology brings, such as learning through feedback, seeing patterns, making connections and working with dynamic image.” In addition, teachers and students can download and use GeoGebra at home as it is an open-source software.

Aims of the research: The principal aims of the study are to investigate (a) impressions, feelings, beliefs, and new knowledge developed by the participating pre-service teachers, (b) evaluate tasks written in GeoGebra by the participants, and (c) evaluate pre-service teachers' motivation to continue using the software to teach Mathematics.

The research questions are:

1. How do pre-service mathematics teachers respond (for example, ratings of tasks, attitudes and mathematical issues) to a GeoGebra workshop?
2. How do pre-service mathematics teachers engage in a GeoGebra workshop?
3. Do GeoGebra tasks written by pre-service teachers contain prompts that will encourage students to experiment and build their mathematical understanding?

The following four chapters include the literature review, methods, results, and discussion and implications. The literature review includes a synthesis of my understanding regarding the research and theory concerning my role in educational technology. The next chapter explains the methods for data collection and analysis. The results chapter presents the findings. In the last chapter, I discuss and interpret the data, which details the study's findings and contributions to my learning, including implications for future work and research.

CHAPTER TWO - REVIEW OF LITERATURE

Introduction

Each of the areas described in this literature review was essential for this study, which examined the design, development, and implementation of the GeoGebra workshop for pre-service teachers. The development of this study considered literature on GeoGebra, teacher training and technology integration; the role of technology in mathematics education; pre-service teachers' perceptions of technology; barriers in technology integration; benefits of engagement in learning, and instruction design. Research from this literature review served as a guide for developing instruction that will meet pre-service teachers' needs, helped pre-service teachers integrate technology, and refine my professional practice. In addition, as Beile & Boote (2005) suggested, this literature review moves beyond summarizing the research into a synthesis of the various literature bases and their application to the foundation of this study.

For high quality professional development, "*It is important to know in which way a software package can be introduced to novices most effectively*" (Mously, Lambdin, & Koc, 2003, p. 401). This serves to minimize unnecessary difficulties and impediments during the introduction process for teachers and to facilitate the first contact with the new software tool as much as possible. It is important that teachers feel comfortable with operating a new software tool, because teachers who are comfortable will be more likely to integrate this tool into their teaching practices than teachers who experienced initial difficulties (Mously et al., 2003). In this workshop, the open-source software GeoGebra was selected from the pool of available software packages for mathematics teaching and learning (e.g., dynamic geometry software (DGS), computer algebra systems (CAS), spreadsheets), because GeoGebra is a versatile tool that combines the ease of use of DGS with features of CAS and is free and available.

What is GeoGebra?

GeoGebra is a dynamic mathematics software (DMS) designed for teaching and learning mathematics at all levels. The software combines the ease of use of a dynamic geometry software (DGS) with certain features of a computer algebra system (CAS) and therefore, allows for bridging the gap between the mathematical disciplines of geometry, algebra, and even calculus (Hohenwarter and Preiner, 2007). On the one hand, GeoGebra can be used to visualize mathematical concepts as well as to create instructional materials. GeoGebra also has the potential to foster active and student-centered learning by allowing for mathematical experiments, interactive explorations, as well as discovery learning (Bruner, 1961).

Short History of GeoGebra

The development of GeoGebra began in 2001 as Markus Hohenwarter's Master's thesis project at the University of Salzburg, Austria. After studying mathematics education as well as computer engineering, he started to implement his idea of a programming software that joins dynamic geometry and computer algebra, two math disciplines that other software packages tend to treat separately. His main goal was to create educational software that combines the ease of use of dynamic geometry software with the power and features of a computer algebra system, which could be used by teachers and students from secondary school up to college level. After publishing a prototype of the software on the Internet in 2002, teachers in Austria and Germany started to use GeoGebra for teaching mathematics, which was, at this point, rather unexpected by the creator, who got a lot of enthusiastic emails and positive feedback from those teachers (Hohenwarter and Lavicza, 2007, p. 49 – 50).

In 2002, Hohenwarter received the European Academic Software Award EASA in Ronneby, Sweden, which finally inspired him to go on with the development of GeoGebra in order to enhance its usability and extend its functionality. Further development of GeoGebra was funded by a DOC scholarship awarded to Hohenwarter by the Austrian Academy of Sciences, which also allowed him to earn his PhD in a project that examined pedagogical applications of GeoGebra in Austrian secondary schools. During the next four years GeoGebra won several more software and media awards in different European countries, including Austria, Germany, and France (Hohenwarter and Lavicza, 2007).

Since 2006, GeoGebra’s ongoing development has continued at Florida Atlantic University, USA, where Hohenwarter works in a teacher training project funded by the National Science Foundation’s Math and Science Partnership initiative. During the last two years of close collaboration with a number of middle and high school mathematics teachers, GeoGebra was enhanced by including a range of important features. This enhanced functionality enabled the creation of user defined tools and significant simplification in the steps required for user creation of interactive instructional materials, the so called *dynamic worksheets*.

GeoGebra is freely downloadable from the Internet and thus it is available both in schools and at home without any limitations (Hohenwarter & Lavicza, 2007). To date there is only limited research available in relation to the effective integration of GeoGebra into teaching and learning mathematics. However, research on other dynamic geometry packages suggests that dynamic software can be effectively integrated into mathematics education and have the potential to foster student-centered and active learning (Jones, 1999; Laborde, 2002; Erez & Yerushalmy, 2006).

Beyond DGS features GeoGebra also offers additional algebraic and graphical representations of mathematical objects which can also contribute to students' deeper understanding of mathematical concepts (Duval, 1999). Developing dynamically connected DGS and CAS features within a single software package was one of the desires of researchers for development (Schumann & Green, 2000). GeoGebra not only offers a novel dynamically connected learning environment, but also its development aimed at delivering a software package that can be utilized in a wide range of grade levels.

By attempting to follow the 'KISS' principle ('keep it short and simple'), developers emphasized that users should be able to use the software intuitively without having advanced computer skills (Hohenwarter,Hohenwarter and Lavicza, 2009)

GeoGebra's User Interface

Since GeoGebra joins dynamic geometry with computer algebra, its user interface contains additional components that are not found in pure dynamic geometry software. Apart from providing two windows containing the algebraic and graphical representation of objects, components that enable the user to input objects in both representations as well as a menu bar are part of the user interface (see figure 1). Preiner (2008) described the features of GeoGebra tools as follow:

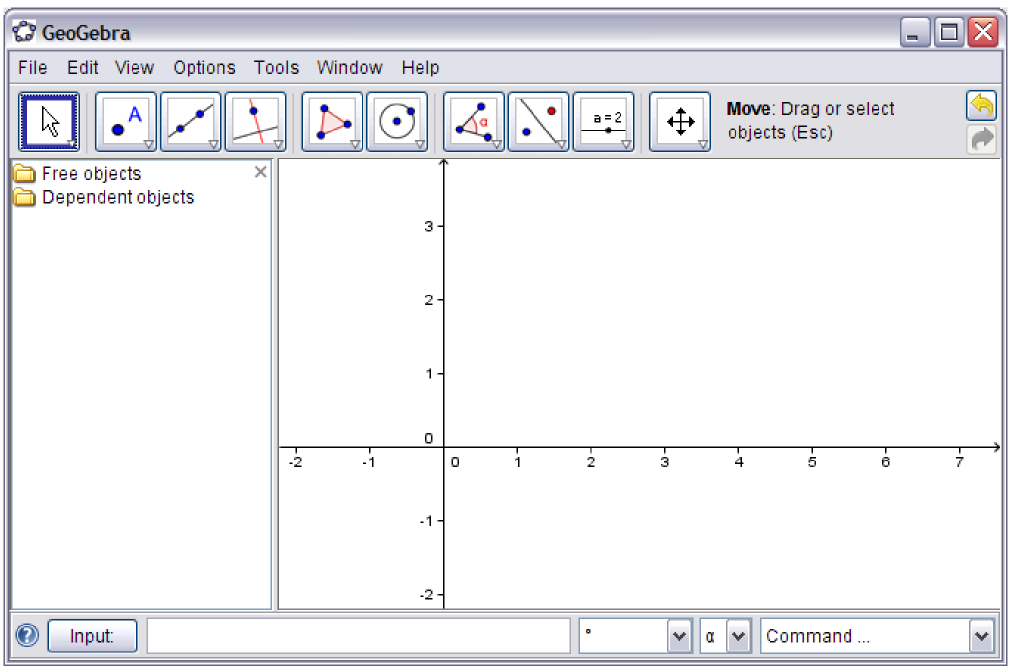

Figure: 1: GeoGebra's user interface

***Graphics window*:** The graphics window is placed on the right hand side of the GeoGebra window. It contains a drawing pad on which the geometric representations of objects are displayed. The coordinate axes can be hidden and a coordinate grid can be displayed by the user. In the graphics window, existing objects can be modified directly by dragging them with the mouse, while new objects can be created using the dynamic geometry tools provided in the toolbar.

Toolbar: The toolbar consists of a set of toolboxes in which GeoGebra's dynamic geometry tools are organized. Tools can be activated and applied by using the mouse in a very intuitive way. Both the name of the activated tool as well as the toolbar help, which is placed right next to the toolbar, give useful information on how to operate the corresponding tool and, therefore, how to create new objects. In the right corner of the toolbar the *Undo* and *Redo* buttons can be found, which enable the user to undo mistakes step-by-step.

***Algebra window*:** The algebra window is placed on the left hand side of the GeoGebra window. It contains the numeric and algebraic representations of objects which are organized into two groups:

- *Free objects* can be modified directly by the user and don't depend on any other objects.
- *Dependant objects* are the results of construction processes and depend on 'parent objects'. Although they can't be modified directly, changing their parent objects influences the dependant objects. Additionally, the definition of a dependant object can be changed at any time.

Additionally, both types of objects can be defined as *auxiliary objects*, which mean that they can be removed from the algebra window in order to keep the list of objects clearly arranged. Algebraic expressions can be changed directly in the algebra window, whereby different display formats are available (e.g. Cartesian and polar coordinates for points). If not needed, the algebra window can be hidden using the *View* menu.

Input field**:** The input field is placed at the bottom of the GeoGebra window. It permits the input of algebraic expressions directly by using the keyboard. By this means a wide range of pre-defined commands are available which can be applied to already existing objects in order to create new ones.

Menu bar**:** The menu bar is placed above the toolbar. It provides a wide range of menu items allowing the user to save, print, and export constructions, as well as to change default settings of the program, create custom tools, and customize the toolbar.

Construction protocol and Navigation bar**:** Using the *View* menu, a dynamic construction protocol can be displayed in an additional window. It allows the user to redo a construction step-by-step by using the buttons of a navigation bar. This feature is very useful in terms of finding out how a construction was done or finding and fixing errors within a construction. The order of construction steps can be changed as long as this doesn't violate the relations between dependent objects. Furthermore, additional objects can be inserted at any position in order to change, extend, or enhance an already existing construction. Finally, the *Navigation bar for construction steps* can be displayed at the bottom of the graphics window, allowing repetition of a construction without giving away the required construction steps ahead of time.

Teacher Training and Technology Integration

Mathematical skills and knowledge are steadily gaining importance for everyday life in many countries all around the world where “mathematics is viewed as a necessary competency for critical citizenship” (Adler, Ball, Krainer, Lin and Novotna, 2005, p. 360). This heightens the importance of making mathematics education accessible to all students and increasing their mathematics proficiency so as to prepare them for life outside school. In order to provide a higher quality education for students, capable teachers who are willing to implement creative learning environments with technology for the purpose of maximizing their students’ learning success are desperately needed (Adler et al., 2005).

Teachers’ professional development is a key factor to successful integration of computers into classroom teaching. Several studies have revealed that whether beginner or experienced, Information Communication Technology (ICT) related training programs develop teachers’ competences in computer use (Bauer & Kenton, 2005; Wozney et al., 2006; Franklin, 2007), influence teachers’ attitudes towards computers (Hew and Brush, 2007; Keengwe and Onchwari, 2008) as well as assisting teachers reorganize the task of technology and how new technological tools are significant in student learning (Plair, 2008). Müller and his colleagues (2008) related technology training to successful integration of technology in the classroom. In a study of 400 pre-tertiary teachers, they showed that professional development and the continuing support of good practice are among the greatest determinants of successful ICT integration.

The aforementioned discussion is further supported by Wilson (2008, p.415) who stated "it is teachers who will make the difference between success and failure, and it is teacher education that must serves as a major conduit that connects teachers with new technologies." Zbiek and Hollerbrands' (2008, p.292) view concurs with the need for teacher training when they revealed that "there may exist stages through which teachers pass or a level of comfort and familiarity with the technology and curriculum before they are able to focus on students and what they are learning."

Recognizing the central role that teachers play in their students' learning, training for in-service and pre-service teachers needs to be adapted in order to effectively integrate technology into mathematics teaching. Wilson (2008, p.416) added impetuous to the need for teacher training when she wrote, "There is a common plea for teachers to deepen their knowledge and transform their practice." This was also supported by The International Commission on Mathematical Instruction (2004, p. 360 – 361) they added, "a focus needs to be on fostering students' understanding of mathematical concepts and creating more effective learning environments with technology". NCTM (2000, p.25) insists on technology-supported school mathematics and declares: "The effective use of technology in the mathematics classroom depends on the teacher. Technology is not a panacea. As with any teaching tool, it can be used well or poorly. Teachers should use technology to enhance their students' learning opportunities by selecting or creating mathematical tasks that take advantage of what technology can do efficiently and well — graphing, visualizing, and computing."

Moreover, research suggests that for the successful integration of technology into classrooms, many teachers think that merely providing technology is not enough (Cuban, Kirkpatrick & Peck, 2001). The main reason for using technology in mathematics education is to increase teacher effectiveness and improve student learning; therefore, teachers should learn not only how to use technology but also how to incorporate it into their instruction (Doğan, 2012).

Lagrange, Artigue, Laborde and Trouche (2003, p. 257) implied that better teacher performance in terms of mathematical content knowledge, pedagogy, and technology integration in combination with knowledge about research outcomes would sufficiently prepare teachers for an easy and effective integration of new technology into their classrooms. In contrast, Monaghan (2001) revealed many teachers are still struggling with the task of effectively using technology for everyday teaching, and evidence for the predicted improvement of students' achievement through effective use of technology for teaching and learning mathematics is still rare. Therefore, researchers became aware of the additional complexity of this process causing them to make more cautious predictions about a successful integration of technology and its impact on mathematics education.

Zbiek and Hollebrand (2008) claimed that teachers need support in managing technology, developing confidence in using technologies, and securing an appropriate curriculum for improvement in the entire teaching and learning process. They added that these requirements must also be accompanied by a deep knowledge of mathematics and effective teaching practices.

Pre-service education planners have also recognized that it is essential to address this issue and provide opportunities for learning about technology in education during the pre-service experience. Green and Gilbert (1995, p.13) reiterate that “colleges and universities would be doing a major disservice to their students if they failed to provide appropriate opportunities (including structured curricular experiences) to develop and enhance information technological skills as part of the undergraduate experience.” According to Bulut & Bulut (2011) findings, pre-service teachers’ belief that knowing how to use technology during learning and teaching is necessary for effective instruction. Hence, Kokol-Volj (2007) added that training pre-service teachers about how to use technology during their teaching is an essential aspect of mathematics education programs. They need to know how to integrate appropriate mathematical software to their instructions.

Finally, pre-service teachers’ content knowledge needs to be supported by using technological tools in teacher training programs. Niess (2006) indicated the technology competencies for mathematics teacher candidates. Niess (2006) further stresses that mathematics teacher candidates should have sufficient conceptual understanding of K-12 mathematics to support it by using technology, understand how the students learn mathematics and how technology influences this learning. He also posited that it is important for pre-service teachers to know the effective use of technology in teaching and learning mathematics, experience the use of a variety of technological tools to increase the students’ and their own mathematical learning.

In order to support teachers with the challenge of successfully integrating technology into mathematics teaching and learning, many professional development opportunities need to be offered that are either adapted to the new tasks, or newly created in order to foster change in teaching practice in the short run and cause improvement of student achievement in the long run (Lawless and Pellegrino, 2007, p. 575). By actively using technology during professional development events, teachers are supposed to gather new and different experiences in terms of learning mathematics that goes beyond their own encounters as students themselves. In this way, they would learn about new approaches of teaching with technology and become better prepared for its effective integration into their own teaching practice (Mously et al., 2003). Additionally, teachers need to learn how to selectively use software in their classrooms, how to increase the interactivity and flexibility of mathematics learning, and how to improve student achievement by providing new and more effective learning opportunities (Mously et al., 2003).

In short, solely providing new technology to teachers does not guarantee its successful integration into mathematics teaching and learning. Appropriate technological training needs to be provided in order to support teachers with this task by teaching them not only the use of new software tools but also by introducing them to methods of how to effectively integrate technology into their teaching practices (Preiner, 2008 and Wilson, 2008). Hence, Darling-Hammond, Wei, Andree, Richardson & Orphanos (2009) also emphasized that the improvement of professional learning and development of educators is crucial in transforming schools and increasing academic achievement.

Teachers' Perceptions of Technology

Teachers' perceptions towards technology is an important factor affecting the decision whether or not to adopt technology, and yet it is intriguing to find that perceptions appear to be malleable through training, in particular regarding teachers' self-efficacy, attitudes, and beliefs. Gningue (2003) found that the attitudes and beliefs of teachers who were engaged in a long-term professional development program (a 15- week, 45 hour-graduate course) on the use of the graphic calculator and the Geometer's Sketchpad changed significantly compared with their counterparts who were only given short-term training workshops (three workshops totaling 7 hours) with the same types of technological tools. Watson (2006) showed that educational technological training can enhance teachers' self-efficacy with respect to the use of the Internet in the classroom, and this effect still exists after several years. Hartsell, Herron, Fang & Rathod (2009) reported a significant increase in confidence among middle school in-service mathematics teachers in using technology to solve mathematical problems after attending a four-week intensive professional development workshop on graphic calculators and other generic application software. However, it is important to note that positive perception changes among mathematics teachers may not necessarily occur after training. One study by Jimoyiannis and Komis (2007) indicated that after a nationwide basic ICT training program focusing on the application of ICT in education, mathematics teachers remained negative about using ICT in education and were skeptical about the possible changes brought about by ICT in the school mathematics culture.

Zakaria and Lee's (2012) findings revealed that most teachers found that the tools and features of GeoGebra were easy to use. Tatar (2013) added that teaching GeoGebra has a statistically significant effect in raising prospective mathematics teachers' perception levels regarding the use of technology. He further emphasized that, teachers must be trained and encouraged in order to actualize the integration of technology into mathematics courses.

Similarly, Darling-Hammond & Bransford (2007) implied that if the prospective teachers are required to perform high quality teaching, they must get the same quality education in faculties. He added that if prospective teachers do not gain experience related to computer assisted environments during their pre-service years, or if teachers do not gain the same experiences via in-service training, they cannot be expected to perform proper computer assisted mathematics instruction. Wiest (2001), emphasized that teacher training is extremely significant in regard to the rising use of technology in teaching. Thus, great effort must be maintain to constantly ensure that there is high quality teacher training in terms of technology use at the pre-service level.

The Role of Technology in Mathematics Education

Technology is permeating all the different levels of mathematics teaching and learning today, transforming mathematics from traditional pencil and paper learning to a mixture of calculator, computer and pencil and paper learning environments. Education is no longer about memorizing facts and pictures, but rather, it is about learning where to find this information, and more importantly, it is about how and where the information which has been acquired can be used. Learners must actively construct their own understandings rather than simply absorb what others tell them (Bransford, Brown, & Cocking, 2000). As technology continue to dominate the classrooms it has become imperative for educational organizations to develop technology-related standards (Lawless & Pellegrino, 2007) to ensure an effective integration of technology into teaching and learning. An example of such an organization is the National Council of Teachers of Mathematics (NCTM), which is the world's largest association of mathematics teachers. NCTM 2011, declared that "technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning (NCTM, 2000, p. 11)."

