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The Impact of Geogebra Software on the Performance of Grade 10-Algebra Students in Graphing Quadratic Functions in Al Ain

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THE IMPACT OF GEOGEBRA SOFTWARE ON THE PERFORMANCE OF GRADE 10-ALGEBRA STUDENTS IN GRAPHING QUADRATIC FUNCTIONS IN AL AIN

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This thesis is submitted in partial fulfilment of the requirements for the degree of Master of Education (Curriculum and Instruction)

Under the Supervision of Dr. Adeeb Jarrah

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Declaration of Original Work

I, Khaled Waleed Sheikh Qasem, the undersigned, a graduate student at the United Arab Emirates University (UAEU), and the author of this thesis entitled "*The Impact of GeoGebra Software on the Performance of Grade-10 Algebra Students in Graphing Quadratic Functions in Al Ain*", hereby, solemnly declare that this thesis is my own original research work that has been done and prepared by me under the supervision of Dr. Adeeb Jarrah, in the College of Education at UAEU. This work has not previously been presented or published, or formed the basis for the award of any academic degree, diploma or a similar title at this or any other university. Any materials borrowed from other sources (whether published or unpublished) and relied upon or included in my thesis have been properly cited and acknowledged in accordance with appropriate academic conventions. I further declare that there is no potential conflict of interest with respect to the research, data collection, authorship, presentation and/or publication of this thesis.

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Abstract

GeoGebra is an interactive mathematics program for teaching and learning mathematics from early school years up to the university level. The program is considered dynamic mathematics software that enables student to see and explore mathematical concepts, their relations, and theories. The main objective of this study is to examine the effect of using GeoGebra on students' understanding of Quadratic Functions in 10th grade Emirati students in Al Ain, United Arab Emirates. A quasi-experimental design was employed to collected data using a pre-test and post-test tool to evaluate the effectiveness of the GeoGebra software intervention. Eighty-five (n=85) participants were randomly divided into two groups of control and experimental. The result of the post-test indicated a statistically significant point of preference of using GeoGebra for the experimental group over the control group. Specifically, results revealed that students who were exposed to GeoGebra achieved a higher average score (M= 22.10, SD= 5.363) on the overall score compared to the score (M= 17.56, SD= 5.655) of students of the control group as well as all the examined outcomes except the Interpret and use the graph of a quadratic function post factor. The research findings will facilitate further research on the use of GeoGebra on different concepts in mathematics. Additionally, it gives some recommendation for professional development for the implementation of GeoGebra in classroom practices for mathematics teachers.

Keywords: GeoGebra, Function, Quadratic Function, Transformations, Translations, Parameter, Achievement.

Title and Abstract (in Arabic)

أثراستخدام برنامج جيوجبرا (GeoGebra) على أداء طلبة الصف العاشر في رسم الدوال التربيعية في مادة الجبر في منطقة العين

الملخص

يعتبر برنامج الجيوجيبرا أحد البرامج التفاعلية التي تساعد في تعلم الرياضيات منذ المراحل الأساسية وحتى المرحلة الجامعية، ويعتبر برنامجا ديناميكيا يمكِّن الطلاب من استكشاف العلاقات والمفاهيم الرياضية.هدفت هذه الدراسة إلى الكشف عن أثر استخدام الجيوجبرا في استيعاب وظائف الدالة التربيعية لدى طلاب الصف العاشر الإماراتيين بمدينة العين – الإمارات العربية المتحدة. ولتحقيق هدف الدراسة، تم إجراء بحث شبه تجريبي لجمع البينات خلال الدراسة وذلك باستخدام أداة اختبار قبلي وبعدي لقياس مدى تأثير استخدام برنامج الجيوجبرا في أداء الطلاب.تكونت عينة الدراسة من 85 طالبا من طلبة الصف العاشر تم تقسيمهم عشوائيا، وتوزعت هذه العينة على مجموعتين، مثلت إحداهما المجموعة الضابطة، في حين مثلت الأخرى المجموعة التجريبية. وقد أظهرت نتائج الاختبار البعدي وجود فروق ذات دلالة إحصائية لصالح المجموعة التجريبة على حساب المجموعة الضابطة، وعلى وجه التحديد كشفت النتائج أن طلاب المجموعة التجريبية حصلوا على معدل أعلى إجماليا (المتوسط الحسابي= 22.10، الانحراف المعياري= 5.363) مقارنة بالمجموعة الضابطة (المتوسط الحسابي= 17.56، الانحراف المعياري= 5.655) وكذلك هو الحال بالنسبة لجميع نتائج الاختبارات باستثناء التفسير واستخدام الرسم البياني للدالة التربيعية.من المتوقع أن تساهم نتائج الدراسة في فتح أبواب دراسات أخرى متعلقة باستخدام الجيوجيبرا في تدريس مفاهيم الرياضيات. بالإضافة إلى أنها ستقدم بعض التوصيات المتعلقة بالممارسات والتطوير المهني لمعلمي الرياضيات.

مفاهيم البحث الرئيسية: جيوجيبرا، الدالة، الدالة التربيعية، التحويلات الهندسية، الانسحاب، معامل، الإنجاز.

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Dedication

To my beloved parents, family and colleagues.

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List of Abbreviations

ANOVA	Analysis of Variance
ATHS	Applied Technology High Schools
CAS	Computer Algebra Systems
CT	Computer Technology
DGS	Dynamic Geometry Systems
IAT	Institute of Applied Technology
M	Mean
NCTM	National Council of Teachers of Mathematics
NSTA	National Science Teacher Association
PISA	Programme for International Student Assessment
SD	Standard Deviation
STEM	Science, Technology, Engineering, and Mathematics
TBMEC	Tahnoun Bin Mohammed Educational Complex
TIMSS	Trends in International Mathematics and Science Study
UAE	United Arab Emirates

Chapter 1: Introduction

1.1 Chapter 1 Overview

Technology is considered a new element in the structure of education in the last three decades. The use of technology has increased in classrooms as a supporting tool in the teaching and learning process (Cubukcuoglu, 2013). The role of technology goes beyond only using machines, devices and software to the effect it could have on all elements of education, for example, teachers and learners, curriculum with its wide definition, teaching methods, assessment and the whole community in a broader view. It is obvious that technology has a positive role in raising the efficiency of the educational process by solving a lot of educational problems such as the knowledge flow, the revolution of information explosion, the increasing number of learners, and the individual differences between learners (Ogbonnaya, 2010). In addition, educators claim that it improves the achievement of students, for example Muir-Herzig (2004) stated that , "The use of Technology in education enhances students' learning and helps the educators to encourage a constructivist class environment". Furthermore, many studies have shown that the retention rate of students for knowledge, mastering higher-order thinking skills, and adopting positive attitudes and a greater motivation for the future learning in the traditional learning is limited, while in active learning integrated with modern technologies, the survival rate of information is much higher (Lester, 2014).

Technology in education today includes digital learning tools, which varies from one school to another. The technological tools, such as computers, mobile devices, calculators, open resources, software, platforms, digital books, Internet, etc are all examples of technology used currently in learning settings. Technology, as many teachers suggest, increases the engagement of students in the learning process, motivates them to learn faster and serves the idea of student-centered learning (Darling-Hammond, Zielezinski & Goldman, 2014). Technology has a significant role in online learning, it helps in keeping students and teachers get connected all the time which adds more productivity to this process. The new generation of learners is heavily dependent on technology in his or her life, which shows the need of using technology in their learning to increase the quality of education. Modern technology can offer many means of improving teaching and learning in the classroom (Lefebvre, Deaudelin & Loiselle, 2006).

Technology is closely related to teaching and learning of mathematics. The importance of using technology in learning mathematics is widely acknowledged. To excel well in mathematics, high level of cognitive processes such as critical thinking, reasoning and imagination are required (Rajagopal, Ismail, Ali & Sulaiman, 2015). As a result, new teaching or learning approaches should be considered when mathematics is learnt "Mathematics should be approached with different types of learning methods where students can enhance their understanding and make the learning fun" (Dogan & Icel, 2010). Therefore, old traditional ways of teaching and learning must be changed to meet the needs to revolutionize education, to let students see and feel the real beauty of mathematics and to develop a deep understanding of mathematics concepts. This is clearly emphasized by the National Council of Teachers of Mathematics (NCTM), which highlights the important role of technology "technology is essential in teaching and learning mathematics; it influences the mathematics taught as well as enhances student's learning" (NCTM, 2000, p. 24). The NCTM underlines the significance of using the suitable technology to build a deep understanding of mathematics, which should take students to a greater level of constructing higher logical skills, like critical thinking, decision-making, reflection, reasoning, and problem solving. Integration of Technology in mathematics classrooms is essential to ensure that students can learn whatever they want in the best ways. Appropriate learning approaches enriched with the suitable technology tools could take the learning process from only transferring knowledge to the level of constructing the knowledge and relate it to students' experience as stated by Zengin and Tatar (2017).

In Australia, the mathematic curriculum policy encouraged the use of technology to help students to develop their mathematical abilities (Australian Association of Mathematics Teachers, 1996; Australian Education Council, 1990). This policy stressed on how technology could play a significant role for students to explore connections between algebraic and graphical representations in simple quadratics, circles and exponentials. Using digital technology when appropriate would help students to study all relations in transformations such as translations, reflections and stretches of all graphs. In the United Arab Emirates (UAE), technology is widely emphasized in the curriculum particularly in the teaching of mathematics. For example, the Institute of Applied Technology (IAT) began integrating technology into the classroom in 2009 through a program called One-to-One E-learning Solution. The IAT claims that their educational standards in the curriculum are supported by the use of technology across all subjects. Finding the best ways of integrating technology into classroom practices is one of the obstacles the teachers face. Integrating technology into mathematic classes is a slow and difficult process, especially in the Arab world, given the low perceptions of the use of technology among teachers as well its availability in various parts of this region.

During the past few decades, there has been a great evolution in mathematical software packages. Among the great amount of software, there are two important forms of software contributing to the teaching and learning of mathematics: Computer Algebra Systems (CAS) and interactive or Dynamic Geometry Systems (DGS). These two tools have had a high influence on mathematics education. However, these are not connected to each other at all. Fortunately, there is a software system called GeoGebra that integrates possibilities of both dynamic geometry and computer algebra in one program for mathematics teaching (Hohenwarter & Jones, 2007). GeoGebra is a dynamic mathematics' software for all levels of education that brings together geometry, algebra, spreadsheets, graphing, statistics and calculus in one easy-to-use package. GeoGebra is an open-source (freely- available) software program created by Markus Hohenwarter for his master's thesis project at the University of Salzburg, Austria in 2001(Zengin, Furkan & Kutluca, 2012).

GeoGebra is an interactive mathematics program for teaching and learning mathematics from elementary to university level. The shapes can be constructed by means of a mouse, touch screen or input bar using commands. The elements can also be animated by moving them and used to illustrate or prove mathematical and engineering theories (Lester, 2013). The philosophy of the program is based on a strong conviction and deep belief that every student can learn mathematics if given the opportunity to learn, and solve problems of a level appropriate to his abilities as quickly as they fit. The program is based on a scientific concept that depends on learning by doing. Mathematics requires a lot of practice to master its skills and to understand its concepts and to link these skills and concepts. Therefore, providing sufficient opportunities for practice makes student learning of mathematics possible. And then, gradually the student can move to more difficult issues or mathematics problems after he or she has mastered the previous concepts needed to solve them. Thus, the awe of mathematics and lack of confidence in the ability to learn it gradually disappears (Noorbaizura, & Leong, 2013).

1.2 Statement of the Problem

Students in high school begin to come across higher levels of mathematics, they are introduced to new concepts that aim to increase students' abilities of solving real-life problems. In algebra courses, the concept of the quadratic function is a perfect example where students could connect mathematics and model the real world. The NCTM (2000) states that students need to "learn to use a wide range of explicitly and recursively defined functions to model the world around them. Moreover, their understanding of the properties of those functions will give them insights into the phenomena being modeled" (p. 288).