Fey et al's (1984) findings revealed that as computer technology within the mathematics classrooms experience an explosive growth both in terms of development as well as availability; it is also accompanied by an enormous enthusiasm concerning the potential of new technology for teaching and learning mathematics. Consequently, Lawless and Pellegrino (2007) and Cuban et al(2001) highlighted that substantial among of money was invested into equipping schools with hardware, software, and Internet access in order to create an environment that allows technology integration into classrooms.

Furthermore, technology has been proven useful for helping students to examine mathematics not only as a set of procedures, but more as reasoning, exploring, solving problems, generating new information and asking new questions. Van Voorst (1999) added that technology "helps them to better visualize certain mathematical concepts" (p.2). Several studies also revealed that activities that encourage the construction of images can greatly enhance mathematics learning (Wheatley & Brown, 1994). Hollebrands' (2007) research revealed that students can benefit from technology as it provides new learning opportunities that can greatly engage students of different mathematical skills and levels of understanding with mathematical tasks and activities. Ashburn and Floden (2006) also emphasized the importance of using technology in mathematics, noting that tools that instantly relate the graphical and symbolic representations of mathematical expressions can help make understanding goals more accessible to students. They further stated that "simulations that make abstract concepts visible and manipulatible can help students comprehend the nature and applications of key ideas" (p.30).

There are many studies which investigated the integration of technology into mathematics teaching and learning of different topic areas (Gonzales & Herbst, 2009; Liang & Sedig, 2010; Lagrange, 2010; Milovanovic et al. 2011; Lotfi & Mafi, 2012) in which they all concluded that technology can be used to help with visualization and better representation of mathematics objects and procedures by exploring different graphical representations. The visualization of mathematical concepts and exploring mathematics in multimedia environments can foster their understanding in a new way. Van Voors, 1999 (p. 2) reports that technology was "useful in helping students view mathematics less passively, as a set of procedures, and more actively as reasoning, exploring, solving problems, generating new information, and asking new questions." Furthermore, he claims that technology helps students to "visualize certain math concepts better" and that it adds "a new dimension to the teaching of mathematics".

Moreover, a technological environment allow teachers to adapt their instruction and teaching methods in a more effective way to meet their students' needs (NCTM, 2000, p. 24). By integrating educational tools into their everyday teaching practice, they can provide creative opportunities for supporting students' learning and fostering the acquisition of mathematical knowledge and skills. On the one hand, gifted students can be supported more effectively than ever by nurturing their individual interests and mathematical skills. On the other hand, weaker students can be provided with activities that meet their special needs and help them to overcome their individual difficulties. Thereby, students "may focus more intently on computer tasks" and "may benefit from the constraints imposed by a computer environment". Additionally, students can develop and demonstrate deeper understanding of mathematical concepts and are able to deal with more advanced mathematical contents than in 'traditional' teaching environments (NCTM, 2000, p. 24).

Barriers in Technology Integration

Hohenwarter & Lavicza, (2007) implied that the integration of new technologies into everyday teaching and learning of mathematics has proven to be a slow process that involves multiple challenges for teachers and students. In spite of the considerable promise that technology provides for the reform of mathematics education, there are potential barriers to the fulfilment of that promise. The incorporation of technology into mathematics generates a list of objections and concerns identified by Bingimlas (2009):

1. Lack of teacher confidence

2. Lack of teacher competence

3. Resistance to change and negative attitudes

4. Lack of time

5. Lack of effective training

He reported in his research findings that not enough training for teachers in the use of Information Communication Technology (ICT) in the classroom was a problem. He noted the need for pedagogical training for teachers rather than simply training them to use ICT tools.

Buabeng-Andoh’s (2012) research findings revealed that barriers that discourage the use of ICT by teachers can be categorized are into teacher-level, school-level and system-level barriers. He further explained that teacher-level barriers include lack of teacher ICT skills; lack of teacher confidence; lack of pedagogical teacher training; lack of follow-up of new and lack of differentiated training programs. He added that the school-level barriers are comprised of absence of ICT infrastructure, old or poorly maintained hardware, lack of suitable educational software, limited access to ICT, limited project-related experience, lack of ICT mainstreaming into school's strategy and the system-level barriers include rigid structure of traditional education systems, traditional assessment restrictive curricula and restricted organizational structure.

This research will aimed to minimize one of these barrier by offering training to teachers in an introductory workshop by using GeoGebra to provide pedagogical training in the teaching and learning of mathematics.

Benefits of Engagement in Learning

Engagement can be viewed as a multidimensional and dynamic process. Kemp (2006) and Guerrero, Walker & Dugdale (2004) research findings reveals that the used of software encourage students engagement. Therefore, this workshop seeks to analyze pre-service teachers' authentic engagement. Fredricks, Blumenfeld, and Paris (2004) propose three dimensions of learner engagement. They are cognitive engagement, which is defined as the learner's mental investment in learning, effortful strategy use, and thinking and commitment to academic work. Emotional engagement they referred to a learner's affective reactions to academic activities. In addition, behavioral engagement was viewed as active participation in academic activities and is demonstrated through attention, persistence and asking and answering questions.

Newmann (1992) implies that students who are engaged are involved in their own learning are making a psychological investment in learning. Newmann (1992, p.1) added engaged "students take pride not simply in earning the formal indicators of success (for example, grades), but in understanding material and incorporating or internalizing it in their lives." Students' engagement also refers to a "student's willingness, need, desire and compulsion to participate in, and be successful in, the learning process promoting higher level thinking for enduring understanding" (Bomia, Beluzo, Demeester, Elander, Johnson, & Sheldon, 1997, p. 294).

According to Marks (2000), engagement is closely linked with students' academic achievement and optimal human development. Kuh, (2009) refers to engagement as the quality of effort and participation in authentic learning activities. In addition, Alvarez (2002) found that if students are not engaged when doing academic tasks, they tend to acquire only a minimal amount of knowledge because engaged students are prepared to take a personal risk or chance in the learning task.

Furthermore, Schlechty (2001), implied that for a truly engaged learner, the joy of learning inspires a persistence effort to complete a given tasks even though it is difficulty. Saeed and Zyngier (2012) added that as students become engaged they develop the skills to work with others and acquire the skill of transferring knowledge to solve problems creatively. They further stated, that the most engaging task, “allows for creativity, sparked curiosity, provided an opportunity to work with others, and produced a feeling of success (p. 253).”

The workshop was designed to ensure active engagement from pre-service teachers. It required them to be attentive as well as in attendance; it required the students to be committed to completing the different tasks and hopeful find some intrinsic value in the workshop activities. Schlechty (2002, p.64) add impetus to this goal when he wrote that “the engaged student not only does the task assigned but also does the task with enthusiasm and diligence.”

Research Basis for Workshop Design

Bu, Mumba, Henson & Wright (2010) in their research, introducing GeoGebra to elementary teachers utilized a task-centered instructional strategy and found that teachers were encouraged to build interactive and dynamic conceptual models as a way to learn, to teach, and to foster metacognition. Francom & Gardner (2014, p.29) stated that the term *task-centered learning* was chosen because “the focus of this type of learning and instruction is not simply instruction in the behavioral sense of the word (i.e. direct instruction)”. Moreover, Bu et al (2010) added that this strategy emphasis is placed on knowledge application and integration. According to Merrill (2007), in the task based approach each topic in a given area is taught in turn (See Figure 1). He further explains that the arrows in the figure represent presentation/demonstration of the information, concepts, and processes included in the topic. Periodically students will be given a practice or test activity to assess the degree to which learners are acquiring the knowledge or skill component being taught. After the instruction is completed for the first topic the next topic is taught in like manner. Toward the end of the workshop there is often a culminating experience where learners are required to apply the knowledge and skills that they have been taught or skill component being taught.

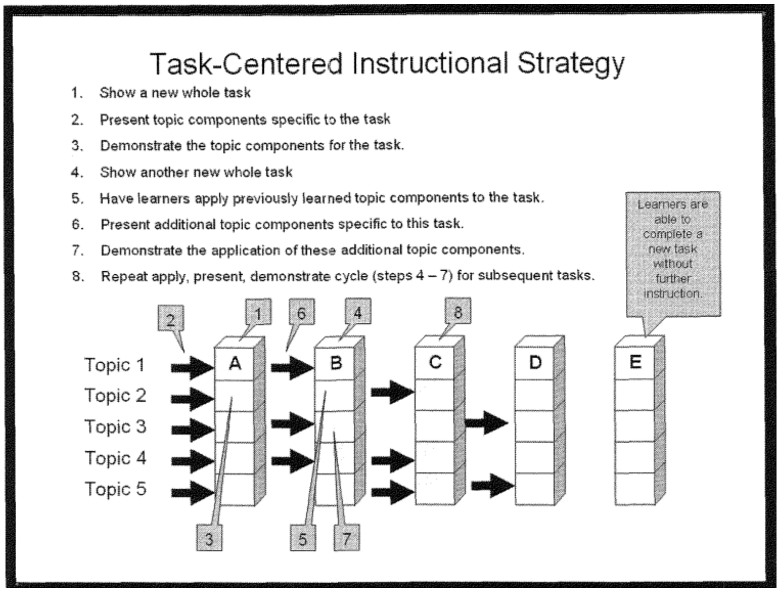

Figure 2: A task-centered instructional strategy copied from Merrill, 2007

Collins, Brown & Holum, (1991) proposed a similar task-centered framework. They suggested that when teachers demonstrate a target learning task they should point out important performance aspects, articulate the reasons why the task is done in a certain way, and explain the thought processes that are needed to complete it. In support to task based instruction, Reigeluth (1999) posited that when learners are exposed to task base instruction they will be required to do tasks that progressively increase in complexity and they will eventually reach a level of mastery for the most complex learning tasks.

Merrill, Barclay & van Schaak (2008, p. 174) claim that “learning is facilitated when learners are engaged in a task-centered approach to instruction” and this is deemed as one of the most important principle in the task centered approach (Francom & Gardner, 2014). Furthermore, Francom and Gardner (2014) proposed these steps in the implementation of the task based approach including: demonstrate how to perform the task; provide supportive information relevant to the task; provide procedural information relevant to the task and point out important aspects of the task. Therefore, based on the positive feedback from literature this workshop utilized the task based approached in introducing pre-service teachers to the GeoGebra software.

Summary of Chapter Two

This chapter sought to discuss many of the pertinent literature that looked at the use of GeoGebra in the classroom and teachers' perceptions of the effectiveness of this software. Initially, a brief discussion on what exactly is GeoGebra was explored. The work of Hohenwarter and Preiner (2007) was pivotal to this discussion, which saw GeoGebra as dynamic geometry software that can bridge the gap between several mathematical disciplines.

The chapter then went on to provide some historical background on the development and implementation of the software and chart the course of the software into the United States of America to where much emphasis was put into its user friendliness and internet compatibility. It also provided a description of the user interface offered by the software.

The chapter then discussed the integration of technology and teacher training. The writings of Adler et al (2005), and Wilson (2008), to name a few, were used to support that there is need for teacher training. Specific mention was made of the need for the integration of technology and mathematical content by teachers and discussed how teachers' perception of technology is paramount to its effective implementation in the classroom. The role of technology in mathematics education and some barriers in integrating technology into the mathematics classroom were expounded upon. This led to research basis for the workshop design in the study, bringing the chapter to a close.

CHAPTER THREE – METHODS

In this chapter the discussion turns to the methods and context used in the study. This research lends itself to a qualitative approach, as it focused on a particular group of individuals (pre-service secondary mathematics teachers), bringing personal values into study, investigating the context or settings of participants and validating the accuracy of findings (Creswell, 2003). A detailed description of the workshop is outlined, followed by recruitment and sampling methods. Each instrument used to collect data is fully described. Finally, the method of analyzing data is explained in detail.

The initiative that is being reported concerns a four day training series using a workshop format and focusing on DGS (GeoGebra). Since the group that was being trained is small and it was desirous to look at teachers' impressions in some depth, qualitative case study methodology was utilized. A case study is research in which the researcher explores in depth a program, an event, an activity, a process, or one or more individuals (Creswell, 2003, p. 15). According to Marshall and Rossman (1999), case study has a complex design. A case study may require multiple sources of data, such as interviews and document analysis. Another characteristic of case study research is that it is bounded by time and activity (Stake, 1995).This case study integrated various methods/instruments such as, questionnaires, task and video analyses.

Yin (2003) states that case studies are the preferred strategy when *how* or *why* questions are being posed, when the investigator has little control over events, and when the focus is on a contemporary phenomenon with some real-life context. Amongst all qualitative research traditions, a case study would fit best with my methods particularly since I have proposed *'how'* research questions.

The Workshop

The GeoGebra introductory workshop was designed in order to help the participating pre-service teachers achieve the following objectives.

Table 1: *Objectives of the workshop*

Workshop Days	Objectives
1	***Mathematical:*** • Explain the term geometry and distinguish between Geometry and measurement • Use and understand common Geometric object such as points, lines and segments • Use and understand properties of a triangle to construct different types of triangles. • State and discuss the triangle inequality theorem. • Construct different triangles centers and describe how they can be used in solving application problems. ***Technological:*** • Describe and use common features of dynamic Geometry environments (DGEs) • Describe parent-child relationship among geometric objects in a DGE. • Distinguish the difference between drawing and constructing. • Recognize that dragging different points of a geometric figure can result in different behaviors. • Create different constructions of a single geometric object using a DGE. • Find the length of the sides of polygons. • Create the interior of a triangle. • Measure the area of a triangle. • Measure angles of a triangle. ***Pedagogical:*** • Discuss the level of cognitive demand of mathematical tasks • Discuss the difference between evidence and proof.

Table 1 Continued

Day 2	***Mathematical:*** • Explain the difference between partitional and hierarchical definitions. • Critique definitions and select definitions that will be most useful. • Use properties of quadrilaterals to construct different quadrilaterals. • State definition for a geometric transformation • Proof the Pythagorean theorem ***Technology:*** • Measure segments and angles • Construct different quadrilaterals • Use the calculator tool to explore relationships • Use a DGE to apply reflections, rotations, and translations to points and polygons. • Use the dragging feature to identify fixed points. • Use measuring tools to examine lengths of segments, measure angles and distance between points. ***Pedagogical:*** • Anticipate difficulties students may have when learning geometric transformations.
Day 3	***Mathematical**:* • Provide a description of algebra • Use multiple representations to interpret and reason about arithmetic and geometric sequences. • Define variable (including dependent and independent); • Identify different uses of variables • Express regularity in patterns using algebraic expressions • Express relative relationships between expressions. • Define function family • Describe defining characteristics of particular function families • Model data using function families ***Technological*:** • Create a recursive patterns in spreadsheets • Create a line graph from data in a spreadsheet • Creating sliders to represent function parameters ***Pedagogical:*** • Use multiple representations to help students build deep understanding of function families • Analyze student thinking about parameters and function families
Days 4	***Mathematical:*** • State the equation of a straight line • Distinguish the difference between parallel and perpendicular line • Write Mathematical of high cognitive demand ***Technological:*** • Creating sliders • Creating parallel and perpendicular lines • Creating Mathematical task ***Pedagogical:*** • Recognizing effective questioning strategies

The workshop consisted of four days. The objectives outlined in table 1 and the Geometry and Algebra tasks that pre-service teachers (PSTs) completed during the workshop were adopted from Hollebrands and Lee (2012) and McCulloch, Lee and Hollebrands (2014). The content of each of the days is described here:

Day 1: Basic Geometric Constructions

In Day 1 the PSTs learned how to create basic geometric constructions in GeoGebra. They were introduced to a selection of dynamic geometry tools as well as different features of GeoGebra which facilitated the construction process. In addition, teachers were introduced to a dynamic geometry tool selected for certain characteristics that facilitate construction. PSTs became familiar with a variety of different features of dynamic geometry environments (DGEs) and pedagogical issues that arise when students are learning geometry with technology. The different sections of the day included: What is Geometry; Parent-child relationships by creating a line segment, a point on the line segment and dragging and deleting the points A, B and C then described what changed and what didn't change. They also explored the concept of invariance in a DGE, constructed a right angle, an isosceles and equilateral triangles and measuring lengths and angles of a triangle. PSTs constructed the median of the triangle and use that knowledge to solve the partition of a triangular shape land problem.

Day 2: Constructing and exploring special quadrilaterals

On this day, PSTs learned about constructing and exploring properties of special quadrilaterals. They constructed a square and solved a problem involving a piece of land that was an irregular shaped convex quadrilateral using GeoGebra. PSTS discussed their solutions with the class. PSTs also learned geometric transformation using GeoGebra such as, translation, rotation and reflection.

Day 3: Conducting proofs, creating linkage and introducing algebra

On Day 3, PSTs worked in pairs and completed a task using GeoGebra to prove the Pythagorean Theorem; this task served as a review of the previous two workshop sessions. PSTs dragged the triangle and observed the changes and noticed that the sum of the area of the squares on the legs of the triangle is always equal to the area of the square of the hypotenuse.

In addition, PSTs reviewed the concept of algebra and were reminded of the difference between an expression and an equation. They were exposed to dynamically linked representation of sequences. PSTs were given a lottery problem to solve involving the generation of sequences using the spreadsheet view in GeoGebra. PSTs also created a line plot from an ordered set in a spreadsheet. This was done by adding a graphics view to the GeoGebra document while keeping the spreadsheet view. They created different graphs (such as, sine, cosine and quadratics) by using the input bar in GeoGebra to input algebraic equations. PSTs also create and use sliders to change the coefficients of the equations of graphs and examined the transformation of the different graphs.

Day 4: Solving problems and writing tasks

To begin the final day, PSTs were given a task to create sliders and then manipulate them to create parallel and perpendicular lines. This task gave PSTs the opportunity to review the information from the previous workshops. PSTs struggled at first with this task, therefore the facilitator engaged PSTs in a discussion on the equation of a straight line, the gradient of a line and how to identify perpendicular and parallels lines. The facilitator discussed how to write a good mathematics task with PSTs and highlighted task of low and high cognitive demand. PSTs used GeoGebra and worked in small groups to create a task of high cognitive demand that can be used with students (The actual tasks are listed in chapter 4).

Recruitment and Sample

The population, or potential target audience for the study, consisted of pre-service teachers from the St .Vincent Community College, Division of Teacher Education (SVCCDTE). The sample consisted of 21 pre-service teachers who attended the workshop sessions and consented to participate in one or more aspects of the study. For a PST's data to be included in the study, he or she was required to participate in the workshop sessions. Each participant in the study signed a consent form approved by the Institutional Review Board (see Appendix F).

For this research, I employed a purposive/convenient sample. That is, I intentionally targeted and 'handpicked' (Cohen, Manion and Morrison, 2000) the particular group I was interested in, thereby deliberately avoiding representation from the wider teaching population. I acknowledged that the views of other pre-service teachers and more so from the wider Vincentian teaching community may have provided additional insights into the area of concern. However, due to manageability of data and time constraints, I decided to restrict the study to only one group of pre-service teachers at the Community College. This ultimately would afford me opportunities for a more in-depth investigation.

For this research, access was negotiated at different levels. First, I sought permission from the Director of St .Vincent Community College. Second, permission was sought at the level of the Division of Teacher Education via the Dean. This was done through electronic mail (email) (see Appendix H). In addition, the consent of the pre-service teacher was sought (see Appendix F & H). This was a critical priority since there was video-taping of workshop sessions.