Algebra courses in high school should assist students to "come to understand the concept of a class of functions and learn to recognize the characteristics of various classes" (NCTM, 2000, p. 297). Therefore, it is important for all students to comprehend that all quadratic functions share the same characteristics, then they can move on easily to learn other polynomial functions. Furthermore, understanding quadratic functions transformations would make it easier for students to learn other types of functions transformations. Unfortunately, students face a lot of difficulties and develop misconceptions when they learn quadratic functions and their transformations, which may influence their achievements as number of researches have revealed as mentioned in the study of (Zengin & Tatar, 2017). Zengin and Tatar (2017) further pointed out that understanding quadratics requires the ability to build a solid relationship between the abstract, visual and concrete representations of mathematical objects, and students are particularly handicapped by their inability to formulate and transpose algebraic expressions. In addition, the subject is confounded by inter-relationships between functions (Ross, Bruce & Sibbald, 2011). GeoGebra provides tools for graphical, numerical and algebraic representations of mathematical objects on the same interface. Therefore, different representations of the same object are assembled dynamically and any change in one of these representations is automatically transformed to the other ones (Kepceoğlu & Yavuz, 2016).

Although many studies had been conducted all over the world investigating the influence of technology to support learning of different concepts in mathematics, few changes are seen in the schools' curriculum to integrate more technology in classes despite the fact that most of these studies revealed the positive correlation between the use of technology and students' achievements. In addition, studies examining the effect of using software on students' abilities in learning quadratics or graphing quadratic functions are limited.

This study aims to determine the effect of the graphing application GeoGebra in the teaching the concept of Quadratic Functions and their graphs against the traditional teaching methods. The problem of the study is to assess the impact of this technology on the learning of Grade 10 students of quadratic functions.

1.3 Purpose of the Study

The purpose of the study was to identify the effectiveness of using GeoGebra on students' understanding of quadratic functions. In addition, the study assessed the impact of GeoGebra on students' ability to graph quadratic functions. Finally, the study is aiming to assess the impact of GeoGebra on students' ability to analyze the effect of changing various parameters on quadratic functions and their graphs.

1.4 Research Questions

This study aimed at addressing the following research questions:

1. What is the effectiveness of using GeoGebra on students' understanding of quadratic functions compared to the traditional approach?
2. What is the effectiveness of using GeoGebra on students' abilities to graph Quadratic Functions?
3. What is the effectiveness of using GeoGebra on students' abilities to analyze the effect of changing various parameters on quadratic functions and their graphs?

1.5 Significance of the Study

In UAE, Ministry of Education Strategic Plan 2017-2021 encourages developing the UAE society that is driven by science, technology and innovation, but so far a little evidence of using technology is noticed in the schools especially in learning and teaching mathematics. This lack of research has motivated the researcher to conduct the current study that may add to the literature in this field and may provide some insights and recommendations to UAE educational leadership to observe the influence of GeoGebra on the students' performance in graphing quadratic functions and take policy initiatives to enhance using the tool in all high schools in the UAE. Another possible significance of current study is introducing the software to the teachers in the local community, which may improve standards of teaching and learning mathematics in classroom. The study may provide students with opportunity to explore new technologies in mathematics. Furthermore, the findings of this study may help curriculum planners to recommend for more technology integration in the mathematics curriculum in the UAE.

1.6 Definition of Terms

- GeoGebra: is dynamic mathematics software for all levels of education that brings together geometry, algebra, spreadsheets, graphing, statistics and calculus in one easy-to-use package.
- Function: The modern definition of a function is: a function $f: S \rightarrow T$ consists of two sets $S\ and\ T$ together with a rule that assigns to each $x\ \in\ S$ a specific element of T, denoted $f\ (x)$ (Burnett-Bradshaw, 2012). In other words, a function is a relation between variables (for example x and y) in which each value of the input variable x is linked with only one value of the output variable y. Functions can be represented in different ways: graphs, tables, mapping, ordered pairs, equations or words as defined in the textbook.
- Quadratic Function: is a polynomial function with 2 as the largest exponent, it can have three terms: quadratic, linear and constant. The graph of a quadratic function is called a parabola. There are two forms for quadratic functions: the standard form and the vertex form. The standard form of a quadratic Function is $f(x) = ax^2 + bx + c, a \neq o,$ while the vertex form is $f(x) = a(x - h)^2 + k, a \neq 0.$
- Function's Transformations: a change in the shape of the graph of the function caused by mathematical operations that produce translation, reflection, dilation or a rotation for the parent function.

- Translations: is movement of a body from one point of space to another such that every point of the body moves in the same direction and over the same distance, without any rotation, reflection, or change in size.
- Parameters: a quantity whose value is selected for the particular circumstances and in relation to which other variable quantities may be expressed. For example, in the quadratic function represented in either form: the symbols a, b, c, h and k are parameters that determine the behavior of the function f.

1.7 Limitations

The context of this study is limited to the students and teachers from the Applied Technology High Schools in Alain (ATHS). Due to the small number of the sample, it cannot be representative of the whole school population in the UAE. Adding to that, the selection of the sample is not random since students are not normally distributed as students are divided into clusters. The final limitation is that math curriculum is unique and only implemented in ATHS system, which is slightly different from public schools.

1.8 Delimitations

The study is delimited to selected sample of grade 10 students in one of schools in Alain, which follows specific curriculum.

Chapter 2: Literature Review

This chapter includes the review of related literature and studies about the role of GeoGebra in mathematics and in other subjects. The review of literature helped in clarifying the importance of the mathematical software GeoGebra in teaching and learning mathematics. Specifically, the researcher has perused literature that examined the attitudes towards GeoGebra among teachers and students, its use in different topics of geometry and algebra teaching and learning, and its use as an assisting instrument in other subjects as science and geography.

2.1 Introduction

Technology is widely used in today's classrooms around the world. As Muir-Herzig (2004) mentioned in his study it can be useful in enhancing teaching and learning process. Computers and software are considered important elements, which have significant influence to change schools to become closer to student-centered learning environment and can increase the role of a student in developing his knowledge in any subject.

The use of computer technologies for teaching mathematics are growing in the field of education. There are several software applications, which are designed to improve the students learning of mathematics such as Mathematica, MATLAB, Maple V, Geometers' Sketchpad, and Autograf (Rajagopal et al., 2015).

An open source such as GeoGebra with a lot of features has the ability to build organized activities that jump over the visualization difficulty in mathematics (Hohenwarter, Hohenwarter, Kreis, & Lavicza, 2008). GeoGebra software supports science, technology, engineering and mathematics (STEM) education and innovations in teaching and learning worldwide (Kramarenko, Pylypenko, & Zaselskiy, 2020). GeoGebra is a software that can address all aspects of mathematics especially geometry and algebra at the same time in the same window.

2.2 Theoretical Framework

The results from recent international studies like TIMSS and PISA revealed a huge gap between the United Arab Emirates students' performance in Mathematics and the top countries. Therefore, it is clear that there is a need to change how students learn and build their own mathematical knowledge. The traditional way of teaching mathematics when the teacher is the center of the learning process has to be changed and more attention should be directed towards learning mathematics in an approach where students are considered as the heart of the learning process with an emphasis on development of thinking, understanding and problem-solving skills. This process may provide the students a chance to stand up for the requirements of the present and the future with both technical and mathematical knowledge and skills. Knowledge is no longer an end in itself as it could be obtained from any source; students should be trained to concentrate their efforts on how to reach, produce and apply this knowledge to solve real-life problems.

Although the role of good teaching cannot be neglected in the classroom, it has become clear that it is inadequate in the rapidly changing world. Currently, meaning of learning has changed as the daily practices are heavily influenced by technology, which emphasize the need to modernize all elements of the educational systems, including adapting new learning strategies in new learning environments (Unianu & Purcaru, 2014). The use of technology in classes is not an aim in itself, but integration of technology is seen as an effective tool that increases the performance of students in tests and develop their intellectual skills, such as problem-solving, critical-thinking, creativity and communication in a collaborative environment.

According to the International Society for Technology in Education, the purpose of integrating technology is improving learning of a content and increasing the chances for learners to succeed in the era of digitals, stressing on the need to develop the intellectual competencies which are essential to efficiency of learning where students are seen as thinkers who construct knowledge, and develop innovative products and processes using technology (Dondlinger, McLeod & Vasinda, 2016). They cited a study by Tamim, Bernard, Borokhovsk, Abriam, and Schmid (2011) that compared using technology in learning environments with instructions built on constructivism against instructivist (traditional) approaches, they reported that no significant differences were found in students' achievement under traditional approaches, while they assured that the effective way lies in the field of constructivism if the maximum impact of technology in education is to be reached.

Li and Ma (2010) conducted a meta-analysis of the effects of computer technology on school students' mathematics learning in 2010. They reviewed studies that examined the impact of computer technology (CT) on mathematics achievement for students in grades K-12. They found "statistically significant positive effects" of CT on mathematics achievement as results from these studies showed students who learnt mathematics using CT achieved better than those who did not, thus CT should be considered a keystone on the ground of good teaching. In addition, they linked the effective impact of technology on mathematical achievement with teacher practices under constructivism against traditional approach. Combining technology and constructivism together in the teaching- learning will produce a new vision of education that seems to be much more committed to a deep understanding and building the essential knowledge and skills (Li & Ma, 2010).

In the constructivist approach, technologies are not used as direct means to teach students, instead technology role is more like a facilitator in the learning process to provide rich and flexible methods for demonstrating what students know and are capable of doing (Gagliardi, 2007). He added that there was a perfect matching between the practices in classes built on constructivist ground and the use of technology, as both should be used together as a setting to frame teacher's work. Nanjappa and Grant (2003) stated that there is a harmonizing association between technology and constructivism when applying them in learning situations as each one of can support the other. They cited, "By integrating technology with constructivist methods such as problem-based learning and project-based learning, learners are more responsible for and active in the learning process".

Constructivism is a learning theory that focuses on the construction of knowledge in learners as they build on and modify their existing mental models, rather than the transmission of knowledge. In other words, constructivism is concerned more in "how we learn and the thinking process than how a student can remember and recite a quantity of information" (Liu & chen, 2010, p 65). The Constructivist emphasis is on the learner's active involvement in building and shaping their knowledge that interacts with previous experiences in an adaptive dynamic process causing modification or extending previous experience individually or socially. In mathematics, learning effectiveness requires students to be completely involved in a variety of active learning techniques to construct their own knowledge, which confirm that learning is really happening (Major & Mangope, 2012).

The use of GeoGebra software in teaching mathematics can be grounded on the constructivist learning theory as this theory can be clearly linked with the use of technology inside the classroom (Shoemaker, 2013). This study aims to examine the impact of GeoGebra software on student's performance in graphing quadratic functions in a constructivist-teaching framework in which GeoGebra is considered as a tool that can work efficiently to develop student's involvement in his learning process, intending to strengthen the construction of his mathematical knowledge with the potential to keep this knowledge visible and easy to use in any classroom practice (Chrysanthou, 2008).

2.3 Software in Learning

In 1987, the National Science Teacher Association (NSTA) conducted a study and found that, using computers and software to teach can improve student learning motivations, student cooperation, independence, and opportunities for elevating learning abilities (Weng, 2011). Mercer, Jordan and Miller (1994) claimed that motivation allows students to feel responsible for their own learning which creates the independence needed to apply their mathematical skills to complete a task, without relying on any assistance from the teacher or waiting for his supervision (Juan, 2015). Further, Juan (2015) noted in that when studying linear graphs, students were required to consider, practice, interpret, apply, evaluate, and create material, which were the learning types associated with technology integration.

Another benefit from using software in education is that it expands the pedagogical resources available for teachers. According to Bingimlas (2009), he mentioned that teachers have a strong desire for the integration of software into education, but they are confronted with many barriers such as lack of confidence, lack of competence, and lack of access to resources. The suggested solution is to provide real professional development, sufficient time, and technical support. The existence of all these factors can increase the chance of excellent learning and teaching opportunities. (Gilakjani, Lai-Mei, & Ismail, 2013).