Description of Students

Twenty one (21) of the 40 first year pre-service teachers participated in a GeoGebra introductory workshop intuitive at the St. Vincent Community College during the week of May 18-21st, 2015. The teaching experience for the workshop students ranged from 0 year to 16 years (see table 2). This may be surprising as they are all “pre-service teachers”. The explanation follows. In the past in St. Vincent and the Grenadines many persons were allowed to enter the teaching profession without being trained because of a shortage of teachers but now the Ministry of Education has implemented a policy where all teachers must be trained, that is, complete an associate degree in Teacher Education. Therefore all the teachers who were teaching for a number of years were required to be enrolled in the teacher education training program.

The associate degree program in teacher education that PSTs are enrolled in allowed them to be able to become a mathematics teacher at both the primary level (grade 4-6) and the secondary level (grades 7-9). However, one teacher from the early childhood program expressed interest to be involved in the workshop and her request was granted. Therefore, 17 students were enrolled in teacher education program to teacher Grades 4-9 mathematics and 1 student was enrolled to teacher Grade K-3 mathematics, as shown in table 2.

Table 2: *Description of Participants*

Student ID codes	**Gender**	**Teaching years (if any)**	**Which grade level(s) are you being trained to teach?**
A	Female	0	Grades 4-9
B	Female	0	Grades 4-9
C	Female	0	Grades 4-9
D	Male	16	Grades 4-9
E	Female	10	Grades 4-9
F	Female	0	Grades 4-9
G	Female	0	Grades 4-9
H	Female	5	Grades K-3
I	Female	0	Grades 4-9
J	Female	0	Grades 4-9
K	Female	0	Grades 4-9
L	Female	2	Grades 4-9
M	Female	0	Grades 4-9
N	Female	0	Grades 4-9
O	Female	0	Grades 4-9
P	Female	0	Grades 4-9
Q	Female	4	Grades 4-9
R	Female	0	Grades 4-9

Data from the pre-questionnaire provided significant information about the PSTs. On average, the PSTs used a computer at home on 6 days of the week; only 11% of the students stated they do not use it every day. Additionally, 66.7% of the PSTs used a computer on every weekday in school. Table 3 shows a list of the percentages of PSTs' varying activities using the computer at home and at school (outside the classroom). It shows that most of the PSTs use a computer for communication, preparation of lessons and teaching materials, as well as to keep records of their students both at home and at school.

Table 3: *Activities pre-service teachers do with the computer at home and at school*

Activities done with the computer	**At Home %**	**At college %**
Check email	94.4	94.4
Prepare lessons	62.5	62.5
Create teaching aids	82.4	78.5
Look for teaching material	82.4	83.3
Find information online	89.9	94.1

In addition, 100% of the PSTs stated that they are being taught with a computer in combination with a projector as a presentation tool. 100% of the PSTs never used a graphing calculator and 100% are not taught using mathematics software. However 73.3% claimed that they would use technology to help their students discover mathematical concepts. 100% of the PSTs would use technology during a lesson in educational games as a reward. 100% of PSTs were never exposed to the dynamic geometry software GeoGebra.

The most widely used software that the PSTs had been exposed to during their training programs is PowerPoint (100%) followed by word processing software (94.4%), and spreadsheets (82.4%). None of the PSTs were exposed to dynamic geometry software, computer algebra systems and graphing calculators prior to the workshop (see Table 4).

Table 4: *Software pre-service teachers are exposed to during their training program*

Software	**Used during training program**
PowerPoint	100%
Word processing	94.4
Spread sheet	82.4
GeoGebra	0%
Graphing Calculators	0%
Computer algebra systems	0%

From the information in Table 4 we can see zero percentage PSTs has been exposed to dynamic geometry software (GeoGebra), graphing calculators and computer algebra systems; the need for professional development to facilitate the use of mathematical software is obvious. Although PSTs use computers frequently for a wide range of activities, they are not being exposed to educational software that has tremendous benefits for teaching and learning mathematics.

Additionally, all PSTs (100%) believe that mathematics should be taught with the use of technology and that software programs can be used to effectively teach mathematics. However, only 11.1% of PSTs were aware of software that are available to be used to teach mathematics. None (0%) of the PSTs have written a lesson plan to incorporate mathematics software and none (0%) have ever attended a workshop that taught them how to integrate software in the teaching of mathematics. In addition 100% of the PSTs agreed that their role as mathematics teachers would change if software is to be used in the teaching and learning of mathematics. Hence, these demographics imply that the GeoGebra workshop was very timely and served to add new knowledge and skills to further equip PSTs to make mathematics more meaningful to their future students.

Data Collection

Three types of data were collected during the workshop:

- Videos of workshop
- Questionnaires
- Tasks written by students to incorporate the use of GeoGebra.

Each of these will be described below.

Videos

According to Roschelle (2000) video recording are very important in preserving the interaction that takes place during a research. These interactions include “talking, gestures, eye gaze manipulation and computer displays” (Roschelle, 2000, p.709). It also allows investigators to re-examine data again and again (Clement, 2000). A digital camcorder was chosen to video record the work shop because of the following features:

- It is able to superimpose a date and time stamp on the tape with hours, minutes and seconds.
- It consists of a built-in microphone.
- It is easy to use.

Each day of the workshop was video recorded by an outside person who operated the digital camcorder from a location in the classroom that captured the whole class. The camera focused on the activities students was completing using GeoGebra.

Questionnaires

Although questionnaires are mainly recommended for large scale surveys, Cohen et al. implied that it may be used if a site-specific case study is required. He added that “a qualitative, less structured, word-based and open-ended questionnaire may be more appropriate as it can capture the specificity of a particular situation” (Cohen et al., 2000, p.248). Pre and post questionnaires were administered, Evaluation questionnaires were also administered to all PSTs and included questions rating the workshops and GeoGebra features (see Appendix C). A combination of Likert scale items and open-ended questions were utilized. The Likert scale component of the questionnaires focused on the extent to which the workshop (1) had influence on PSTs’ beliefs or views on their teaching practice, the curriculum or mathematics content; (2) had direct impact on PSTs’ teaching practice; and (3) PSTs’ reactions to workshop activities.

This information from the questionnaires was ultimately converted into quantitative data during the analysis process. There were also some questions on the questionnaire that were open-ended and were used to collect qualitative data (see Appendix D). These questions were designed to gather specific examples of direct impact on students’ teaching practices as well as suggestions for improving the program. There were a total of seven different questionnaires that were used in the workshop. All questionnaires were completed online using Google form.

The pre questionnaire was used to collected basic biographic information about PSTs (see Appendix A). It was also designed to determine the use of technology by both PSTs and lectures during instruction and to find out if PSTs were exposed to GeoGebra or any dynamic technology prior to the workshop. It was also used to find out PSTs basic computer knowledge and skills. The findings for this questionnaire were presented as a description of PSTs in the workshop previously in table 1, 2, and 3 above.

Four out of the seven questionnaires were meant to evaluate each day of the workshop. These required PSTs to complete each at the end of each day of the workshop, they filled in a workshop rating where they could rate the difficulty of the workshop activities done with GeoGebra during the workshop on a scale from 0 ('very easy') to 5 ('very difficult') .

The post questionnaire measured PSTs' responses to the use of GeoGebra in terms of their attitude, the curriculum, content and pedagogical issues. This was given at the end of the workshop and has 29-item questionnaire (see Appendix B). Each item has a six point Likert Scale ranging from 0 (Very *Strongly Disagree*) to 6 (Very *Strongly Agree*) see an example of these questions in figure 4. Since there were no previous validated instruments to use, I reviewed similar survey instruments on the use of technology, such as calculators, in teacher education and professional development programs (Burrill, 1992; Guerrero, Walker, & Dugdale, 2004; Kastberg & Leatham, 2005; Brown et al., 2007) and most of the questions were adopted from Bu et al (2010). Based on the analysis of previous research findings in the literature, I also adopted the four chosen factors of attitudes, curriculum, content, and pedagogy from Bu et al (2010) to determine PSTs' response to the use of GeoGebra. Gay (2000) states, if you wish to find out what people think, feel about a particular phenomenon, you need to ask them. Hence, since one of the objectives of my research is to find out PST response to using GeoGebra, I decided to include an evaluative open-ended section of the questionnaire consisting of five (5) questions (see Appendix D). Some of these questions were: *What did you like about the GeoGebra workshop? Is there anything that you didn't like about the GeoGebra workshop? Do you think GeoGebra will be useful to be used with your students?* Figures 3 and 4 show examples of the questionnaires used.

DAY 2 EVALUATION FORM

Please rate the level of difficulty on a scale of 0 – 5 with 0 being the least difficult and 5 being the most difficult

Day 2 Tasks	0	1	2	3	4	5
Constructing a square						
Solving partitioning of land problem of the shape of Quadrilaterals						
Translation of an object						
Reflection of an object						
Rotation of an object						

Figure 3: Sample workshop questionnaire

Question	**Very Strongly Disagree**	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**	**Very strongly agree.**
At the beginning I did not like GeoGebra						
Right now I am more open to explorations using GeoGebra						
I like it because it is free to everyone						
I will share GeoGebra with my students and parents						
I will share GeoGebra with my colleagues and administrators						
I will continue to learn and use GeoGebra						

Figure 4: Sample questions from post questionnaire

Mathematical tasks written with GeoGebra

In order to demonstrate new skills and knowledge gain from the workshop PSTs were required to write mathematical tasks that incorporate the use of GeoGebra. The prompt for the assignment was, “Choose a topic that you will like to teach and create a task in GeoGebra that will stimulate your students’ thinking. You can work in groups of twos or threes.” They worked in groups of twos and threes because they were fairly new to the process of writing mathematical task in a dynamic environment and I think it was necessary that they get support and ideas from each other. The writing of mathematical tasks was the last activity in the workshop. All tasks were written in GeoGebra and emailed to the researcher. PSTs were encouraged to write high cognitive demand tasks that they can use to enhance students' understanding of mathematics and to help them become better mathematical doers and thinkers (Henningse & Stein, 1997).

Data Analysis

Analysis of Video

The Powell, Francisco, & Maher (2003) model for video analysis was used to conduct analysis of the video and audio data. In the first phase of analysis, each of the video recordings of class meetings was viewed. I initial viewed the video recordings so that I could become familiar with the data, not to interpret or to make inferences. Then, I viewed the video recordings several times so that each session could be described. According to Powell et al. (2003), the purpose of viewing video data at the descriptive phase should be to create a record so that an outside observer would be able to have an objective idea of what occurred in the video.

Next, I diverted somewhat from the (Powell et al., 2003) model. In the second phase of the analysis, the video was used as data. I carefully reviewed each video, and then summarized them by identifying significant moments that took place in the workshop (Maher & Martino, 1996a, 1996b, 2000; Maher, 2002). In the third and final stage of the video analysis, the findings from the videos were categorized as follows: the workshop session, video number, a time interval of twenty (20) minutes, summaries description of workshop activities and comments of any significant observation (see Appendix E).

The summary was beneficial in my gaining a better understanding of the events and actions that took place in the workshop and to give readers an idea of activities PSTs participated in during the workshop. It helped me to corroborate information obtained from the students' questionnaire, the other techniques used in the research. For example, although most of the PSTs rated the different tasks in the workshop as easy, the videos revealed that many of them struggled with some of the tasks and needed assistance. This summary also acted as a means of direct observation. Bell (2005) sums this up nicely in noting that direct observation could also be particularly useful in discovering whether people do what they say they do, or behave in the manner they claim to behave.

Participation Engagement Analysis

In this workshop students were given the opportunity to explore concepts in a dynamic environment that exposed them to different representations of knowledge, so that they will be more likely to create a stronger connection among mathematical concepts. PSTs were provided with dynamic worksheets to begin their exploration and were asked questions in order to activate their prior knowledge. In addition, students used GeoGebra to engage in explanation of mathematical concepts and relations between these concepts. They were also given tasks that allowed them to experiment with models such as the lottery payout, in order to test their hypotheses and explore alternative and offer explanations for various phenomena. By engaging students cognitively they utilized learning strategies such as rehearsal, summarizing, and elaboration to remember, organize, and understand the material

(Corno & Madinach, 1983). Because of the type of workshop which the students participated in, I needed to find a framework that could help me understand the participation.

I chose to use the engagement framework suggested by Fredricks, Blumfeld and Paris's (2004, p. 62-65). They suggested three types of engagement that I adopted: behavioral, cognitive and emotional. *Behavioral engagement* may be defined as involvement in learning and academic tasks and includes behaviors such as effort, persistence, concentration, attention, asking questions, and contributing to class discussion (Skinner & Belmont, 1993; Birch & Ladd, 1997). *Emotional engagement* refers to PSTs' affective reactions in the classroom, including interest, boredom, happiness, sadness, and anxiety (Skinner & Belmont, 1993). *Cognitive engagement* may be described as PSTs using metacognitive strategies to plan, monitor, and evaluate their thinking when accomplishing tasks (Pintrich & De Groot, 1990; Zimmerman, 1990).

PSTs' cognitive engagement of exploration, explanation and modeling required behavioral engagement such as manipulation, dragging, creating, questioning, discussion, and collaboration. Furthermore as PSTs worked on their tasks and solved problems they felt totally free to express their emotions and the researcher was able to capture these expressions on camera and was able to describe these emotions as they were expressed.

To analyze PSTs' engagement the researcher viewed each video several times in order to summarizing and described students' engagement in each video. PSTs' engagement was then categorizes as behavioral, emotional and cognitive. Cognitive engagements focused on those activities that simulate thinking, for example PSTs explained their reasoning to questions ask by the researcher. *Researcher: Explain in your own what the term parent child relationship means? PSTs' response: when something is dependent on other thing to be in existence.* Behavioral engagements focused on the action activities that PSTs were engaged in during the workshop for example, *Students manipulating the tools in GeoGebra and discuss task with each other*. Emotional engagements focused on PSTs' reactions to the different tasks during the workshop, for example *PSTs use expression such as sighting and laugher and showed feelings of uncertainty and confidences.* These varying engagement was then tabulated, counted and percentage. The different words to indicate the varying PSTs' engagements were tallied and percentage. This was done to find out which engagement was most dominant.

Analysis of the Questionnaires

Analysis of the data collected via the questionnaires was conducted using the Statistics Program for the Social Sciences Statistics (SPSS), Microsoft Excel (spread sheet) and a transcript of the open-ended questions. The open ended questions findings were then systematic organizing in a table for ease of description and analysis. The information collected on these questions was transformed into numerical data, percentages, mean values and Standard deviations using a statistical software program.

To analyze how the standard deviation relates to the mean, the coefficient of variation (CV) was calculated. This provides a more uniform method of determining the relevance of the standard deviation and what it indicates about the responses of the sample. The closer the

CV is to 0, the greater the uniformity of data. The closer the CV is to 1, the greater the variability of the data.

Task Analysis

To analyze the pre-service teachers' written tasks, I utilized a framework for analysis of dynamic geometry tasks developed by Trocki (2014). This framework was designed to identify qualities of dynamic geometry tasks. It is divided into two parts: allowance for mathematical depth and types of technological action (see Fig. 5). Trocki (2004) based the level of allowance for mathematics depth on work done by Smith and Stein (1998) and types of technological action on work by Sinclair (2003).

Allowance for Mathematical Depth	
Hierarchical Levels	**Descriptions**
N/A	Prompt requires a technology task with no focus on mathematics.
0	Sketch does not have mathematical fidelity required to respond to prompt.
1	Prompt requires student to recall a mathematics fact, rule, formula, or definition.
2	Prompt requires student to report information from the construction. The student is not expected to provide an explanation.
3	Prompt requires student to consider the mathematical concepts, processes, or relationships in the current sketch.
4	Prompt requires student to explain the mathematical concepts, processes, or relationships in the current sketch.
5	Prompt requires student to go beyond the current construction and generalize mathematical concepts, processes, or relationships.

Types of Technological Action	
Affordances	**Descriptions**
N/A	Prompt requires no drawing, construction, measurement, or manipulation of current sketch.
A	Prompt requires drawing within current sketch.
B	Prompt requires measurement within current sketch.
C	Prompt requires construction within current sketch.
D	Prompt requires dragging or use of other dynamic aspects of the sketch.
E	Prompt requires the creation or consideration of multiple examples from which one can generalize.
F	Prompt requires a manipulation of the sketch that allows for recognition of emergent invariant relationship(s) or pattern(s) among or within geometrical object(s).
G	Prompt requires manipulation of the sketch that may surprise one exploring the relationships represented or cause one to refine thinking based on themes within the surprise. (Adapted from Sinclair [2003, p. 312])

Figure 5: The framework for task analysis from Trocki (2014)

Each part of the PSTs' tasks was regarded as a prompt. Trocki (2014) defined mathematical prompts as a "written question or direction related to a sketch that requires a verbal or written response" (p.703). On the other hand, he defined a technology prompt as a. "question or direction that requires a drawing, construction, or measurement within or manipulation of sketch" (Trocki, 2014; p.703).

The different prompts were categorized as mathematical depth and/ or types of technological action. Mathematical depths were coded with number and technological actions were coded with letters. According to Trocki (2014), high quality tasks were deemed as those tasks that contained prompts that will encourage the drawing, measuring, constructing and at the same time the exploration of mathematical relationships, in order to develop a deeper mathematical understanding. Again, more detail is included with the results in Chapter 4.

Summary of Chapter 3

Chapter 3 explained the context and methods utilized in this study. A qualitative case study method, in the form of a workshop was used to provide answers to the research questions. It began with stating the objectives of the workshop, then went on to describe what will take place on the each of the four days.

A description of the recruitment and sample method used to select participants then ensued. For this study, a purposive/convenient sampling technique was employed which was supported by the work of Cohen et al (2000). The chapter then went on to provide a description of the PSTs who participated in the workshop; the various levels that they were being trained to teach. These included 17 females and 1 male with between 0 to 16 years of classroom teaching experience, being train to teach between grades 4 to 9.

Data from a pre-questionnaire was provided indicating the demographics; use of computer and some software experiences of the PSTs were provided. Further, three types of data was collected during the workshop: videos of the workshop, questionnaires, and tasks written by the students to incorporate the use of GeoGebra. At the end of each workshop, the PSTs completed evaluation forms.

To close this chapter, the researcher then went on to speak towards the analysis of the data collected. The work of Powell, Francisco & Maher (2003) was used to inform the analysis of the videos. The questionnaires were analyzed using SPSS, Microsoft Excel and transcription. The analysis of the PSTs' tasks was done using a framework for the analysis of dynamic geometry tasks developed by Trocki (2014).

CHAPTER FOUR – RESULTS

Introduction

In this chapter I present an analysis of data obtained from multiple data sources utilized in the research, namely surveys, video recordings and PSTs' written tasks using GeoGebra. The research questions for this study were:

1. How do pre-service mathematics teachers engage in a GeoGebra workshop?
2. How do pre-service mathematics teachers respond to a GeoGebra workshop?
3. Do GeoGebra tasks written by pre-service teachers contain prompts that will encourage students to experiment and build their mathematical understanding?

In the following sections, the findings that answer these questions are presented. The results from the pre-questionnaire were presented in Chapter 3 when the PSTs were described. In this chapter, I present results from the daily surveys, the post-questionnaire, the task writing, and the videos recorded at the workshop. A discussion of the themes which were revealed followed. In Chapter 5, a discussion about the results and implications will be presented.