2.4 Attitudes towards GeoGebra

Ensuring that teachers hold a positive attitude towards technology integration in their classrooms is important. Teachers must value and understand the necessity for the use of technology in their instructional design, to develop a positive attitude to escape from their traditional teaching methods. A teacher who wants to use GeoGebra in his class should be ready to allow students to build up their knowledge through experiments under his assistance. He/she must be flexible and open-minded to create new methods, which will be suitable for the new situations. On the social side, the impact of GeoGebra may be important in changing opinions about mathematics as a solitary activity to the more harmonic view of mathematics as social activity (Antohe, 2011).

Students need to learn mathematics in an attractive setting, they look for new teaching styles that stimulate their abilities and meet their desires. Their voice should be heard and they must have the opportunity to express their opinions in issues related to their learning process. Kim and Ali (2017) highlighted in his study students' desire to learn other topics in mathematics using GeoGebra after learning a new topic in geometry. Integrating the GeoGebra software in learning activities on the topic of shape and space promoted students' interest to learn mathematics (Kim & Ali, 2017).

Mohamed and Guandasami (2014) conducted a study to investigate students' interest on the use of GeoGebra in mathematics lesson. A sample of 30 students from a secondary school in Malaysia participated in this study. All Students completed four activities on the topic of transformation where they learned the detailed steps through GeoGebra software earlier then interviews and observations were conducted on 15 randomly selected students. Observation sessions indicated that students were excited in using GeoGebra software. According to this study most of the students were capable of learning the tools and were able to complete the activities during the sessions indicating the ease of the software.

Another study was conducted on the attitude of secondary school students towards the use of GeoGebra in learning Loci in two dimensions by Rajagopal, Ismail, Ali and Sulaiman (2015). This study was conducted in Malaysia using correlational design and it showed there was a significant positive relationship between the perceived usefulness and students' attitudes towards the use of GeoGebra in learning Loci in two dimensions. They claimed that attitude of students towards the use of GeoGebra was a result of reasons that students found GeoGebra as a helpful tool for them to learn Mathematics. In other words, when students found the software can be easily handled, they started thinking of that software as useful instrument, however this study was conducted in a small sample of 30 students in two days of time period which may not be enough to measure that interest in GeoGebra. Additionally, the shortage of computers in the school affected the strength of this study as students were sharing the same computer, which could affect the reliability of their attitudes.

2.5 Geometry and GeoGebra

Geometry is the study of shape and space. Geometry and algebra are viewed as the two pillars of mathematics, because they both have fundamental properties used in most mathematic topics. Juan (2015) mentioned in his study that "It is viewed as a fundamental component of mathematical learning and its importance is widespread in many aspects of everyday lives. Geometry is considered a foundational topic to more advanced fields of science, business, technology and engineering" (p.33). He claimed that GeoGebra encourages students to approach mathematics from a practical view where they were capable to modify geometric shapes and figures on the computer screen in order to abstract the mathematical properties that governed these geometrical transformations and constructions. He suggested that mathematics classrooms should be changed into an experimental lab situation, so that the students will be able to discover geometrical rules on their own, which in turn may provide a more powerful learning experience providing immediate feedback for both students and teachers.

Among several studies that investigated the role of GeoGebra in learning geometry, Reis and Ozdemir conducted a study in 2010 to explore how effective GeoGebra was for student's success in grade 12 learning parabola using experimental research model. The study focused on the parabola drawing, showing the elements on the graphics, describing parabola equations and determining the maximum and minimum values of parabola. They concluded that the teaching with materials, which were prepared with GeoGebra, was more effective than traditional method. According to this study, students faced some difficulties with the parabola section because of its abstract nature. To overcome these difficulties, using visuality of the parabola with GeoGebra helped students involve more in learning process and showed them how mathematical concepts were related to their daily lives. They stressed on the importance of visualization to attract students' attention towards math abstract concepts (Reis & Ozdemir, 2010).

Another study carried out in India by Bhagat and Chang (2015), examined the impact of using GeoGebra on the 9th grade students' mathematics achievement in learning a theorem on circles. Studying a sample of 50 middle school students who were divided into an experimental group, which was instructed utilizing GeoGebra, and a control group that was directed through traditional teaching methods. During the intervention, the concept of central and inscribed angles on the same arc in a circle and the relationship between their measures were investigated. The results of this study were consistent with the previous study, indicating the positive influence of using this software in improving reasoning and visualization skills of the students, in addition to motivating the students towards geometry learning. They recommended the integration of GeoGebra use in Indian mathematic curriculum.

Shadaan and Leong (2013) conducted a study using a quasi-experimental design. A pre- and post-tests were applied in two classes of 53 students for one week, with one class assigned as the experimental group and the other as the control, followed by a survey questionnaire to explore the students' perceptions in using the GeoGebra software. Findings of this study showed a significant difference existed in the mean scores between these two groups. The results suggested that students in the experimental group performed better than those in the control group. In addition, students' answers to the questionnaire that investigated students' perceptions showed a positive view on using the GeoGebra in learning about circles. They expressed their satisfaction in using GeoGebra and that they were able to form better connections between previous learning and new learning (Shadaan & Leong, 2013).

In their study, Ljajko and Ibro (2014) found that students who learned the concept of an Ellipse using mathematic instructions developed by using the dynamic applets built with GeoGebra, achieved better results spending less time in drawing sketches and calculations with a possibility to explore more about the characteristics of an ellipse. Juan (2015) studied the effects of interactive software on students' achievement and engagement in geometry classes among secondary school students using GeoGebra. He used mixed methods approach merging the quantitative and qualitative designs. He used a quasi-experimental design with a control and an experimental group, collecting data qualitatively via interviews, which were directed to the two teachers engaged in the study. The sample in the study consisted of 133 10th grade students from a secondary school located in the Cayo District, in the country of Belize. Both groups showed similar engagement, but unexpectedly the study indicated that use of the mathematics software program in the geometry classes had no significant difference on students' achievement. In the post-test, the students in the control group outperformed the students in the experimental group, who were using the mathematics software program. One possible reason for these findings could be that there were two different teachers for the two groups. Another possible reason could be that students and the teacher in the experimental group were not familiar with the software, and were not comfortable in using all of its functions and features.

2.6 Algebra and GeoGebra

Although Algebra is considered as an essential topic within mathematics and especially in high school level, Algebra has been recognized as one of the most difficult topics to learn. It is a key factor to succeed in other mathematical fields and serves as a language for science. Moreover, algebraic knowledge and skills are significant in daily and professional life either directly or as a prerequisite (Jupri, Drijvers & van den Heuvel-Panhuizen, 2014).