Findings from Workshop Evaluation Data

This section presents an analysis of data that was collected each day of the workshop daily surveys. A survey instrument (see Appendix C) to measure PSTs' views was modified from Preiner (2008). Each daily survey asked each PST to respond by rating the activities from very easy to difficult. There were four days of the workshop and each day was 2-3 hours long. The PSTs rated the difficulty of the workshop activities on a scale from 0 (‘very easy’) to 5 (‘very difficult’) every day.

To measure how the PSTs responded to the GeoGebra workshop, an analysis of teachers’ perceptions of tasks done with GeoGebra is presented in table 5. Table 5 depicts the average and variation of the average level of difficulty of PSTs’ perceptions of GeoGebra tasks. The overall mean score for the workshop was calculated as 1.31which may indicate that the workshop was easy. However the coefficient of variation for days 1, 2 and 4 were 0.18, 0.13 and 0.22 respectively and these were rather small. This suggest that these data has a greater deal of uniformity with respect to the mean and there is was a general consensus among the sample. But day 3 coefficient of variability was 0.41 which is rather large, indicating that this data has a great deal of variability with respect to the mean and little general consensus among the sample.

Table 5: *Average rating and variation of averages during the workshop*

Days of workshop	**Average level of difficulty**	**Standard Deviation**	**Coefficient of Variation**
1	1.47	0.27	0.18
2	1.35	0.17	0.13
3	1.17	0.48	0.41
4	1.25	0.27	0.22

Individual workshop activities and ratings

The structure and content of the introductory workshop consisted of four days and each day had different tasks. Tables 6, 7, 8 & 9 provide a list of the activities PSTs were engaged in during the four days as well as their average difficulty rating and Standard deviations. Base on the information in tables 6,7, 8 and 9 none of the workshop activities received a rating greater than 2.00 (day 4 activity 1: Using sliders to create parallel and perpendicular lines). Each PST was expected to complete 19 tasks individually and one task as a group during the four days.

Day 1

PSTs rated understanding the parent child relationship when working in a dynamic environment as the easiest task. The PSTs were never exposed to this concept before but they were able to quickly identify it when they created a line segment. After dragging and deleting points, PSTs recognized that objects were dependent and independent. The most difficult rated task had (using triangle to solve partition of land problem). This task required application of the new knowledge PSTs gained to solve a real life problem (see Fig.6). Only 38 percent of PSTs rated this task as easy (a rating of 0-1), while 14 percent deemed this task as very difficult (a rating of 4-5). The standard deviation in table 6 indicates that the there is a large variation of the data set per task.

Table 6: *Average and Standard Deviation (SD) rating for Day 1 tasks*

Day 1 Tasks	**Average level of difficulty**	**Standard Deviation**
Understanding the concept parent-child relationships in DGE	1.00	1.26
Drawing versus Constructing	1.29	1.48
Constructing a right angle triangle	1.33	1.06
Construction of a equilateral triangle	1.86	1.35
Measuring angles and distances	1.62	1.96
Finding the center of a triangle	1.19	1.40
Using triangle to solve partition of land problem	2.00	1.45

Figure 6: Pre-service Teachers working using triangle to partition a piece of land.

Day 2

Table 7: *Average and SD rating for Day 2 tasks*

Day 2 Tasks	**Average level of difficulty**	**Standard Deviation**
Constructing a square	1.18	1.01
Solving partitioning of land problem of the shape of Quadrilaterals	2.06	1.34
Translation of an object	1.29	1.40
Reflection of an object	1.18	1.33
Rotation of an object	1.06	1.43

Table 7 reveals that PSTs rated the activity (rotation of an object) as the easiest task with GeoGebra. PSTs were familiar with the concept of rotation from high school level, although they did not use GeoGebra before; however the use of GeoGebra made the concept much simpler and easier when compared to how each participant were exposed to the concept at the high school level. Solving partitioning of land problem of the shape of quadrilaterals was rated as the most challenging task with GeoGebra (see Figure 7). This was difficult because students were forced to apply all the new skills and knowledge again from the previous workshop to solve a real life problem. The standard deviation in table 7 indicated that that there is a large variation within the data set per task.

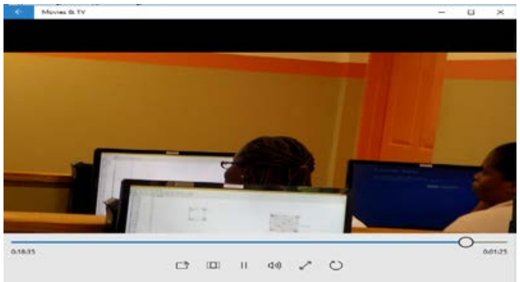

Figure 7: Pre-service Teachers solving partitioning of land problem of the shape of Quadrilaterals

Day 3

Table 8: *Average and SD rating for Day 3 tasks*

Day 3 Tasks	**Average level of difficulty**	**Standard Deviation**
Sequence activities to foster algebraic thinking	1.37	1.30
Creating a line graph from an ordered set in a spreadsheet	1.00	1.00
Creating graph by inputting algebraic equation	1.61	1.73
Using sliders to transform graphs	0.68	0.67

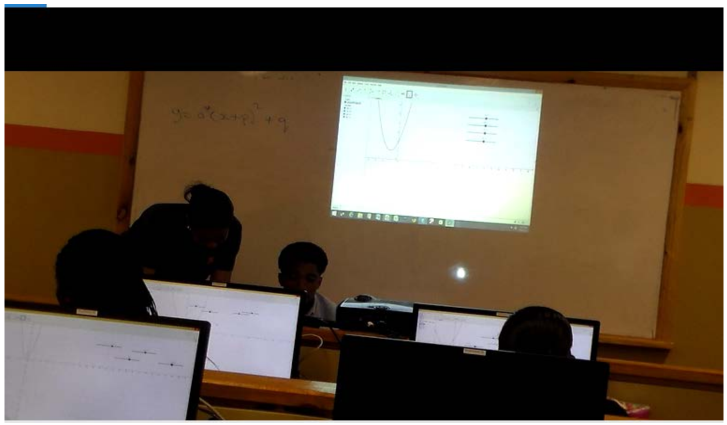

Figure 8: Using sliders to transform graphs

Using sliders to transform graphs was rated the easiest activity (see Table 8). PSTs using the sliders saw the transformation of different graphs as an intuitive and fun activity (see figure 8). In contrast PSTs rated creating graph by inputting algebraic equation as the most challenging activity with. This activity involved students inputting algebraic equations into the GeoGebra input bar and seeing different graphic representations. PSTs had some trouble decide which symbol to input for the different arithmetic symbols. The standard deviation in table 8 indicated that that there is a large variation within the data set per task.

Day 4

Table 9: *Average and SD rating for Day 4 tasks*

Day 4 Tasks	**Average level of difficulty**	**Standard Deviation**
Using sliders to create parallel and perpendicular lines	2.4	1.12
Creating a task using GeoGebra	1.4	1.55
Saving a document using GeoGebra	0.5	0.90
Using GeoGebra tool bars and command when creating a task	0.6	1.11

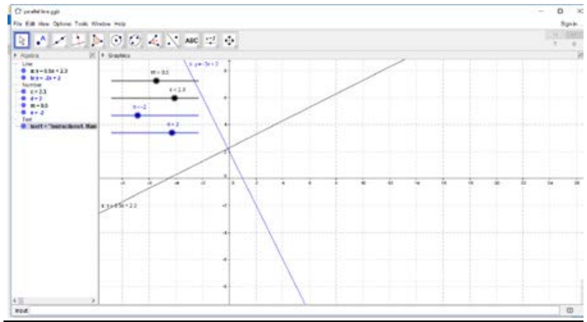

Figure 9: Using sliders to create parallel and perpendicular lines

Table 9 shows that the activity using sliders to create parallel and perpendicular lines was rated the most challenging by PSTs. PSTs had difficulty remembering the concept of parallel and perpendicular lines and they struggled with this task (see Fig.9). Saving a file was rated as the easiest activity. PSTs were familiar with saving documents on the computer; therefore they found this activity very easy. The standard deviation in table 9 indicated that that there is a large variation within the data set per task.

Post Questionnaire Findings

Sixteen out of 21 PSTs responded to the post GeoGebra questionnaire. These results are reported as a way to understand how PSTs' responded to the GeoGebra workshop.

Did pre-service teachers have positive attitudes toward the use of GeoGebra?

All of the respondents had no previous experience with GeoGebra before this workshop. As shown in Table 10, in the beginning, approximately 38% of the PSTs did not quite like the use of GeoGebra but after the workshop the majorities (94%) of the PSTs were more open to mathematical explorations using GeoGebra. All of the PSTs (100%) indicated that they will share GeoGebra with students, parents, their colleagues and administrators and 100 % also agreed that they will continue to use GeoGebra. A moderate number of PSTs (50%) did not think that GeoGebra made mathematics more difficult to learn or teach. The results presented in Table 10 reveal that most PSTs had a positive attitude towards using GeoGebra.

Table 10: *Pre-service teachers' attitude towards GeoGebra*

Question	Very Strongly Disagree	Strongly Disagree	Disagree	Agree	Strongly Agree	Very strongly agree.
At the beginning I did not like GeoGebra	18.8% (3)	1%(6.3)	37.5% (6)	31.3%(5)	0%(0)	6.3%(1)
Right now I am more open to explorations using GeoGebra	0	0	6.3%(1)	6.3%(1)	43.8%(7)	43.8%(7)
I like it because it is free to everyone	0	0	0	25%(4)	18.8%(3)	56.3%(9)
I will share GeoGebra with my students and parents	0	0	0	25%(4)	18.3%(3)	56.3%
I will share GeoGebra with my colleagues and administrators	0	0	0	18.8%(3)	37.5%(6)	43.8%(7)
I will continue to learn and use GeoGebra	0	0	0	37.5(6)	6.3%(1)	56.3%(9)

How did pre-service teachers respond to curricular issues related to GeoGebra?

As shown in the Table 11, most (63%) of the PSTs felt that GeoGebra challenged their conception of mathematics and 94% felt that they could adapt existing materials for GeoGebra use. All of the PSTs (100%) thought that the teachers will have to face challenges from their own students when GeoGebra is used. An overwhelming majority (100%), of them believed that GeoGebra can help students create their own mathematical ideas. Interestingly, some of the PSTs (56 %) felt that the mathematics textbooks that are currently being used have to be revised to make use of GeoGebra. I think this is because of lack of exposure to the use of GeoGebra.

Table 11: *Curricular issues related to GeoGebra Use*

Question	Very Strongly Disagree	Strongly Disagree	Disagree	Agree	Strongly Agree	Very strongly agree.
It challenges my conception of the mathematics I was taught	12.5%(2)	12.5%(2)	12.5%(2)	25 %(4)	12.5%(2)	25%(4)
The textbook has to be revised for me to make use of GeoGebra	0	12.5%(2)	31.3%(5)	18.8%(3)	12.5%(2)	25%(4)
I can adapt existing Materials for GeoGebra	0	0	6.3%(1)	25% (4)	43.8%(7)	25%(4)
GeoGebra will help students create their own mathematical ideas	0	0	0	31.3%(5)	25%(4)	43.8%(7)

Table 11 Continued

The teacher will have to face the challenges from students when GeoGebra is used	0	0	18.8%(3)	25% (4)	31.3(5)	25%(4)

How do pre-service teachers respond to mathematical content when using GeoGebra?

Table 12 reveals that all of the PSTs (100%) felt that they had re-learned some mathematical ideas and the use of GeoGebra has raise their enthusiasm for the effective and wise application of technology to the teaching and learning of mathematics. In addition (100%) also felt that they have gained experience on how to use the different tools of the software and on how to use GeoGebra as a tool to enhance students practice. Most PSTs (94%) felt that they were beginning to see mathematics as a consistent system. It is not surprising then that most PSTs (75%) did not feel that GeoGebra made mathematics more difficult for them. However, the majority (75%) did feel that a new type of mathematics was being taught to them and agreed that GeoGebra can be credited for helping them to realize the need to change their teaching habits in order to allow students more real time exploration opportunities.

In written responses PSTs also indicated that they were able to understand some mathematics content better with the use of GeoGebra. They also believe that using GeoGebra will greatly assist with the teaching of the mathematics content area of algebra and Geometry. Based on the findings in Table 12 PSTs seem to have had a positive response to knowledge and skills gained from the GeoGebra workshop.

Table 12: *Mathematical content issues related to GeoGebra Use*

Question	**Very Strongly Disagree**	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**	**Very strongly agree.**
GeoGebra workshop has helped me relearn some mathematical ideas	0	0	0	12.5%(2)	31.3%(5)	56.3%(9)
GeoGebra made mathematics seem more difficult to me	25%(4)	25%(4)	37.5%(6)	0	0	12.5%(2)
GeoGebra workshop has helped me see mathematics as a consistent system of ideas	0	0	6.3%(1)	37.5%(6)	25%(4)	31.3%(5)
I will like to learn more mathematics	0	0	0	31.3%(5)	25%(4)	43.8%(7)
I feel that a new kind of mathematics is being taught	0	0	12.5%(2)	31.3%(5)	12.5%(2)	43.8%(7)
The use of GeoGebra has raise my enthusiasm for the effective and wise application of technology to the teaching and learning of mathematics	0	0	0	37.5%(6)	18.8%(3)	43.8%(7)

Table 12 Continued

GeoGebra can be credited for helping me to change my teaching habits to allow students real time exploration opportunities	0	0	12.5%(2)	37.5%(6)	12.5%(2)	37.5%(6)
GeoGebra has helped me to make graphical representations of math concepts	0	0	6.3%(1)	50%(8)	25%(4)	18.8%(3)
I have gained experience on how to use the different tools of the software and on how to use GeoGebra as a tool to enhance students practice	0	0	0	18.8%(3)	43.8%(7)	37.5%(6)

How do pre-teacher respond pedagogical issues when using GeoGebra?

Table 13 indicates the majority of PSTs responded positively to pedagogical Issues as it relates to the use of GeoGebra when teaching mathematics. This was very evident when all of the PSTs (100%) agreed that GeoGebra helps them make connections among mathematical ideas; rethink about mathematics teaching; create meaningful activities; students will generally like GeoGebra; they would be willing to learn with their students about GeoGebra; and GeoGebra constructions will provide useful feedback for students. In addition, 94% felt that GeoGebra will help them reach out to more children.

Table 13: *Pedagogical issues related to GeoGebra Use*

Question	Very Strongly Disagree	Strongly Disagree	Disagree	Agree	Strongly Agree	Very strongly agree.
It helps me to make connections between different domains of mathematics	0	0	0	37.5%(6)	25%(4)	37.5%(6)
It will help me reach out to more students	0	0	6.3%(1)	37.5%(6)	18.8%(3)	37.5%(6)
It has helped me rethink about mathematics teaching and learning	0	0	0	31.3%(5)	25%(4)	43.8%(7)
It will allow me to design meaningful activities for my students	0	0	0	31.3%(5)	25%(4)	43.8%(7)
I think students will generally like GeoGebra	0	0	0	37.5%(6)	18.8%(3)	43.8%(7)
I am willing to learn with my students about the new tools	0	0	0	25%(4)	37.5%(6)	37.5%(6)
GeoGebra constructions will provide useful feedback for students	0	0	0	37.5%(6)	25%(4)	37.5%(6)

Open Ended Question Analysis

The findings from the open-ended questions (see Appendix D) are in sync with what researchers had found to be the benefits of the GeoGebra. These PSTs were able to discover these benefits in a short time. In this section, I synthesize the results and providing examples when appropriate. This questionnaire was the final one completed by the PSTs at the end of the four workshops.

What did you like about the GeoGebra workshop?

Fifty three percent (53%) of PSTs liked the way in which GeoGebra interconnected algebra, geometry and spreadsheets together. One PST wrote, "*I really like how you can incorporate the different aspects of mathematics, the algebra, trigonometry and geometry*". Fifty percent (50%) of PSTs liked the animated and dynamic nature of the software; for example, one PST said, "*I like the range of different animated activities for children*". Thirty one percent (31%) of PSTs commented that they like that GeoGebra made mathematics to appear simpler and diverted from the traditional way of doing mathematics for example one PST wrote, *"I like that there's a new way of practicing algebra, spreadsheet and graphs other than the traditional way."* An overwhelming majority of PSTs (90%) liked that they had fun while still learning important mathematics concepts, one PST commented, "*This workshop with GeoGebra made me realized how we teacher can make it easy for students to have fun and at the same time learning.*".

Is there anything that you didn't like about the GeoGebra workshop?

In response to this question, only one PST said yes and her reason was, "*Time did not permit the participants to be exposed to other areas that GeoGebra that may be useful for in Mathematics instruction.*" The remaining PSTs (95%) commented, they simple enjoyed the workshop and thought it was quite timely.

Do you think GeoGebra will be useful to be used with your students?

All of the PSTs (100%) agreed and their reasons were using GeoGebra will help students develop a better understanding of the mathematical concepts and learning will become more meaningful, for example, one PST wrote, "*It will be useful in teaching mathematics with my PSTs because with this software i can give my students a task such as construct a right angle triangle and have them discuss the triangle with a partner without having them use pencil, paper , protractor or a ruler to complete the task.*" Another PST also wrote, "*It can help students construct their own understanding and makes the learning activity more authentic, therefore learning will be more meaningful.*" Forty seven percent (47%) of PSTs also believed with GeoGebra students will enjoy mathematics more when GeoGebra is incorporated. For example, one PST wrote, "*GeoGebra is a fun way to teach students about some topics that most students have difficulties with.*"

Is GeoGebra a useful teaching tool?

All PSTs (100%) agreed that GeoGebra is a useful teaching tool. They claimed that the GeoGebra software can be a great tool to use when teaching challenging topics in geometry and algebra, for example one PST wrote, "*GeoGebra can assist the teacher in* *teaching topics that students can find challenging, such as algebra, geometry and solving of worded problems"*.. Another PST wrote, "*It is very good at providing multiple representations in a relatively short time."* Another PST added, "*It helps to free students from pencil and paper construction so they can explore and justify their findings*."

What gave you the most problems during the workshop?

Based on the result from the table above, there were varying responses to this question. Forty five percent of PSTs (45%) had some difficulties with merging spreadsheet with the graph view. For example one PST commented, "*Merging spreadsheet with the graph view was difficult."* Twenty seven percent (27%) of PSTs stated that "*Creating the task that would be useful in a classroom* was difficulty." Twenty eight (28%) percent of PSTs claimed that using the angle tool and transformation of objects gave them the most problem. For example one PST wrote, *"Finding the angles of triangles gave me the most problem"* and another PST stated that, *"Reflection was a bit of a challenge."*

Tasks Analysis

The different tasks written by students were outlined and analyzed by using the Trocki (2014) task analysis framework that identifies characteristics of prompts associated with how the task was written. This framework is divided into two components: allowance for mathematical depth and technological actions. The levels of allowances for mathematical depth and technological action were coded with numbers and letters respectively. For each task, I show a screen shot of the task in GeoGebra; in the table are the typed words from the task to make reading easier and the coding of the different prompts using the framework.