Havelková (2013) conducted a study that focused on the potential use of the GeoGebra software in a linear algebra course for pre-service teachers. She inquired whether using a set of pre- designed applets would lead to a better understanding of selected algebraic operations. The study involved 34 second- year students in the undergraduate program who were divided into two different groups. Students had attended various lectures on linear algebra prior to the practical seminars. Both the qualitative and quantitative study designs were used. Although the results of this study cannot be generalized because of the small sample size, the use of the GeoGebra as a backing instrument for teaching linear algebra led to success in the experimental group and helped students to increase their knowledge stating their appreciation to the session and its influence on their learning.

Polynomials are an important topic in middle grades-secondary algebra courses, technology can be very helpful when exploring their properties, and GeoGebra makes it easier to explore polynomial properties due to its dynamic features (Hall & Chamblee 2013). Likewise, the absolute value topic is important because of the significance of its concept, especially regarding the theoretical foundation of numbers and its applications. Many studies strongly justified the preference of visualization in teaching and learning absolute value, and by using graphical dynamic software like GeoGebra. One can explain additional problems concerning the shifts of the graphs and the effects of those shifts on the solution of the equations (Stupel & Ben-Chaim, 2014).

Radakovic and McDougall (2012) studied using GeoGebra for teaching conditional probability with area-proportional Venn diagrams. They tested how dynamic visualization can be used to teach conditional probability and Bayes' theorem. Visualization as a feature of GeoGebra made it an ideal instructive tool in probability teaching. One feature was the use of area-proportional Venn diagrams. Another feature was the slider and animation component of GeoGebra allowing students to observe how the change in the base rate of an event influenced conditional probability (Radakovic & McDougall, 2012).

Caglayan (2014) directed his study to investigate the role of GeoGebra in representing polynomial-rational inequalities and exponential-logarithmic functions. Qualitative interviews were used on five pre-service mathematics teachers enrolled in the mathematics education program of a Southeastern U.S. university. The leading outcome was that GeoGebra could be considered as a reasoning tool providing further visual explanations to supplement the analytical approach when needed. The fact that this study was conducted on a sample of 5 students who were studying at the university would affect its generalizability.

The concept of a function is essential in mathematics and it contains all the basic mathematical operations using variables and graphs. Dayi (2015) carried out a study in how GeoGebra contributes to middle grade algebra 1 students' conceptual understanding of functions. His study took place in one Algebra 1 class consisting of 9 students from the seventh grade and 9 students from the eighth grade using purposeful sampling. Data were collected through interviews, classroom observations, post-test, and saved computer files of students' interactions with GeoGebra. He found that GeoGebra helped students to get more correct definitions for a function through more correct concept images of functions. When integrating technology into algebra instructions, students were able to discover more function models. GeoGebra was an ideal tool to perform a transition among the representations. This study signified the role of GeoGebra in a better understanding of the concept of a function definition through verification and exploration (Dayi, 2015).

Trigonometry is an important component of mathematics. It links algebra, geometry, calculus, physics, and engineering. Students consider trigonometry among the topics, which are difficult to master (Zengin, Furkan & Kutluca 2011). In this study, the effect of dynamic mathematics software GeoGebra on student' achievement in teaching of trigonometry was explored. A sample of 51 grade 10 students from a high school in Turkey participated for 5 weeks in this study. They were divided into two experimental and control groups. The experimental group was subjected to the lessons arranged with the GeoGebra software in computer assisted teaching method, while the control group was addressed by lessons shaped with constructive instructions. According to the results of the study, there was an important difference between the achievements of the two groups in trigonometry in favor of the experimental group (Zengin, Furkan & Kutluca 2011).

GeoGebra could generate a positive curiosity within students towards trigonometry. Although some students are underperforming in this topic and they keep struggling with rules and procedures that cannot be stated in algebraic formulas, still GeoGebra may bring students to involve more in learning. In their study, Rahman and Puteh (2016) measured under-achievers' motivation level towards teaching and learning Trigonometry topic using GeoGebra. They found that students had a positive motivation towards the use of GeoGebra in Trigonometry. Students were mostly attracted by angle animation, diversity of colors used and slider function, which help them to see thorough steps in trigonometry. Although the findings of this study were consistent with studies conducted to measure motivation level in a variety of mathematical topics, it showed that the boys overall motivation mean was lower than the girls (Rahman & Puteh, 2016).

2.7 Other Subjects and GeoGebra

GeoGebra also can support other subjects; for example, in physics it may offer in-depth understanding of complex physical phenomena (Marciuc, Miron & Csereoka, 2015). Using GeoGebra, the students had the chance to build simulations of optical phenomena and test the behavior of an optical system in various hypotheses. Modeling activities in GeoGebra have the effect of increasing students' motivation and interest for the study of physics and mathematics.

Another example is application of GeoGebra in geography. Herceg and Herceg-Mandić (2013) conducted an experiment which involved one group of future geography teachers and two first grade classes of secondary school students. The findings of this study were that participants agreed that classes were more exciting when presented in a dynamic way on a computer, and playing with GeoGebra helped them overcome their anxiety around the underlying mathematical concepts (Herceg and Herceg-Mandić (2013).

2.8 Summary

The results of all previous studies support the idea that students are able to engage themselves more in the topic they are learning and enhance their knowledge by using GeoGebra to study relationships between symbolic expression and graphical representation. The literature review revealed that there is a few numbers of studies in relation to UAE context of using GeoGebra in high school mathematics in general and teaching quadratic functions in particular. This study is designed to fill this gap in the literature. This study may underline some learning barriers regarding the integration of technology in the classroom environment and suggest further steps and strategies educators need to take to improve learning mathematics with the use of software. Other areas to be investigated in this area of study is how can teachers model real life situations that interests to students with GeoGebra, what are the requirements of students to build the technical confidence needed and the influence that GeoGebra could have in enhancing the importance of teamwork and communication in such technological activities.