Group 1 Task

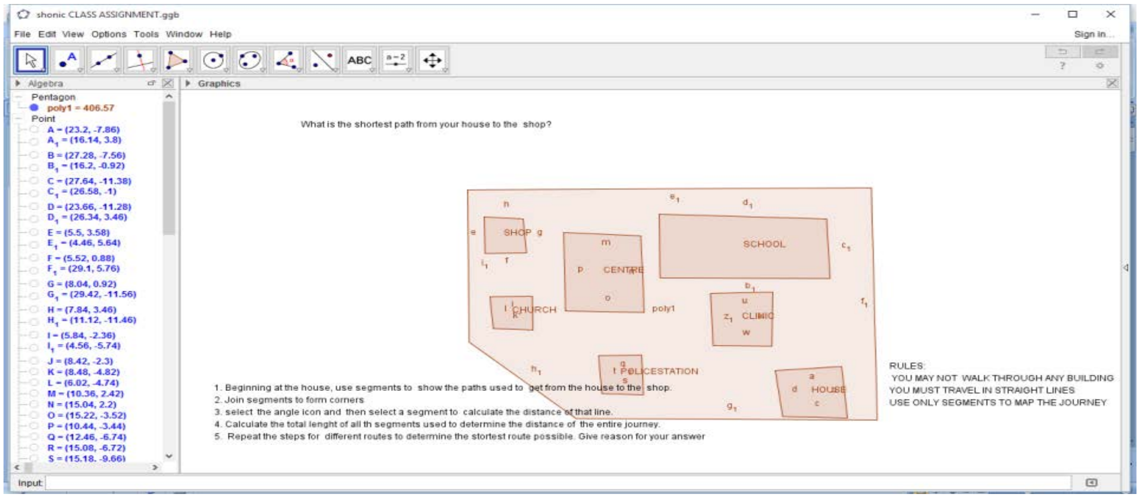

Figure 10: Pre-service Teachers created task of finding the shortest distance

Table 14: *Group 1 Prompts and Coding*

Prompt Number	**Allowance for mathematical depth codes**	**Types of Technological Action codes**
i. Beginning at the house, use segments to show the paths used to get from the house to the shop	1	C
ii. Join segments to form corners	1	C
iii. Select the angle icon and pull down the drop down menu then select a segment to calculate the distance of that line.	1	B
iv. Calculate the total length of all the segments used to determine the distance of the entire journey	2	B
v. Repeat the steps for different routes to determine the shortest route possible. Give reason for your answer.	4	E

Figure 10 Shows PSTs' created task for group 1 and Table 14 shows that this task had 5 prompts with both allowance for mathematical depth and technological action. Three of the mathematical depths prompts i, ii & iii were (coded 1) which only require students to

recall a mathematical fact, rule, formula or definition, while prompt iv (coded 2) requires students to report information about the total length of all the segment used to determine the total distance from the construction. Prompts v (coded 4) require students to examine the mathematical processes to determine the shortest possible route and provide an explanation for their reasoning.

Table 14 also shows that Task 1 also utilizes technological action, prompts i and ii (code C) require constructs of lines segments within current sketch, prompts iii and iv (coded B) require measurement of the line segments and the total distance within current sketch and prompt v (coded E) requires students to examine multiple routes to make a generalization about the shortest possible distance.

Group 2 Task

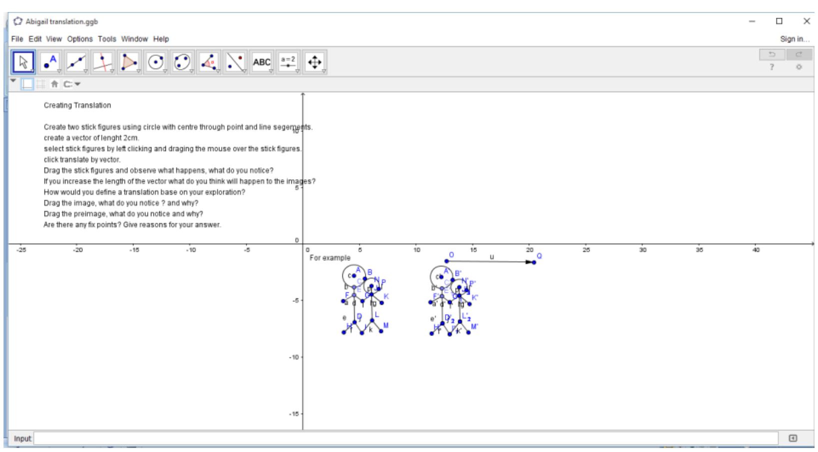

Figure 11: Pre-service Teachers created task of translation of object

Table 15: *Group 2 Prompts and Coding*

Prompt Number	Allowance for mathematical depth codes	Types of Technological Action codes
i. Create two stick figures of a man using the icon the circle with centre through points and line segments.	1	A
ii. Created a vector of length 2cm	1	C
iii. Select the figures by left clicking and dragging the mouse over the stick figures.	N/A	D
iv. Click translates by vector	N/A	D
v. Drag the stick figures and observe what happens, what did you notice?	3	D
vi. If you increase the length of the vector what do you think will happen to the image?	3	C
vii. How would you define the term translate based on your exploration?	5	F
viii. Drag the image what do you noticed? And why?	4	D
ix. Drag the pre-image what do you notice? And why?	4	D
x. Are there any fix points? Give reason for you answer	5	F

Figure 11 shows PSTs' created task for group 2 and Table 15 shows that this task had ten (10) prompts with both allowance for mathematical depth and technological action. Two of the mathematical depth prompts i, & ii (coded 1) require students only to recall mathematics definition of the term segment. Prompts v and vi (coded 3) require students to report information from their observation when dragging the pre- image and the image of the translated object. Prompts viii and xi (coded 4) require students to explain the changes the noticed about the pre-image and the image. Prompt vii and x (coded 5) require students to go beyond the current construction and make a generalize statement about the term translation and about fix points in translation of an object. Prompts iii and iv (coded N/A) only require technology action and no mathematical depth (see Table 15).

All prompts encourage technology action at different levels. Prompts i (coded A) simply require drawing of a stick figure and prompts ii and vi (coded C) require the construction of a vector within the current sketch. Prompts iii, iv, v, vii and ix (coded D) all require the use of dragging and other dynamic aspect such as selecting and clicking to translate an objects and exploring relationships between the pre-image and the image under a translation. Prompt vii and x (coded F) require the manipulation of the pre-image and the image that allows students to recognize the emergent invariant relationship of translations and fix points.

Group 3 Task

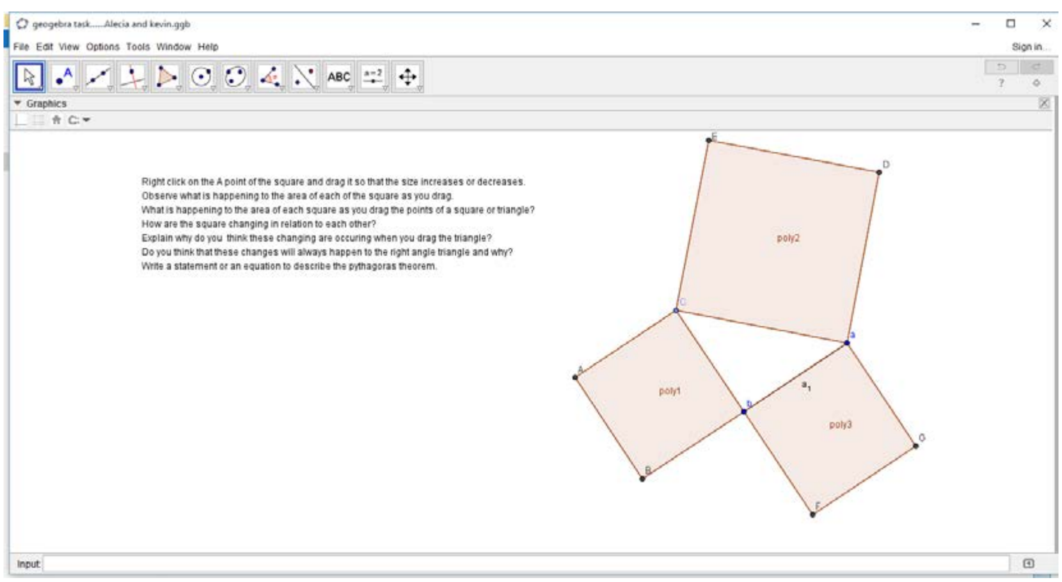

Figure 12: Pre-service Teachers created task of the Pythagoras theorem

Table 16: *Group 3 prompts and coding*

Prompt Number	**Allowance for mathematical depth codes**	**Types of Technological Action codes**
i. Right click on the point A of the square and drag it so that the size increases and decreases	1	D
ii. Observe what is happening to the area of each of the square as you drag.	2	D
iii. What is happening to each area of the squares as you drag the point of a square or on the triangle?	2	F
iv. How are the squares changing in relation to each other as you drag?	4	F
v. Explain why do you think these changes are occurring when you drag the triangle?	4	F
vi. Do you think these changes will always happen to a right angle triangle and why?	5	F
vii. Write a statement or an equation to describe the Pythagoras theorem	5	N/A

Figure 12 shows PSTs' created task for group 3 and Table16 shows that this task had eight (8) prompts with both allowance for mathematical depth and technological action. Prompt i (coded 1) only wanted students to recall the term square and point in order to complete the action. Prompts ii and iii (coded 2) require the reporting of information on the area of the square as it changes dynamically. Prompt iv and v (coded 4) are asking for an explanation for the relationship between the squares and students reasoning for the change. In addition, prompt vi and vii (coded 5) are asking students to go beyond the current construction and generalize about the relationship between the squares and the triangle through an explanation and an expression to describe the Pythagoras theorem.

Most of the technological actions require for the prompts were basically dragging and the manipulation of the sketch so that students will be allowed to recognize the emergent of relationship between the squares and triangle to discover the Pythagoras theorem. Prompts i and ii (coded D) required the action of dragging and prompts iii to vi (coded F) require the manipulation of the objects to recognize relationships. However, prompt v (coded N/A) did not require a technology action but rather students used the information that will they gain through the exploration of the objects to write an expression to describe the Pythagoras theorem (see Table 16).

Group 4 Task

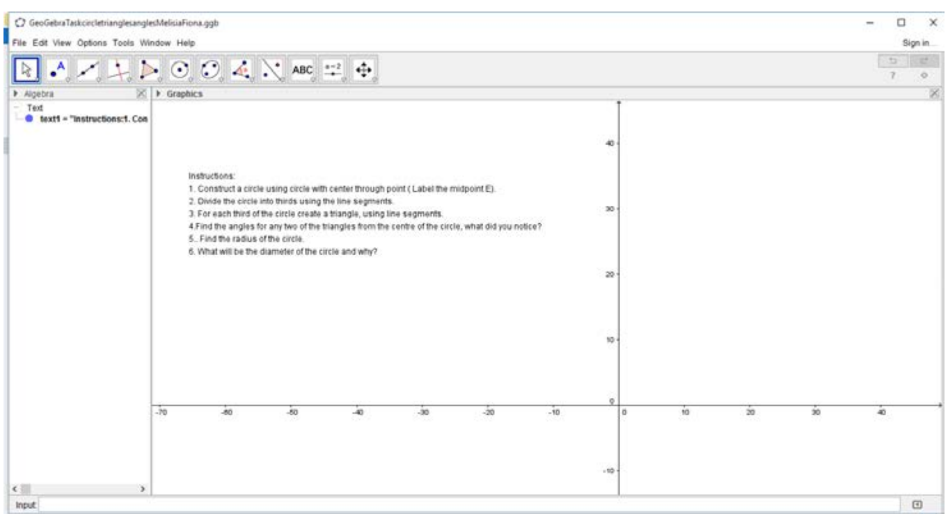

Figure 13: Pre-service Teachers created task with Circles

Table 17: *Group 4 prompts and coding*

Prompt Number	**Allowance for mathematical depth Codes**	**Types of Technological Action codes**
i. Construct a circle with center through a point (label the center E).	1	C
ii. . Divide the circle into thirds from the center using segments.	1	C
iii. For each third of the circle use line segments and create triangles	1	C
iv. Find the angles for any two triangles from the center of the circle, what did you noticed?	2	D
v. What is the length of the radius of the circle?	1	B
vi. What will be the diameter of the circle and why?	4	N/A

Figure 13 shows PSTs' created task for group 4 and Table 17 shows that task 4 seems like a simple task because most of the mathematical depth prompts (coded 1) only require students to recall basic terms such as circle, segment, triangles and radius. Prompt iv (coded 2) simply asked PSTs to report on angles size. Prompt vi (coded 4) requires PSTs to explain a mathematical concept.

Most of the technology knowledge that was required by prompt i, ii and iii (coded C) are the constructions of circles, line segment and triangles. Prompt v (coded B) asks PSTs to apply measurement to find the length of the radius. Prompt vi (coded N/A) did not require any technological action (see Table 17). Students will be allowed to think through what was done dynamically and identify the diameter with justification.

Group 5 task

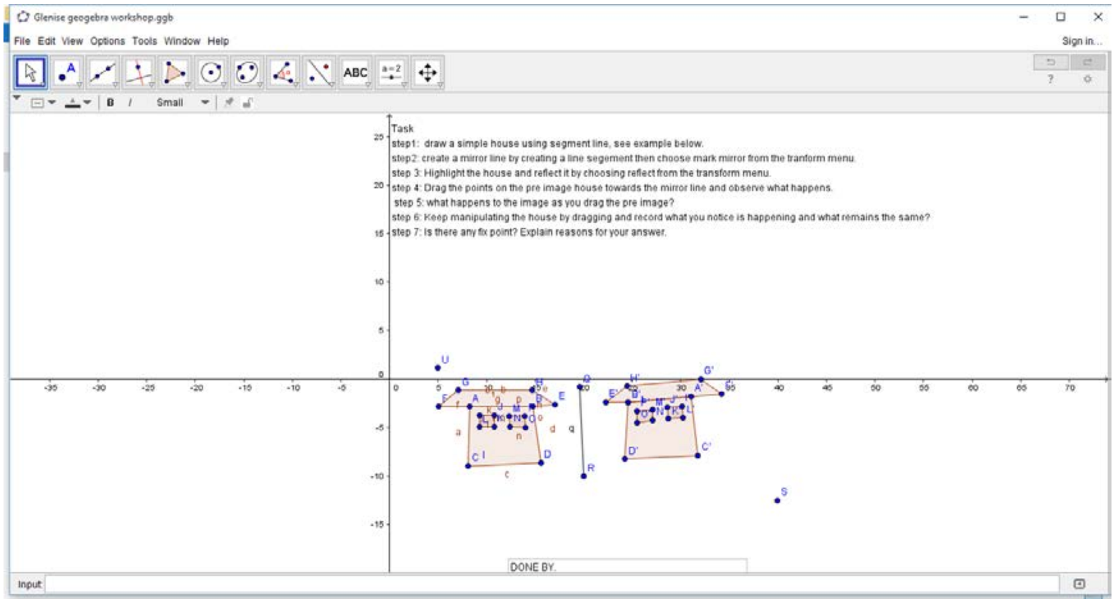

Figure 14: Pre-service teachers create task of reflection of a house

Table 18: *Group 5 prompt and coding*

Prompt Number	Allowance for mathematical depth Codes	Types of Technological Action codes
i. Draw a simple house using line segment, an example is provided below	1	A
ii. Create a mirror line by creating a line segment then choose mark mirror from the transform menu	1	D
iii. Highlight the house you drew and reflect it by choosing reflect from the transformation menu	1	D
iv. Drag a point on the house objects towards the mirror line and observed what happens	2	D
v. What happens to the image as you drag the pre-image?	2	F
vi. Keep manipulating the house by dragging and record what you notice is changing and what remains the same?	4	F
vii. Is there any fix point? Explain reasons for your answer	4	F

Figure 14 shows PSTs' created task for group 5 and Table 18 shows that the mathematical depth of this task increased as the prompt increased. Prompts i, ii and iii (coded

1) only require students to recall the mathematically fact of the terms segment, mirror line and reflect. Prompts iv and v (coded 2) will require students to report what happens to the pre- image and the image as they are dragged towards the mirror line. Prompt vi and vii (coded 4) requires students to consider the mathematical relationship between the pre-image and the image during a reflection and to examine the fix point of a reflection.

The technological action of this task was also progressive as the levels of the prompts increase. Prompt i (coded A) only requires students to draw an object (a house) dynamically, while prompts ii to v (coded D) require students to use the dynamic feature of GeoGebra to create a mirror, reflect an object and to drag the object. Prompt v, vi and vii (coded F) all require students to manipulate the objects to allow students to recognize the invariant relationship during a reflection (see Table 18).

Group 6 task

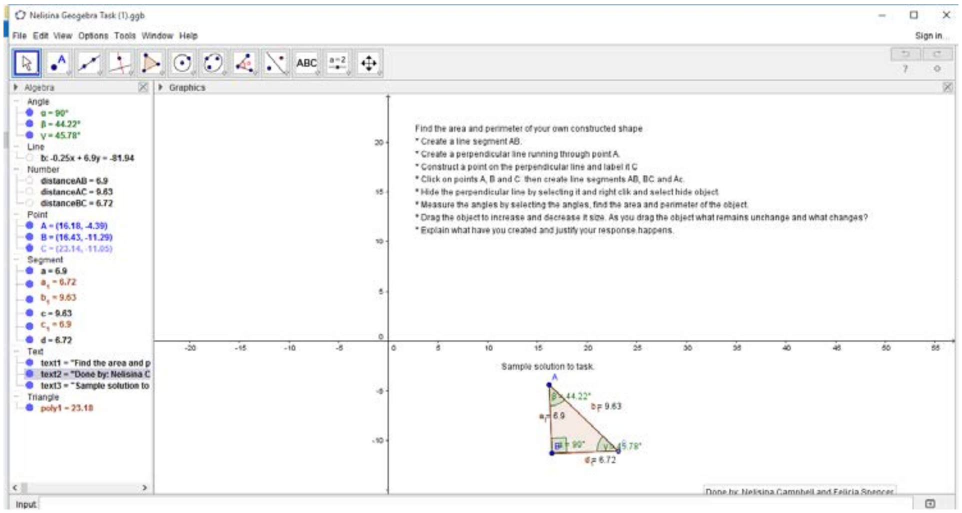

Figure 15: Pre-service Teachers created task of constructing a right angle triangle

Table 19: *Group 6 prompts and coding*

Prompt Number	**Allowance for mathematical depth Codes**	**Types of Technological Action codes**
i. Create a line segment AB	1	C
ii. Create a perpendicular line running through point A.	1	C
iii. Construct a point on the line perpendicular to the line segment AB and label the point C	1	C
iv. Click on points A, B and C. then, create line segment AB, BC, and AC.	1	C
v. Hide the perpendicular line by selecting it and right click and hide object.	N/A	D
vi. Measure the angles by selecting the angles; find the area and perimeter of the object	1	B

Table 19 Continued

vii. Drag the object to increase and decrease it size. As you drag the object what remain unchanged and what changes?	2	F
viii. Explain what have you created and justify you response	4	N/A

Figure 15 shows PSTs' created tasks for group 6 and Table 19 shows that the task prompts did not seem to require much mathematical depth. Five out of the nine prompts (coded 1) only require students to recall mathematical facts about the terms perpendicular lines, line segment and measurement associated with a triangle. Prompt v (code N/A) only required technology with no mathematics focus. Prompt iii and iv (coded 2 and 4) required students to consider reporting their observation as they drag the object and also explain their findings.

The main technological action of this task was the construction of perpendicular lines and line segments, which were evident in prompt i, ii, iii and iv (coded C). Prompt ii (coded B) required students to use the dynamic feature of GeoGebra to measure angles, area and the perimeter of the triangle. Prompt v (code D) only requires the dynamic action of hiding an object and prompt vii (coded F) requires the manipulation of the triangle to examine the emergent of invariant relationships (see Table 19).

Summary of Pre-service Teachers' Created Tasks

Table 14, 15,16,17,18, and 19, provides a summary of the prompts and the codes for each task that were written by the PSTs in the research. Trocki (2014) implied that organizing codes in this manner will provide a good indication of the degree of mathematics reasoning each task promotes. From the information provide in the tables above each task contained prompts with mathematical and technological component. However for task 1, 4, 5 and 6 the allowance for mathematical depth never goes beyond level 4 with only one prompt was at this level and it must be noted that all of these PSTs had no teaching experience.

However task 2 and 3 consistently include both mathematical depths reached at level 5 and these tasks were done by PSTs with some teaching experience. In addition, the tables indicated that as the level of mathematical depth increase little or no technological action was required. This implied as the mathematical depths of prompts increased then more thinking and reasoning is required than technological actions. These were prompts that required students to measure and then drag to consider relationships. Trocki (2014) claimed that these tasks were indications of students doing mathematics, by exploring and understanding the nature of mathematics relationships and forming deeper understanding. Trocki (2014) concluded that high quality tasks must contain prompts that require students to go beyond the current construction and generalize mathematical concepts, processes or relationships.

According to Thomas & Chinnappan (2008) and Zevenbergen & Lerman (2008) technology tools should be used to support students' mathematical development and provide vehicles for representation, communication, reflection, and argumentation. They further claimed that technological tools are most effective when they cease to be solely as external aids; instead becoming integral parts of students' mathematical reasoning. As tools become increasingly invested with meaning, they become increasingly useful for furthering learning.

Video Analysis

As described in Chapter 3, the analysis of PSTs engagement from the videos was adopted from Fredricks, Blumenfled and Paris (2004) who proposed that student engagement has multiple dimensions. By viewing, summarizing and describing video data, I was able to acquire a fairly in-depth knowledge of the content of the videos (see Appendix E), for the summaries description of the workshop sessions). The data gathered was then examined to identify PSTs engagement which was categorizes as behavioral, emotional and cognitive (see Table 20). Table 20 is divided into each day of the workshop; these were further divided into the video number and time per video, followed by a description of the different PSTs' engagement.

Table 20: *A summary of the different types of pre-service teachers' engagement as seen from the video*

Workshop sessions	Video	Time (mins)	Type of pre-service teachers engagement and notes
Session 1	006	0-20	**Behavioral**- PSTs listened attentively to researcher as she explained the objectives of the workshop and read handouts on explanation of the toolbar.
	007	20	**Cognitive-** PSTs explained their reasoning to questions asked by the researcher. Researcher: "what comes to mind when you hear the word geometry?" PSTs' response: "shapes, angles, measurement." Researcher: "Which will you say is the parent?" PSTs' response: "A" Researcher: "Why is c the child?" PSTs' response: "point c is dependent on the line segment."

Table 20 Continued

				Researcher: "Explain in your own what the term parent child relationship means?" PSTs' response: "when something is dependent on other thing to be in existence." **Behavioral**: manipulated the tools in GeoGebra. PSTs working independently to manipulate the software GeoGebra, discussing task with each other. **Emotional:** PSTs expressing confidence by getting the first task completed successfully. Amazement with what the hide tool can do.
	008		20	**Cognitive:** PSTs explored and explained their reasoning. Researcher- "How is the center of the circle and the radius relates to the parent- child concept?" PSTs' response: "The radius is dependent on the center." PSTs' manipulate the triangle to get different types of triangles. **Behavioral:** PSTs created a circle with the center and radius. PSTs drew a triangle. They manipulated objects by dragging and clicking. All PSTs were engaged actively in the tasks and very responsive to questions. **Emotional:** Feeling of uncertainty, needed assistance to get the circle tool. PSTs use expression such as sighting. Expressions of exciting, PSTs were laughing at their own creation.
	009		20	**Cognitive:** PSTs were engaged in explanation as they responded to questions. Researcher: "how will I construct a right angle triangle using paper and pencil?" PSTs: "By using a compass, a ruler and a protractor." **Behavioral:** lots of discussion with each other about the task, helping each other completing the construct of the right angle. Everyone was actively engaged. **Emotional:** Expressions of amazement such as, ooh, wow, because PSTs were able to drag the drawn triangle and create multiple types of triangles. When they were asked to construct an equilateral triangle without any assistance from the researcher, they expressed fear of making errors.

Table 20 Continued

	0010	20	**Cognitive:** PSTs explained as they responded to questioning: Researcher: “What is the difference between drawing and constructing?” PSTs: “When we draw the triangle can be draw in to multiple types but when we constructed the triangle always remained that type. So the right angle triangle always remains right angle.” Researcher: “How will we construct an equilateral triangle using GeoGebra?” PSTs: “Using parallel lines, we can use circles and radius.” **Behavioral:** Construction of a right angle triangle, dragging and testing to see if the triangle remained right angle. **Emotional:** Expression of uncertainty, needed assurance from the researcher to know if they were doing the construction correctly.
	0011	20	**Cognitive:** PSTs modeled the construction of an equilateral triangle and isosceles triangle on their own. One PST also demonstrated the construction of an isosceles triangle to the rest of the class. **Behavioral:** Using the drag test to make sure that the triangle will always be an equilateral and isosceles. PSTs were all activity engaged and remained on tasks. They collaborated and offered each other assistance. **Emotional:** PSTs showed determination even though some were not getting the triangles correct they were still trying. Some were still enjoying the activity although it appeared difficult for them, they were laughing at their own mistakes.
	0012-0013	40	**Cognitive:** PSTs were engaged in explanations as they responded to questions. Researcher: “Can any tell me how would I find the mid- point of a triangle?” PSTs: “First find the midpoint of each line and then connect them, where all the lines meet that is called the midpoint.” PSTs were challenge to solve a problem to divide a triangle piece of land into equal halves.

Table 20 Continued

			Behavioral: PSTs worked individually but shared ideas on getting the task completed. PSTs listened attentively to instructions and the summary of the first session. **Emotional:** PSTs expressed confidence and excitement in completing tasks. PSTs were exclaiming Yes, I am getting it!
Session 2	0014	20	**Cognitive:** PSTs were given a list of definition for a square and were asked to select one of the definitions and construct a square. **Behavioral:** PSTs asked questions such as, "Can we use a circle, and can we use perpendicular lines?" PSTs keep on tasks and completed the activity individually and share ideas with each other. **Emotional:** PSTs were enjoying the task; they were laughing at their silly mistakes as they worked.
	0015-0016	40	**Cognitive:** Through exploration PSTs discovered their own error with the construct of a square as the use the drag test and make the necessary corrections. PSTs were given the problem to solve an irregular quadrilateral piece of land into two halves. Responses to questions: Researcher**:** "How will you start this problem?" PSTs: "we will use diagonals and mid-points." PSTs explained their own understanding of what was required to complete the task. **Behavioral:** PSTs used the drag test, draw quadrilateral using the polygon tool, and work individually. **Emotional:** Some PSTs expressed being a bit puzzled but they were motivated to complete the task on their own. They did not request any assistance. PSTs had fun working; they laughed a lot as they worked
	0017-0018	40	**Cognitive:** They were engaged in explanation by responding to questions: Researcher: "How would you define a translation after manipulating the pre-image and the image?" PSTs: "It is a clone, a shadow of each other, it is a transformation." Researcher: "What would say are two properties of a rotation?"

Table 20 Continued

			PSTs: "It must have a center and an angle of rotation." **Behavioral:** PSTs looked at a video on translation attentively. PSTs completed translation, rotation and reflection using GeoGebra. **Emotional:** PSTs were very excited, amazed and happy with their creations. They laughed a lot and made sounds like, ooh, wow, oh my and giggles.
Session3	0021	20	**Cognitive:** PSTs were engaged in exploration by completing a task that was built on previous knowledge gained in the workshop to discover the Pythagoras theorem using GeoGebra all on their own. **Behavioral**: PSTs engaged in a discussion and engage research through questioning. PSTs: "If we don't students don't memorize the Pythagoras theorem, would they remember this in an exam?" Another PSTs: "Yes, I think they will remember more because they will understand now." Researcher: "yes I agree they will remember it because that this task help them to develop understanding." **Emotional:** PSTs were motivated to complete the task on their own and required little help. PSTs were also more comfortable with the software, they were asking less questions of where to find different tools and icons.
	0022-024	60	**Cognitive:** PSTs were engaged in questioning to activate their prior knowledge. Researcher: "when you hear the term algebra what come to mind?" PSTs: "x and ys" Researcher: "what is the difference between an algebraic expression and an equation?" PSTs: "equation we have to solve and expression we just simplify." PSTs completed a task to through exploration to determine which payment option is best. They were engaged in modeling by using formulas to derive the sequence and the cumulative sequence, and then they determine which option was best and why. PSTs explored further by merging the spread view with the graphic view to see the two graphs of their sequences.

Table 20 Continued

			Behavioral: PSTs asked a lot of question because the task seems a bit difficult for them. However, there were lot of discussion about the tasks and those who were finished first when around and assisted the others. PSTs drag the formula down in order to copy it to 29 because the starting point is zero **Emotional:** PSTs expressed feelings of uncertainty they kept asking if they were on the right track. Some PSTs were saying to each other I had no idea what I am doing now. Even though PSTs were uncertain all of them were determining to complete the task and there were sighs of relief when they were completed.
	0025	20	**Cognitive:** PSTs were engaged in reasoning via questioning on the same task from 0024. Researcher: “Look at your graphs, what is the difference between them and why?” PSTs: “the straight line graph represents the constant payout while the other graph represents exponential growth as it drastically increased.” **Behavioral:** PS were dragging the zoom icon to help them to see the different graphs. They complained that they were unable to see the graphs since they had to zoom quite a lot. There is also lots of discussion about the task. **Emotional:** PSTs were all laughing at their mistakes when the realized the task was not very difficult.
	0026	20	**Cognitive:** PSTs learn how to input different algebraic equation in the graphic view. **Behavioral:** PSTs engaged in putting the equation individually, they changed the color and the style of the graph. **Emotional:** PSTs exclaimed, “where this software was all the time, what?” And there was laughter at how simple drawing graphs appeared.
	0027-0028	40	**Cognitive:** PSTs respond to questions about how the graph is changing as they manipulate the sliders. PSTs’ responses: “it changes the graph to a maximum and a minimum, it is shifting the graph vertically, and it is shifting the graph horizontally.” They engaged in exploration and explanations.

Table 20 Continued

			Behavioral: PSTs created sliders to observe the transformation of graphs both algebraic and trigonometric functions. **Emotional:** PSTs were having fun playing with the sliders, PSTs made expressions such as wow, ooh and laughter
Session 4	0029	20	**Cognitive:** PSTs learned GeoGebra can be used to create animation through a video presentation and can be used to create tessellation through a demonstration done by the researcher. They learn through explanation. **Behavioral:** PSTs listened attentively. **Emotional:** PSTs expressed excitement when the saw GeoGebra can be used for animation. There were expressions of wow, ooh, oh might.
	0030	20	**Cognitive:** PSTs solved a task by creating sliders using an equation of a straight line and they were expected to manipulate the sliders to create parallel lines and perpendiculars. They were engaged in exploration. **Behaviour:** PSTs were able to determine when the lines were parallel and perpendicular by looking at the slope, while some PSTs need to be reminded. PSTs were also engaged in a discussion about writing mathematical task at a high cognitive level. **Emotional:** PSTs were a bit apprehensive when they learnt it was time to create the mathematics task. They thought they may not be able to do it.
	0031-0033	90	**Cognitive:** PSTs used their knowledge and skills gained through the workshop to write a mathematical task using GeoGebra. **Behaviour:** PSTs were very engaged in the activity with lot of discussion in the groups and at times they got a bit loud disagreeing to agree. **Emotional:** At the end of the activity PSTs expressed a sense of achievement because they were able to successful create a task using GeoGebra. They also expressed gratitude for being a part of the workshop and they all expressed a desire to learn more about GeoGebra.

Table 20 highlights that the different ways in which PSTs were engaged seemed evenly distributed throughout the workshop sessions. Words to indicate cognitive engagement such as explain, justify thinking and use previous knowledge represented 26% of the total words in the table that highlighted engagement. While words to indicate behavioral engagement, such as manipulate, dragging and discuss, represented 46% of the total number of words in the table that describe engagement. Furthermore 28% of the words used to describe engagement such as, laugher, uncertainty and exciting, implied emotional engagement. Behavioral engagements seem like the most popular PSTs' engagement.

PSTs' cognitive engagement included mainly four actions: exploration, explanation, modeling and problem solving. PSTs explore different tasks to discover different concepts, such as the Pythagoras theorem, construction versus drawing and parent- child relationship.

PSTs also engaged in the workshop by performing behavioral actions. They manipulated objects by dragging and clicking. They created shapes and objects in a dynamic environment. PSTs demonstrated their willingness to help each other by offering assistance to those who appeared to be struggling. PSTs participated well in class discussions and listened attentively when it was required.

In addition, PSTs engaged emotionally during the workshop. They exhibited varying expressions of emotions al throughout the workshop. The most common expressions were feelings of exciting and awe. As PSTs completed a task successful there were sounds of excitement in the form of laugher, exclamations of “yes”, “wows” and “oohs”. PSTs appear in awe when they discovered the power of the dynamic environment by using GeoGebra to produce multiple examples of a given concept simple by dragging or sliding. There were also expressions of fear and uncertainty when PSTs were asked to solve a problem or a task on their own, their facial expression appeared apprehensive. As the workshop due closer to the final day more expression of confidence were observed, PSTs were able to complete tasks on their own with little help from others.

Summary of Chapter Four

Chapter 4 consists of the analysis of the data resulting from the research. It began with a brief introduction which rehearsed the research questions. The next section explored the findings from the workshops evaluation data using the average difficulty level of the various tasks, the standard deviation and the coefficient of variability and analyzed the post questionnaire.

Analysis of the various tasks using GeoGebra done by the PSTs was presented. These included: finding the shortest path from a house to the shop; translation of an object; Pythagoras theorem; cycles; reflection of a house; and constructing a right angle triangle. The chapter then concluded with a presentation of a summary of the transcript of the various workshop videos, indicating the times in minutes for each session. The transcripts sought to speak towards the emotional, behavioral and cognitive interactions of the PSTs.

CHAPTER FIVE – DISCUSSION AND CONCLUSION

The purposes of this study were threefold: 1) Explaining pre-service teachers responses to the GeoGebra workshop; 2) to describe pre-service teachers' engagement in the GeoGebra workshop; 3) to explore if GeoGebra tasks written by pre-service teachers contain prompts that will encourage students to experiment and build their mathematical understanding. Using the frameworks of Preiner (2008), Bu et al (2010), Fredricks, Blumenfeld, and Paris (2004) and Trocki (2014) to analyze PSTs' responses, engagement and tasks, the researcher focused on describing pre-service teachers' experiences in an introductory GeoGebra workshop. The answers to the research questions follow.

How do pre-service teachers respond to the GeoGebra workshop?

To answer this question, the self-reported findings of the PSTs from the daily surveys given in the workshops, opened responses about the general impression of the GeoGebra software and the post questionnaire will be used. The end of the day surveys from the workshops was used to answer PSTs' responses to the GeoGebra workshop. This response was divided up into several categories, responses to the task done with GeoGebra, PSTs' responses in terms of attitude, curricular issues, mathematical content, and pedagogical issues as it relate to GeoGebra.

Task done with GeoGebra

PSTs became familiar with the GeoGebra software while completing mathematics tasks simultaneously. The findings of PSTs' responses to tasks done with GeoGebra revealed that these mathematical tasks done using GeoGebra were easy. The level of difficulty of each item assessed by PSTs did not exceed the mean value of 2.4. Similar findings were found by Green and Robinson (2009), Preiner (2008) and Zakaria and Lee (2012). The most difficult tasks in the workshop (that is, task with a rating of a mean value greater than 2) were solving partitioning of land problem shaped as quadrilaterals, using sliders to create parallel and perpendicular lines and using triangle to solve partition of land problem. These tasks involved PSTs solving a problem that required higher order thinking. However the coefficient of variation indicated that the data for day 1, 2 and 4 have a greater deal of uniformity with respect to the mean, and this implied that there was general consensus among the sample that the tasks done on these days of the workshop were easy. But day 3 coefficient of variability was much higher thus indicating that this data has a great deal of variability with respect to the mean and there is little general consensus among the sample that the tasks done on this was easy.

However the researcher found that average rating of a mean value less than 2 did not correspond well with the description of the day's activities from the video. The videos revealed that the workshop participants took a long time to complete the different tasks and needed lots of assistance. Furthermore, the PSTs' responses to open ended questions also indicated that they encountered several difficulties when using the software. A few of these difficulties that they highlighted include merging the graphic view with the spread; transformations and finding the angles of triangles using the GeoGebra angle tool (see Appendix D). PSTs may have responded that completing tasks with GeoGebra as easy because it may have been more difficult for them to complete the same task without the use of the software.

It was quite evident from the findings that these PSTs enjoyed learning very much when using GeoGebra that by the end of each day of the workshop they forgot about their struggles with the different tasks. Their responses of the task being easy with GeoGebra may be a good indicator that they are willing to use GeoGebra during mathematics instructions. Studies implied that when teachers feel comfortable while learning about new software they are more inclined to integrate the software into their classes (Mously et al., 2003 and Almas and Krumsvik (2008).

Attitudes

Although at the beginning of the workshop 38% of PSTs indicated did not like GeoGebra the finding reveal that their feelings towards GeoGebra was overall very positive. PSTs may not have like GeoGebra at the beginning of the workshop because of their lack of prior exposure to dynamic environment and may have perceived that using GeoGebra will be difficult. At the end of the workshop there was a great change in attitude with the majority (94%) of PSTs wanting to explore GeoGebra more and 100% want to share the GeoGebra with their colleagues, students and parents. PSTs’ open ended responses reflected that they had fun doing mathematic with GeoGebra and they also thinks that other students will have fun doing mathematics when using GeoGebra. Buabeng-Andoh (2012) strongly advocate that when teachers are assured that technology can make their teaching interesting, easier, more fun for them and students, more motivating and more enjoyable negative attitudes toward technology can be reduced.

Curricular issues

The findings revealed that the majority of the PSTs felt that using GeoGebra had challenged their existing conceptions of mathematics and helped them to experience new ideas in mathematics. This was also evident in their open ended responses as they concurred that GeoGebra diverted from the traditional approaches to the teaching of mathematics. Van Voors, (1999) also found this to be true, when he implied that technology can be used to help students view mathematics as less passively, as a set of procedures, and more actively as reasoning, exploring, solving problems, generating new information, and asking new questions. Throughout the workshop PSTs were engaged in exploring, explaining and solving problems. They also agreed that the textbooks need to be changed if GeoGebra is to be used in teaching of mathematics, as the tradition textbook do not allow for much exploration. Importantly, all of the PSTs believed that GeoGebra will help PSTs create their own mathematical ideas. PSTs opened responses also highlighted that they believe that the use of GeoGebra in the teaching and learning of mathematics will benefit PSTs greatly.

Mathematical content

PSTs positively responded to the knowledge and skills gained from participating in the workshop. All of the PSTs felt they were re-learning some mathematical ideas and the use of GeoGebra has raise their enthusiasm for the effective and wise application of technology to the teaching and learning of mathematics. Guerrero's work (2010) supported this hypothesis and discussed that using technology to explore geometry in depth would present teachers with different mathematics content, which results in an expectation from teachers to be more confident in their content knowledge.

In addition, an overwhelming majority of PSTs also felt that they have gained experience on how to use the different tools of the software and on how to use GeoGebra as a tool to enhance student practice. Their beliefs is well supported by the citation of NCTM, (2000, p. 11), "technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning." Most PSTs felt that as a result of using GeoGebra they were beginning to see mathematics as a consistent system. Bu et.al (2013, p.73), stated, "if a teacher sees mathematics as a consistent and connected system of ideas, she or he would naturally be more open to explorative actions in the classroom and encourage students to proceed in the same direction". Therefore, it was not surprising that most PSTs did not feel that GeoGebra made mathematics more difficult for them and felt that a new type of mathematics was being taught to them. These findings were very similar to Bu. et al (2013) research. Theoretically, this GeoGebra workshop can be credited for helping PSTs realized the need to change their teaching habits in order to allow students more real time exploration opportunities.