Chapter 3: Methods

3.1 Chapter 3 Overview

This chapter describes the research methodology that was used to answer the research questions related to the impact of GeoGebra software on the performance of Grade-10 algebra students in graphing quadratic functions in Alain. This topic covered how to graph quadratic functions and their translations. Questions that guided this study are:

1. What is the effectiveness of utilizing GeoGebra on students' understanding of quadratic functions compared to the conventional instruction?
2. What is the effectiveness of utilizing GeoGebra on students' abilities to graph quadratic functions?
3. What is the effectiveness of utilizing GeoGebra on students' abilities to analyze the effect of changing various parameters on quadratic functions and their graphs?

The chapter begins by providing detailed description about the context of the study, sampling and population selection, the research design, instruments to collect the data, procedure, ethical issues and the data analysis techniques.

3.2 Context of the Study

The study took place in the Applied Technology High Schools (ATHS) in Al-Ain city in United Arab Emirates. The ATHS educational system has two campuses in Al-Ain: Tahnoun Bin Mohammed Educational Complex (TBMEC) in Al-Khurair area and Al-Aqabiya campus in the area of Asharej. Both schools include male and female students who are separated in different buildings. The ATHS schools range from grade 6 to 12 with students placed in different clusters starting from grade 10. The ATHS mathematics curriculum follows the American Curriculum. The textbook used for grade 10 is Algebra 2 by Charles, Hall and Kennedy (2015) and published by PEARSON.

3.3 Research Design

This study used a quantitative quasi-experimental design, which enabled the researcher to investigate the impact of using GeoGebra software on students' performance in graphing quadratic functions. Data included students' scores on a pre-test and a post-test in graphing quadratic functions using GeoGebra software. The collected data showed the influence of the software on the scores of students. The students were divided into two groups:

Experimental group: it contained two sections, one male and one female and these two sections were taught quadratic functions by using GeoGebra (N= 40).

Control group: It contained two sections, one male and one female and these two sections were taught quadratic functions by using regular teaching methods (N= 45).

A diagnostic test was implemented before the beginning of the study to ensure that students had the same level of mathematical knowledge and the background. A pretest was given to the two groups to test the equivalency between the two groups before starting the study. After three weeks, a posttest was given to the two groups, in order to compare the achievements of the two groups after the implementation of the GeoGebra software.

3.4 Population and Participants

The population selected for this study was the TBMEC campus from the Applied Technology high schools located in Al-Ain city in UAE. TBMEC campus has 1,006 students, with three grade 10 regular male sections including 62 students and three grade 10 regular female sections including 62 students. To accommodate the gender differences, two boys and two girls' sections were chosen. The classes were selected using cluster sampling strategy. The sample of this study included 85 grade10 students participated in this study 45 of them were female and the rest (40) were male students. All students are the UAE nationals. After the four classes were selected, two classes were selected randomly to be the control groups while the other two classes were the experimental groups. The experimental and the control group, each included a male and a female section.

3.5 Instruments

At the beginning, the quantitative data collection instrument included a pre-test and a post-test assessment on graphing quadratic functions that was given to algebra course students in both experimental and control classes at TBMEC campus. The pre-test and post-test assessments were developed by the researcher though the Quizzes website that allowed the researcher to conduct a student based formative assessment where questions appear on each student's screen, so they can answer questions at their own pace, and review their answers at the end. Students can complete their assessment using any type of device with a browser, including PCs, laptops, tablets, and smartphones.

Face validity of the test was established by distributing the test to 5 mathematics teachers and the curriculum specialist in Abu Dhabi. The 5 teachers were grade 10 math teachers in different campuses, who had extensive knowledge and expertise in mathematics. Suggestions and feedback were taken into consideration before administering the test.

Reliability of the test was evaluated by administering the test to a small sample of grade 10 male and female students not participating in the main study, and then data were analyzed using SPSS to calculate the Cronbach's alpha value to measure the internal consistency of the test.

3.6 Procedures

A 3-week Algebra unit on graphing quadratic functions measured students' performance. A quasi-experimental design with two control groups and two experimental groups was used. In this study the dependent variable was the students' scores on the mathematics test. The independent variable was the use of GeoGebra in the classroom. All classes participated in a pre-test in quadratic functions, then the experimental groups were subjected to the lessons prepared with the GeoGebra software in computer supporting teaching method, while the control groups were subjected to the lessons formed with constructive instructions without use of GeoGebra. A post-test was applied to the four classes.

The teaching pedagogies that was integrated in this study were discussed with skilled teachers at his campus, those who had good experience in using GeoGebra in their classes. This discussion included practicing graphing different types of quadratic functions using GeoGebra that were needed to teach this unit. The researcher planed with the teachers how to design the lessons in this unit integrating technology into the lesson plans taking into consideration their opinions.

Each class learnt this topic in 12 sessions, distributed over 3 weeks and , with each session lasting for 90 minutes. The same content was covered in each lesson for the four classes, with the only difference being that the control groups did not not use GeoGebra or any graphing application, while the experimental groups used the mathematics software program in their learning. All classes received the same assessments for this topic, which included class-work activities, quizzes and assignments. Then the scores on the pre-test and post-test were analyzed to determine if there was any effect on student performance.

3.7 Ethical Issues

For ethical considerations, the researcher applied for an approval to conduct the research from the director of high schools' system, the school principals and student's parents. A descriptive outline of the study, starting date, duration, participants, procedure, and the benefits of the study were sent to the school administration. During the implementation period; the researcher updated the lead teacher in the TBMEC with the students' participation and improvement. The participant students in the study were equally treated with highest confidentially. At the end of this study, students received clear information about their results in both pre- and post-tests.

3.8 Data Analysis

To determine if there was any impact of using GeoGebra on student performance, the students completed a pre-test earlier to learning the unit. Students sat for the post-test after the concepts were taught. To analyze the data from the pre and post-tests on student performance, both descriptive statistics and inferential statistics were used to generate meaningful information from the raw data. The descriptive statistics were used to find the standard deviation and mean scores on both tests. A t-test was used to determine if there was any significant difference between the experimental and the control groups in order to answer the research questions based on the scores on the two tests.