PSTs also indicated by their open ended responses that they were able to understand some mathematics content better with the use of GeoGebra. They also believe that using

GeoGebra will greatly assist with the teaching of the mathematics content area of algebra and geometry. These findings were in agreement with Hohenwarter & Preiner (2007) and Hohenwarter & Jones (2007) when they implied that GeoGebra is a dynamic mathematics software that reveals the connections between geometry and algebra.

Pedagogical issues

PSTs' response to this section of the questionnaire implied that the use of GeoGebra will significantly improve the pedagogy of mathematics. They unanimously agreed that GeoGebra have helped them to make connections among mathematical ideas and to rethink about how mathematics is being taught. They also agreed that GeoGebra can be used to create meaningful activities. These findings served as an indicator of PSTs' willingness to introduce GeoGebra in the teaching and learning of mathematics. Furthermore, I firmly believe that teachers' beliefs about the use of technology for instruction may be the most important factor in whether or not they use it, and how it is used (Drier, 2001; Russell et al., 2003).

How do pre-service mathematics teachers engage in a GeoGebra workshop?

Cognitive engagement

PSTs were meaningful and actively engaged in the introductory GeoGebra workshop. The atmosphere created by the researcher allowed PSTs the freedom of expression. Therefore PSTs were engaged cognitively, behaviorally and emotionally. This categorization of engagement was adopted from Fredricks, Blumenfeld, and Paris (2004). GeoGebra is referred to as a cognitive tool and hence it is expected that PSTs who have been exposed to GeoGebra would have engaged cognitively (Karadag & McDougall, 2011). The finding revealed that PSTs were engaged cognitively mainly through explanations and exploration. PSTs were asked to explain their thinking as they worked on various tasks through the workshop. This type of cognitive engagement with GeoGebra was also utilized by Karadag & McDougall (2011), who claimed that as students engaged through explanation they become ready to create connections between the new content and the old knowledge.

PSTs were also engaged in exploration through deriving formula and generalizations. This type of cognitive engagement was also evident in research (Karadad & McDougall, 2011). They wrote "learning by exploring demands more cognitive work performed by students when compared to explaining because they are expected to develop an understanding of the curricular material by themselves" (Karadad & McDougall, 2011, p.177). These PSTs also recognized this important feature of teaching mathematics with GeoGebra and implied that, GeoGebra can be used to help students develop deeper understanding of mathematical concepts.

PSTs were also engaged cognitively by creating simple model using GeoGebra. The modeling involved creating recursive equations by using the spread sheet view, to decide which lottery pay out option was better. Karadad & McDougall (2011) also supported the use of models to engage students cognitively. They implied that, when students are able to model mathematical concepts dynamically it reflects their ability to understand concepts and software features. Hence, the findings indicate that PSTs were exposed to varying levels of cognitive engagement during the workshop. It is with great expectations that PSTs will model cognitive engagement in their future classes.

Behavioral engagement

PSTs' engagement was also categorized in terms of behavioral. Throughout the workshop, PSTs exhibited behaviors such as, manipulating and dragging of dynamic creations. They were also engaged in multiple discussions, active participation and questionings. This type of engagement among PSTs was also supported by Bomia et.al (1997) when they referred to students' engagement as the "willingness, need, desire and compulsion to participate in, and be successful in, the learning process promoting higher level thinking for enduring understanding" Bomia et.al (1997, p. 294).

Emotional engagement

Moreover, PSTs were engaged emotionally; in all of the workshop days, they displayed different types of emotional engagement. They exhibited the joy of success after completing a given task even though it took them a long time and they struggled through the tasks. This type of engagement was also expressed by Schlechty (2001), when he implied that for a truly engaged learner, the joy of learning inspires a persistent effort to complete a given tasks even though it is difficult. There were also expressions of uncertainty when PSTs were given an unfamiliar problem. Their expression of excitement was however most dominant. They were ever so often excited when they experienced the power of the dynamic environment. There were always expressions of laughter whether it was of joy or over a silly error. They also expressed team spirit; they demonstrated concern for their colleagues by offering assistance to ensure everyone was successful in completing the different tasks.

Do GeoGebra tasks written by pre-service teachers contain prompts that will encourage PSTs to experiment and build their mathematical understanding?

The findings revealed that those PSTs with some years of teaching experience wrote tasks that contained more prompts that will encourage PSTs to experiment and build mathematical understanding. Gorder (2008) supported this finding when he reported that teacher experience is significantly correlated with the actual use of technology. This meant that their tasks contained both technological component and mathematical depth reached at level 5. Trocki (2014) claimed that prompts at these levels will help students to form a deeper mathematical relationship. I think the PSTs with classroom experience in writing objectives and tests that encouraged the utilization of the bloom's taxonomy, gave them an advantage at writing better tasks.

The other PSTs, who had no prior teaching experience, wrote task 1, 4, 5 and 6 with mathematical depth that did not go beyond level 4. This was a good attempt considering that it was their first time at writing dynamic tasks. PSTs were not given a formal session about how to write good mathematical tasks but they were exposed to high quality dynamics tasks each day of the workshop and I think this assisted them in learning to writing task that can stimulate some level of students' thinking. This task based approach to introducing pre-service teachers to GeoGebra is well supported by Merrill et al. (2008, p. 174), who claimed that "learning is facilitated when learners are engaged in a task-centered approach to instruction." I was especially happy to see the collaborative efforts of the PSTs when working on writing the mathematics tasks. I belief with more coaching these PSTs will become more proficient at writing high cognitive tasks individually.

Limitations

There are some limitations to this study that need to be addressed. First, the study was purposely conducted with secondary PSTs where few had prior teaching experience and the majority with no teaching experience but none of them had any formal teacher training. Therefore, when making conclusions about their responses we need to take this fact into account and not generalize to practicing teachers or teachers at other levels. One other limitation with this study is the time factor. The entire study took place during a limited span of time, a period of four days. It was assumed that this amount of time is sufficient to introduce PSTs to GeoGebra. However, it is possible that a more in-depth analysis could be done over a longer period of time and the PSTs commented that they wished that the workshop was longer.

Being the sole teacher of the workshop was very difficult to monitor and assist all the PSTs when they needed help. This also limited the number of tasks that we were able to complete during the research. In addition the findings and discussions may be considered subjective as it was only seen from one perspective.

Another limitation was the researcher's limited experience with the GeoGebra software; therefore I may not have been the best and most competent facilitator. With a more experience facilitator the results of this researcher may differ. Therefore, the pre-service teachers' exposure to GeoGebra was limited to my personal knowledge of working with GeoGebra.

Implications

The impetus for the study stemmed from an initiative from the Government of St. Vincent and the Grenadines dubbed "One Laptop per Child policy". All secondary school teachers and students received laptops to be used in their classes. There is a need for adequate professional development and support so that teachers can use the technologies to teach mathematics effectively to benefit their students. Due to a lack of training, knowledge of available software and support, the teachers have difficulty making good use of these laptops independently during mathematics instruction. This study provides a beginning and proof of concept case study to beginning changing that.

It is imperative that when teachers are being introduced to new software that they are not only trained to use it but they must be engaged with tasks that can develop deeper mathematical understanding. This study shows that with appropriate professional development, and a successful adoption and integration of PSTs' training into teaching; it will help them to perceive the technological innovation as better than traditional practices that they were exposed to.

In addition, based on my experience while conducting this research I suggest that when teachers are introduced to new software their mathematical content knowledge should be targeted in order to prepare them for the challenge of dealing with more complex students' questions.

Additionally, analysis of the videos revealed that is important that teachers are given time to practice when using new technology. They must also be given the opportunity to learn new skills and knowledge, as well as to share and collaborate with peers. I further believe that when this is done teachers are most likely to integrate the technology into their teaching.

The use of the task based approach expounded upon in the literature review was successful in helping the pre-service teachers master the different tasks during the workshop (Reigeluth, 1999). I will therefore propose the use of this approach in future workshops of similar nature, since this approach allowed for active engagement. Drijvers (2011) also suggests that this approach allows for the appropriate information to be provided at the right moment and so the information they receive will not become overwhelming.

Alvarez (2002) had posited that when PSTs are engaged in doing tasks they gain more knowledge than when just listening to teachers. The PSTs in the study also concurred that they gained a wealth of knowledge in just a few days hence they rated the task with GeoGebra as easy. In general, the data analysis revealed that the task-oriented nature of the daily sessions seemed to appeal more to the PSTs and it has helped to keep them focused and motivated throughout the workshop.

Future work

This workshop is the beginning of a whole set of professional development which teachers throughout the length and breadth of St. Vincent and the Grenadines will experience. Upon my return, it is my plan to spearhead the implementation of similar workshops for mathematics teachers in St. Vincent and the Grenadine. I will seek to work with my colleagues in education to introduce teachers at all levels to the different dynamics software that I have learned about at NC State University.

I am also hoping to do further research with both teachers and students, especially with students, to try to understand their thinking about different mathematics concepts. I would also like to conduct a workshop with teachers at the secondary schools on writing tasks of a high cognitive level because whether or not teachers are introduced to a dynamic software it is imperative that they all learn to write tasks that stimulate students thinking, reasoning and construction of knowledge.

It is with great hope and anticipation that upon my returned to my home country that the teaching and learning of mathematics will see a diversion from procedure and formulas and reeducated mathematics teachers. I am very cognizant that this of course will only be realized after much work on my part along with support from my colleagues in education. I am therefore on a mission to revolutionized Mathematics Education in St. Vincent and the Grenadines.

Conclusion

In conclusion, the journey through this research of exploring PSTs' experiences with the use of GeoGebra has been stimulating and rewarding. The findings from this workshop will certainly help my future classrooms in becoming a more interactive place. I cannot see myself utilizing solely the traditional way of teaching any more. I have learned and learning is a change of behavior.

PSTs responded very positively to the introduction of GeoGebra, in all aspects. They claimed that completing task using GeoGebra was easy; they demonstrated a positive attitude towards using it. They also provided positive feedback as it relates to mathematical content, curricular and pedagogical issues and they were all willing to introduce and use this new software with students. I think that these finding are good indicators of change in the future teaching and learning of mathematics in Vincentians schools. It is apparent that similar workshops with a task based design need to be conducted for the purpose of teacher awareness and to encourage and support teachers to use GeoGebra with their own students throughout the island of St. Vincent and the Grenadines and other countries.

Going on the strength of the overwhelmingly positive results gained from the findings of this research, I can conclude with confidence that the workshop was successful in introducing pre-service teachers to a whole new perspective of teaching mathematics to enhance students' conceptual understand of mathematics. I can already visualize the far reaching effects of this research workshop in helping to transform the teaching and learning of mathematics in school throughout St. Vincent and the Grenadines.

Although, I have only became aware of GeoGebra software during the fall semester at NC State University, 2014, there were enormous benefits that I gained from being exposed to it, as well as the potential gains I perceived it would have as a pedagogical tool. I think that this software can be used to help transform the teaching and learning of mathematics in St. Vincent and the Grenadines. This fact was the compelling force for me to go back to St. Vincent and introduce GeoGebra in the form of a research workshop to future teachers. This workshop is only the beginning; the wealth of knowledge gained from my short time at North Carolina State University will continue to compel me to share.

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APPENDICES

Appendix A

Pre-Questionnaire - An investigative workshop initiative for pre-service mathematics teachers at the St. Vincent and the Grenadines Community College in the use of dynamic geometry software (GeoGebra)

Gender

- ☐ Male
- ☐ Female

Teaching years (if any)

Please type yours years of teaching experience

[ ]

Which grade level(s) are you being trained to teach?

- ● Early Childhood
- ● Primary
- ● Secondary

How many days per week do you use a computer at home?

[ ]

How many days per week do you use a computer at School (not during classes)?

[ ]

I use my computer at home to:

	Yes	No
Check e-mail	●	●
Prepare lessons	●	●
Create my own teaching aids	●	●
Look for teaching materials from the internet	●	●
Find content information on the internet	●	●
Keep record of my PSTs' grades	●	●
Other	●	●

I use my computer at at school (not during classes!) to:

	Yes	No
Check e-mail	●	●
Prepare lessons	●	●
Create my own teaching aids	●	●
Look for teaching materials from the internet	●	●
Find content information on the internet	●	●

	Yes	No
Keep record of my PSTs' grades	●	●
Other	●	●

If you chose "yes" for Other, please list

____

____

____

____

____

____

If you were to use a computer to prepare your lessons: Which kind of technology will you use to prepare your lessons?

	Yes	No
presentation software (e.g. PowerPoint)	●	●
word processing software (e.g. Word)	●	●
spreadsheets (e.g. Excel)	●	●

	Yes	No
dynamic Geometry Software (e.g. Geometer's Sketchpad)	●	●
computer algebra systems (e.g. Derive)	●	●
Graphing calculators	●	●

Technology Use in the Classroom - How many days per week are you taught using mathematics soft ware software?

Technology Use in the Classroom - How many times per week do you actively use computers in class?

Technology Use in the Classroom - How would you use technology during a lesson

	Yes	No
As a presentation tool with a projector	●	●
To help my PSTs discover mathematical concepts	●	●
For educational games as a	●	●

	Yes	No
reward		
Other	●	●

If you chose "yes" for other, please list

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Technology Use in the Classroom - 4. Which kind of technology are exposed to use in your teachers' training program?

	Yes	No
presentation software (e.g. PowerPoint)	●	●
word processing software (e.g. Word)	●	●
spreadsheets (e.g. Excel)	●	●
dynamic Geometry Software	●	●

	Yes	No
(e.g. GeoGebra)		
computer algebra systems (e.g. Derive)	●	●
graphing calculators (e.g. TI 83)	●	●

Do you know how to....

	Yes	No
left click (MacOS: cick)	●	●
right click (MacOS: Apple click)	●	●
click and drag	●	●
create a new folder	●	●
select a file or folder	●	●
select a series of files or folders	●	●
save a file	●	●
delete a file or folder	●	●
copy and paste text	●	●
make a screen shot	●	●

	Yes	No
insert pictures into a word file	●	●
make printouts	●	●
open a web browser	●	●
find information on the internet	●	●
upload files to the internet	●	●
create a web page	●	●
use html code	●	●
create a mathematical task using technology	●	●

Do you believe mathematics should be taught with the use of technology?

- ● Very Strongly Agree
- ● Strongly Agree
- ● Agree
- ● Disagree
- ● Strongly Disagree
- ● Very Strongly Disagree

Do you think that software programs can be used to effectively teach Mathematics?

- Very Strongly Agree
- Strongly Agree
- Agree
- Disagree
- Strongly Disagree
- Very Strongly Disagree

Are you comfortable using technology to teach mathematics?

- Very Strongly Agree
- Strongly Agree
- Agree
- Disagree
- Strongly Disagree
- Very Strongly Disagree

Do you think that computer assisted instructions can be used to enhance the teaching and learning of mathematics?

- Very Strongly Agree

- Strongly Agree
- Agree
- Disagree
- Strongly Disagree
- Very Strongly Disagree

Are you aware of any mathematics software program that can be used to teach mathematics?

- Yes
- No

If your answer to the previous question was yes, please state the software(s).

Have you write a lesson plan to in cooperate mathematics software to teach the lesson?

- ● Yes
- ● No

Have you ever attended a workshop that taught you how to integrate software in the teaching and learning of mathematics?

- ● Yes
- ● No

If your answer to the previous question is yes, please provide examples.

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Do you think your role as a mathematics teacher would change if software is used in the teaching and learning of mathematics?

- ● Very Strongly Agree
- ● Strongly Agree

- o Agree
- o Disagree
- o Strongly Disagree
- o Very Strongly Disagree

Have you ever used the software GeoGebra?

- o Yes
- o No

If your answer to the previous question is yes, please give a brief description of your experience.

Submit

Appendix B

Post Questionnaire - An investigative workshop initiative for pre-service mathematics teachers at the St. Vincent and the Grenadines Community College in the use of dynamic geometry software (GeoGebra)

Teachers perception toward GeoGebra's Use

	Very Strongly Agree	Strongly Agree	Agree	Disagree	Strongly Disagree	Very Strongly Disagree
In the first session, I did not like GeoGebra	●	●	●	●	●	●
Right now, I am more open to explorations using GeoGebra	●	●	●	●	●	●
I like GeoGebra because it is free to everyone	●	●	●	●	●	●

	Very Strongly Agree	Strongly Agree	Agree	Disagree	Strongly Disagree	Very Strongly Disagree
I shared or will share GeoGebra with PSTs and parents.	●	●	●	●	●	●
I shared or will share GeoGebra with my colleagues and administrators	●	●	●	●	●	●
I will continue to learn and use GeoGebra	●	●	●	●	●	●
GeoGebra makes mathematics unnecessarily difficult for me to learn and	●	●	●	●	●	●

	Very Strongly Agree	Strongly Agree	Agree	Disagree	Strongly Disagree	Very Strongly Disagree
teach.						
GeoGebra challenges my conception of the mathematics I teach.	●	●	●	●	●	●
The textbook has to be revised for me to make better use of GeoGebra.	●	●	●	●	●	●
I can adapt existing learning materials for GeoGebra	●	●	●	●	●	●

	Very Strongly Agree	Strongly Agree	Agree	Disagree	Strongly Disagree	Very Strongly Disagree
GeoGebra helps PSTs create their own mathematical ideas.	●	●	●	●	●	●
The teacher will have to face the challenges from PSTs when GeoGebra is used	●	●	●	●	●	●

Knowledge and skills gained related to GeoGebra Use

	Very Strongly Agree	Strongly Agree	Agree	Disagree	Strongly Disagree	Very Strongly Disagree
GeoGebra helped me	●	●	●	●	●	●

	Very Strongly Agree	Strongly Agree	Agree	Disagree	Strongly Disagree	Very Strongly Disagree
relearn some mathematical ideas.						
GeoGebra makes mathematics more difficult for me	●	●	●	●	●	●
GeoGebra have learned some mathematics that would otherwise be difficult to learn	●	●	●	●	●	●
GeoGebra helps me see mathematics as a consistent system of ideas	●	●	●	●	●	●

	Very Strongly Agree	Strongly Agree	Agree	Disagree	Strongly Disagree	Very Strongly Disagree
I would like to learn more mathematics using GeoGebra	●	●	●	●	●	●
I feel that a new kind of mathematics is being taught.	●	●	●	●	●	●
The use of GeoGebra has raised my enthusiasm for the effective and wise application of technology to the teaching/learning enterprise.	●	●	●	●	●	●

	Very Strongly Agree	Strongly Agree	Agree	Disagree	Strongly Disagree	Very Strongly Disagree
GeoGebra can be credited for changing my teaching habits to allow PSTs real-time exploration opportunities.	●	●	●	●	●	●
GeoGebra is responsible for helping me to make graphical representations of math concepts	●	●	●	●	●	●
Teachers and their PSTs are able to make the connections	●	●	●	●	●	●

	Very Strongly Agree	Strongly Agree	Agree	Disagree	Strongly Disagree	Very Strongly Disagree
between the pictures, the math concepts, and the symbolic representation						
I have gained experience on how to use the different tools of the software and on how to use GeoGebra as a tool to enhance their own practice	●	●	●	●	●	●
I have gained experience on how to use the	●	●	●	●	●	●

	Very Strongly Agree	Strongly Agree	Agree	Disagree	Strongly Disagree	Very Strongly Disagree
different tools of the software and on how to use GeoGebra as a tool to enhance their own practice						

Pedagogical Issues Related to GeoGebra Use

	Very Strongly Agree	Strongly Agree	Agree	Disagree	Strongly Disagree	Very Strongly Disagree
GeoGebra helps me make connections between different domains of mathematics	●	●	●	●	●	●

	Very Strongly Agree	Strongly Agree	Agree	Disagree	Strongly Disagree	Very Strongly Disagree
GeoGebra will help me reach out to more children	●	●	●	●	●	●
GeoGebra will help me rethink about mathematics teaching and learning	●	●	●	●	●	●
GeoGebra allows me to design meaningful activities for PSTs	●	●	●	●	●	●
I think PSTs generally will like GeoGebra	●	●	●	●	●	●

	Very Strongly Agree	Strongly Agree	Agree	Disagree	Strongly Disagree	Very Strongly Disagree
I am willing to learn with my PSTs about the new tools	●	●	●	●	●	●
GeoGebra constructions provide useful feedback to the PSTs.	●	●	●	●	●	●

Submit

Appendix C

Please rate the level of difficulty on a scale of 0 – 5 with 0 being the least difficult and 5 being the most difficult

Day 2 Tasks	0	1	2	3	4	5
Constructing a square						
Solving partitioning of land problem of the shape of Quadrilaterals						
Translation of an object						
Reflection of an object						
Rotation of an object						

Day 3 Tasks	0	1	2	3	4	5
Sequence activities to foster algebraic thinking						
Creating a line graph from an ordered set in a spreadsheet						
Creating graph by inputting algebraic equation						
Using sliders to transform graphs						

Day 4 Tasks	0	1	2	3	4	5
Using sliders to create parallel and perpendicular lines						
Creating a task using GeoGebra						
Saving a document using GeoGebra						
Using GeoGebra tool bars and command when creating a task						

Appendix D

Opened responses from pre-service teachers based on the experience during the introductory GeoGebra workshop.

Questions	*Responses*
What did you like about the GeoGebra workshop	*The range of different animated activities for children* *It showed how teaching mathematics can be fun. I really like how you can incorporate the different aspects of mathematics, the algebra, trigonometry and geometry.* *That there's a new way of practicing algebra, spreadsheet and graphs other than the traditional way.* *It was very informative* *One of the biggest problems our students are facing today is with geometry and algebra.* *This work made me realized how we teacher can make it easy for students to have fun and at the same time learning.* *I understood some maths concepts a lot better because the class was quite interactive and the teacher was patient.* *I liked the activities that we did, especially the algebraic tasks.* *I liked that I learnt about a program that can be used to help in the teaching of mathematics.* *The work shop taught me that mathematics could be fun whether in teaching or learning. I liked the way that technology is in cooperated with mathematics, teaching students how to use both in harmony.* *I liked that the workshop exposed me to GeoGebra.* *I was able to explore something that I had not known existed.* *The simple way something can be created was impressive, and it made me look forward to the next step or the other thing I would learn.* *It facilitated the participants with an alternative method of for mathematics instruction through the aid of technology.*
Is there anything that you didn't like about the	*I think the workshop was well done. It was a good exposure for the time allotted and the much was covered. I also appreciate the interactive time between the teacher and the students.* *There was not anything that i didn't like about the workshop. I enjoyed it.* *I simply enjoyed the workshop and wished that it could have lasted longer.*

GeoGebra workshop?	*Time did not permit the participants to be exposed to other areas that GeoGebra may be useful for in Mathematics instruction.*
Do you think GeoGebra will be useful to be used with your students?	*Students will have more fun doing maths* *It can be fun at the same time engaging students in meaningful learning.* *It creates a fun learning environment for children* *Instead of having students go through the long process of remembering formulas using this new software can help them a long way.* *Students today love technology and everything is done online and by using this students will have fun playing around with it* *The software will help students to understand mathematical concepts.* *GeoGebra will be useful because students can use GeoGebra to create shapes, graphs and solve mathematical problems.* *To spark their interest in topics.* *Because it is a fun way to teach students about some topics that most students have difficulties with.* *GeoGebra is fun and interesting.* *It will be useful in teaching mathematics with my students because with this software i can give my students a task such as construct a right angle triangle and have them discuss the triangle with a partner without having them use pencil, paper , protractor or a ruler to complete the task.* *Also with this software students can learn how to create their own animations, design animations, create their own mathematical problems and solve mathematical problems.* *It makes the learning activity more authentic, therefore learning will be more meaningful.* *It will help students to construct their own understanding of certain mathematics concepts.* *Also, it will assist the teacher in teaching topics that students can find challenging, such as algebra.*
Is GeoGebra a useful teaching tool?	*Teacher do not have to give students formula. The students will come up with their own explanation.* *A teacher can use different aspects of it to teach/ do demonstrations to students. It can be used to teach as well as have fun in the classroom.* *It involves using technology with fun activities that will keep students engaged.* *Students can always practice at home after they have learnt a new task at school.* *It show an easy way for students to solve problem* *Provide multiple representation in a quick time* *The software is very students friendly and allows for easy manipulation and understanding of the material* *GeoGebra is a useful tool because it can provide students with hands-on experience in creating tasks and solving problems.* *To give students the opportunity to represent what is learnt in mathematics.* *It is an exciting and educational teaching and learning tool.*

	GeoGebra is a useful teaching tool because with this software teachers can teach students how to use GeoGebra to do geometry, algebra and statistics in mathematics. *Instead of using pencil and paper, students can use it to make creations, solve problems, and be able to understand, explain and justify their answers.* *GeoGebra can assist the teacher in teaching topics that students can find challenging, such as algebra, geometry and solving of worded problems.*
What gave you the most problems during the workshop?	*Merging spreadsheet with the graph view* *The workshop was very much interesting and engaging. I was very willing to participate and because of my knowledge of using the computer i had a good understanding when it was time to do demonstrations. All aspects were good and didn't pose much of a problem for me.* *Creating the task that would be useful in a classroom* *Reflection was a bit of a challenge.* *The algebra* *Reflections, mirroring and rotations of objects* *Did not really have any problems.* *Algebra* *Finding the angles of triangles gave me the most problem.* *Finding the second graph.* *Creating the task for the students.*

Appendix E

Summary descriptions of event seen in the workshop videos

Workshop sessions	Video	Time (mins)	Description of video sessions	Comments
Session 1	006	20	Facilitator introduced herself to the PSTs and states the objectives for the workshop. PSTs read and signed the consent form. The dean of the College of teacher education gave a brief welcome remark. PSTs were introduced to GeoGebra interface.	
	007	20	PSTs were introduced to a variety of different features of dynamic geometry environments (DGEs) and pedagogical issues that arise when PSTs are learning geometry with technology. PSTs were asked to define the term geometry in their own words. PSTs were introduced to the idea of parent-child relationship when working in a dynamic geometry environment (DGE). PSTs created and labeled a line segment, then labeled a point on the segment. PSTs drag points A, B, and C and describe what changes and what stays the same. PSTs then deleted the line segment and notice what happened and explained it in terms of parent-child relationship.	
	008	20	PSTs created and labeled a circle, then dragged the different points on the circle and observed how the circle changed. PSTs described the similarities of parent-child relationships to the independent and dependent variables that are often introduced to PSTs in algebra. <u>Drawing versus constructing</u> Facilitate asked PSTs the difference between drawing and construction to stimulate a short discussion. PSTs were asked to draw a triangle by	

			using the point tool and segments. Through guided instructions they measured the lengths of the segments and angles of the triangle. They dragged the points of the triangle to create different types of triangles.	Some PSTs took a long time on this activity.
	009	20	PSTs constructed a right angle triangle by following the steps given by the facilitator. They constructed a perpendicular line and points on the perpendicular line and created line segments to complete the right angle triangle. After completing the triangle they hid the perpendicular line. They used the angle tool to measure the angles. They were asked to drag the triangle at any point to determine if it remained a right angle.	
	0010	20	PSTs discussed the importance of understanding the difference between drawing and constructing. PSTs were given guided steps to construct an equilateral triangle because most PSTs struggled with this activity the facilitator demonstrated it.	
	0011	20	PSTs were still working on the constructing the equilateral triangle. Then the Facilitator challenged PSTs to construct an isosceles triangle without any help but using the properties of an isosceles to guide their construction.	Some PSTs could not remember what's an isosceles triangle.
	0012-0013	40	PSTs were provided with the steps to find the midpoint of a triangle. These steps assisted them in solving a task of partitioning a triangular piece of land between two daughters. PSTs worked in pairs to complete this task. Facilitator summarized what was learned in session 1.	

Session 2	0014	20	Construction of Quadrilaterals Facilitator questioned PSTs to stimulate a discussion on the definition of quadrilaterals and how the different definitions can influence the constructions of different quadrilaterals. PSTs were given the options to choose a definition for a square and use their previous knowledge from session 1 to help them construct a square.	PSTs were engages in discussion among themselves and stating the need to draw two circles (8:23-9:50)
	0015-0016	40	PSTs continued working on the construction of the square. Facilitator and PSTs discussed how to construct special quadrilaterals using GeoGebra. PSTs were engaged in solving a partitioning land problem involving an irregular quadrilateral shaped piece of land using GeoGebra.	A participant was able to identify his error in constructing the square. (1:45) Find the midpoint seem to be most difficult for PSTs (12:37) PSTs explained their understanding of the problem.(18:04)
	0017-0018	40	Transformations PSTs observed a video presentation on translation using a vector using GeoGebra. They created a stick figure and followed the steps the facilitator provided to translate the stick figure. PSTs were asked to drag points on the pre-image and image stick figure and explain what happened as they did this. They were also asked to define a translation. PSTs were asked to mark a line or segment as a mirror and perform a reflection with guided instructions. They were asked to drag points on both the pre-image and the image and notice what happens. They were asked if there were any fix points in a reflection. PSTs were engaged in a short discussion about the properties of a	PSTs were very excited and engage in this activity. They were able to make connection with the pre-image

			reflection. PSTs mark a point as the center called point c and perform a rotation using guided instructions. They dragged point c and different points on the stick figure and described what they observed. PSTs were engaged in a discussion about which points are fixed and the importance of point c. Facilitator summaries the all that was done in session 3	and image with parent /child relationship in a DGE. PSTs make comments like “wow, great, it is like a clone or shadow.” (16:03)
Sessoin3	0021 0022-024 025	20 60 20	PSTs worked in pairs and completed a task using GeoGebra to prove the Pythagoras theorem. PSTs dragged the triangle and observed the changes and noticed that the sum of the area of the squares on the legs of the triangle is always area of the square of the hypotenuse. PSTs voice concerns about the practicability of using GeoGebra in the school setting. Introducing algebra with Geogebra PSTs were engaged in a discussion on what is algebra, differentiating between coefficient and variables, expression and equation. PSTs completed different sequence pattern as a starter for the next activity. PSTs completed a task that dynamically linked representations of sequences. PSTs were given a scenario of lottery payout choices and make a decision of which option is best. They used the spreadsheet view to generate recursive sequences. PSTs had to input formulas to create sequence and cumulative sequence in the spread sheet view. Participant created a line plot from an order data set in a spreadsheet with guided instructions. PSTs added a graphic view to the GeoGebra document while keeping the spreadsheet view.	PSTs worked together and completed this activity with much assistance. PSTs were concerned if cooperating teachers will prevent them from using the software (0:26-27) Another PSTs commented it will be a good opportunity to use the laptops given to PSTs(0:28) PSTs communicat

	0026 0027- 0028	20 40	For the first 5 minutes PSTs were still working on creating the line plot. PSTs were taught how to input algebraic equation into the GeoGebra input bar and see the different graphic representations. PSTs created sine and cosine graphs and making sliders. PSTs used the sliders to observe the transformations of different graphs. PSTs were engage in a discussion to determine when there is a horizontal shift, vertical shifts, a stretch or a shrink in the graphs.	ed a negative attitude towards algebra. (4: 54) This activity seemed like the most difficult task for PSTs. They needed a lot of help with this activity. PSTs were very interesting with this activity
Session 4	0029 0030 0031-	20 20 90	PSTs were shown a video on how to create an animation using GeoGebra. Facilitator engaged PSTs in a discussion and demonstration on using GeoGebra to link mathematics with art and creating tessellations. PSTs were given a task to create sliders and then manipulate them to create parallel and perpendicular lines. Facilitator engaged PSTs in a discussion on the equation of a straight line, the gradient of a line and how to identify perpendicular and parallels lines. Facilitator discussed how to write a good mathematics task with PSTs and highlighted task of low and high cognitive demand.	 PSTs were able to complete the activity without much difficulty.

	0033		PSTs used GeoGebra and worked in small groups to create a task of high cognitive demand to use with one of the classes. Facilitator recapped all that was learned during the four sessions of the workshop and reminded PSTs to complete all questionnaires before leaving. She also thanked PSTs very much for participating in the workshop.	PSTs participated well in creating the task.

Appendix F

Informed Consent Form for Research

Research's Name: Samantha Porter

Principal Investigator: Samantha Porter
Academic Adviser: Dr. Karen Keene

What are some general things you should know about research studies?
You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time. The purpose of research studies is to gain a better understanding of a certain topic or issue. You are not guaranteed any personal benefits from being in a study. Research studies also may pose risks to those that participate. In this consent form, you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form, it is your right to ask the researcher for clarification or more information. A copy of this consent form will be provided to you. If at any time you have questions about your participation, do not hesitate to contact the researcher named above.

What is the purpose of the study?
This research project is to investigate a workshop initiative for pre-service mathematics teachers at the St. Vincent and the Grenadines Community College in the use of dynamic geometry software (GeoGebra).
What will happen if you take part in the study?
If you agree to participate in this study you will be asked to participate in the 4 day workshop. During the workshop, you are asked to allow yourself to be part of the video and audio recording. You will also allow your work, including homework, to be copied for use in this research. Additionally, you will allow the researcher to use your results on a pre and post questionnaire and an assigned lesson plan activity. To protect your identity you will be assigned a random number and all work will be kept according to that number. It may be necessary, however, to connect your work with your class participation. In this case, a pseudonym will be used in all research analysis and reporting. Your image on the video may be used in research analysis, but your name will not appear in any reporting.

No additional commitments of time or work are required beyond time and work required for the course are required for your participation in this study.

You are free to withdraw from participation in this study and free to continue to take this course, without penalty. If you choose to withdraw from the research at anytime, we will remove all your work from our research data. We will not use their image or words they said. From that time on, you will be placed with your back to the data collection or where you are not taped at all. If we use groups in the taping, your group will not be used. You can continue to take the course without penalty.

Risks

There are no foreseen risks to this research, although as stated, the researchers of this study will also be the instructor of this course.

Benefits

The direct benefits will be that you may learn mathematics at a deeper level for teaching it in the future. Additionally, the research will directly benefit the body of knowledge in mathematics education by providing information on teachers' ability to: design and pose tasks, orchestrate PSTs sharing/thinking and ideas and discussion, respond appropriately to diverse PSTs needs, conduct formative assessment, and provide closure.

Confidentiality

The information in the study records will be kept strictly confidential. Video recordings and work products from these workshop will be stored on secure servers at the Friday Institute for Educational Innovation and in the researcher's office at the Friday Institute for Educational Innovation. With your consent (signature below), particular clips from the video recordings will be shared with people beyond our project team. You will not be identified by name in such presentations or materials, or in any written or oral reports of the research. The video and audio tapes will be destroyed two years after the completion of the project.

Compensation

None

What if you have questions about this study?

If you have questions at any time about the study or the procedures, you may contact the researcher, Samantha Porter, 3920 Jackson Street, Apt.Q215, Raleigh 27607 NC. Phone 919-913-6491.

What if you have questions about your rights as a research participant?

If you feel you have not been treated according to the descriptions in this form or your rights as a participant in research have been violated during the course of this project, you may contact Deb Paxton, Chair of the NCSU IRB for the Use of Human Subjects in Research Committee, Box 7514 NCSU Campus (919.515-4420)

Content to Participate

I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may withdraw at any time by telling the researcher. I understand that the researchers may use pieces of the videotapes for research purposes, or possibly during presentations at conferences. They may use my work as well. My name will not be used.

_______________________	_______________________
Participant Signature	Participant Name (please print)
_______________________	_______________________
Interviewer Signature	Interviewer Name (please print)

____

Date

Appendix G

Dear teachers,

I am investigating the educational experiences and views of pre-service mathematics teachers in an introductory workshop on the use of GeoGebra in the teaching of mathematics. Therefore, I hope to conduct these workshops with current pre-service teachers from the St. Vincent and the Grenadines Community college. For the purpose of data preservation, the sessions will be video-recorded and will take approximately one hour per session. There will be a maximum of four sessions.
The data and results of these interviews will be used for academic purposes only. For ethical reasons, the names of participants will be anonymous. Participants have the right to opt out from the research as well as the rights to review materials in respect of the taped sessions and questionnaires. All involvement in the workshop will be voluntary.

It is my greatest wish that this study will facilitate the improvement of and contribution to educational development in mathematics teaching with the use of ICT. I do sincerely hope you will be willing to be involved and thank you very much in advance for participating in this study.
With kindest regards and many thanks,

Yours sincerely,

Samantha Porter

Appendix H

9th March, 2015

Mr. Nigel Scott
Director of the St. Vincent Community College
Villa, St. Vincent

Dear Mr. Scott
I am presently at the stage in my Masters Degree program of conducting my research as part of my thesis requirement. This research will describe a professional development initiative for Pre-service Mathematics Teachers in the use of dynamic geometry software (GeoGebra). My plan is to engage pre-service teachers at the St. Vincent Community College Division of Teacher Education in a four-day introductory workshop to provide them with an overview of GeoGebra and its possibilities of integration in the teaching/learning of secondary school mathematics.
I am therefore seeking permission to conduct these workshops as part of the data collection process during the month of May, 2015 between the week of the 18th and the 22nd. This process will involve gathering data from no more than 15 pre- service teachers and video taping of the four sessions.

The four GeoGebra introductory workshops will be designed in order to help the participating
Pre-service teachers achieve the following objectives.

- Participants will become familiar with the basic use of GeoGebra (for example, user interface, applying tools, changing properties of objects).
- Participants will learn about where to get help and support for the use of GeoGebra.
- Participants will learn about common characteristics of paper-and-pencil constructions and dynamic geometry constructions (e.g. the *Line through two points* tool corresponds to a straight edge, the *Circle with center through point* tool corresponds to a compass).
- Participants will learn about fundamental differences between paper-and-pencil constructions and dynamic geometry constructions (e.g. a drawing is different from a construction).
- Participants will learn how to create basic geometric constructions (e.g. quadrilaterals, triangle centers).
- Participants will learn to apply transformations to objects (e.g. reflections, rotations).
- Participants will learn how to find out about the use of unfamiliar tools (e.g. toolbar help, online manual).
- Participants will learn to enter algebraic expressions (e.g. to create points, functions, conic sections).
- Participants will learn to use sliders to explore the impact of parameters on algebraic expressions and their graphical representations.
- Participants will learn how to use pre-defined commands in GeoGebra.

• Participants will learn to create instructional task by combining GeoGebra with text processing software

Please note that any information gathered from the investigation will only be utilized for the intended purpose and measures will be taken to ensure that anonymity and confidentiality are maintained. In addition, I would be willing to discuss any important issue arising out of the research with you.

For ethical purposes, North Carolina State University will send a document to you relative to my research.

I can be contacted at spporter@ncsu.edu if there is a need for further clarification.

Thank you for your kind co-operation and I am looking forward to a speedy and favourable response.

Yours sincerely

....

Samantha Porter (Mrs.)
Lecturer, St.Vincent Community College
Division of Teacher Education