3.9 Summary

This chapter discussed the methodology and the procedures that were followed during this study which aimed to investigate the impact of The GeoGebra software on students' understanding of quadratic functions and their graphs in grade 10. This chapter begins with an outline of the the study context which was the ATHS two schools in Al-Ain city, including a description of students' genders, grade levels, nationality and the curriculum implemented. Next, the TBMEC was introduced to be the selected sample from the population of the study and grade 10 students as its participants. The study used the cluster sampling strategy as 4 classes (as clusters) were chosen randomly out of 6 available, two groups were formed: an experimental (N= 40) and a control (N= 45). Each group contained two subgroups one male and the other one was female participants. The research employed a quantitative quasi-experimental design where a pre-test and a post-test for both groups were carried out.

The test contained 40 multiple choice questions was created by the researcher through the quizzes website that were based on the content delivered to the students. All questions where matched to 6 leaning outcomes from the mathematics curriculum in the system.

Next, the face validity, reliability of the test and the ethical dimension of the study were discussed, with a result of a valid and reliable test. The study's procedures were explained, both groups sat for a pre-test and a post-test and data were collected, keeping in mind that the experimental group was taught using GeoGebra software during the study period, while the control group was taught by the traditional method. The statistical software program SPSS (version 24.0) was used to analyze students' results, standard deviation and mean scores from both tests were evaluated, and an independent sample t-test was used to determine if there was any significant difference between both groups' scores.

Chapter 4: Results

4.1 Chapter 4 Overview

In the previous chapter, the methodologies and procedures that have been adopted for the present study were discussed in. The sample size, population, as well as techniques for sampling have been also discussed in detail. This chapter presents the results of the investigation that was carried out in the previous section. The researcher was keen to find out whether using GeoGebra software has an impact upon the performance of the students in Grade 10 while graphing Quadratic Functions. The study assessed the difference if any in the test scores of the learners who were trained and exposed to the GeoGebra software with those who were not.

4.2 Difficulty and Discrimination Coefficients

Difficulty coefficient can be described as the percentage of the students who answered wrong while taking the tests (Khairani & Shamsuddin, 2016) whereas discrimination coefficient on the other hand measures the correlation between each item with the overall grade (Subramaniam, Gupta, Singh, & Ravishankar, 2019). The value of the acceptable difficulty coefficient of a given set of data should lie within the range of 0.20-0.80. On the other hand, an ideal discrimination coefficient should be greater than that of 0.39 (Subramaniam et al., 2019). As it can be seen from Table 1 both conditions are met indicating that the data chosen and used was suitable for the analysis. As argued by Khairani and Shamsuddin (2016) when the values lie outside the acceptable ranges, the data may not be appropriate for analysis. More so, where a negative discrimination coefficient is obtained in a research study, then the data must be deleted from the analysis. Table 1 presented below reveals for the difficulty as well as the discrimination coefficients for each of the test items together with sample sizes.

Table 1: Difficulty and Discrimination Coefficient for Each of the Items Considered in the Test.

S No	Difficulty coefficient	Discrimination coefficient	S No	Difficulty coefficient	Discrimination coefficient
1	0.70	0.53(*)	21	0.70	0.48(*)
2	0.70	0.67(**)	22	0.65	0.76(**)
3	0.70	0.78(**)	23	0.30	0.46(*)
4	0.70	0.75(**)	24	0.70	0.86(**)
5	0.60	0.71(**)	25	0.40	0.58(**)
6	0.50	0.49(*)	26	0.65	0.52(*)
7	0.65	0.66(**)	27	0.50	0.53(*)
8	0.70	0.51(*)	28	0.60	0.54(*)
9	0.65	0.71(**)	29	0.70	0.60(**)
10	0.80	0.65(**)	30	0.75	0.76(**)
11	0.65	0.67(**)	31	0.50	0.57(**)
12	0.40	0.61(**)	32	0.60	0.59(**)
13	0.35	0.55(*)	33	0.55	0.62(**)
14	0.70	0.68(**)	34	0.60	0.68(**)
15	0.75	0.60(**)	35	0.80	0.68(**)
16	0.35	0.57(**)	36	0.55	0.72(**)
17	0.50	0.54(*)	37	0.40	0.52(*)
18	0.60	0.74(**)	38	0.65	0.56(**)
19	0.70	0.81(**)	39	0.55	0.52(*)
20	0.60	0.62(**)	40	0.60	0.58(**)

Based on the discrimination and difficulty coefficients from above, it can be seen that none of the items within the sample set needs to be omitted as all the values lie within the stipulated range and can be considered for further analysis.

4.3 Students' Understanding of Quadratic Functions Related to Group Variable

To find out the equality between the groups, means and standard deviations of students' prior understanding of quadratic functions were calculated. Because of small sample sizes, the student t-test analysis was conducted to examine whether there are any statistically significant differences in these means. Results of analysis using the SPSS are presented Table 2 below.

Table 2:The T-Test Results of Students' Prior Understanding of Quadratic Functions Related to Group Variable

Variables (Pre-Test Composite Items)	Group	N	Mean	Std. Dev.	t	df	Sig. (2-tailed)
Interpret and use the vertex form of a quadratic function	Experimental	40	1.90	1.392	1.244	83	0.217
	Control	45	1.53	1.325			
Interpret and use the standard form of a quadratic function	Experimental	40	2.13	1.067	0.288	83	0.774
	Control	45	2.20	1.307			
Interpret and use the graph of a quadratic function	Experimental	40	6.33	1.873	1.202	83	0.233
	Control	45	5.82	1.969			
Graph transformations of function $f(x) = x^2$	Experimental	40	3.55	1.768	1.066	83	0.290
	Control	45	3.18	1.451			
Interpret a quadratic function in a real-life context	Experimental	40	0.75	0.870	0.209	83	0.835
	Control	45	0.71	0.843			
Demonstrate an understanding of quadratic equations	Experimental	40	2.78	1.493	1.268	83	0.208
	Control	45	2.42	1.055			
Pre-Test Scores (total)	Experimental	40	12.05	3.012	1.957	83	0.054
	Control	45	10.80	2.873			

The results of descriptive statistics and ANOVA for the students' prior knowledge has been presented above. The results in Table 2 reveals that there was no statistically significant difference at (α= 0.05) due to group variable because the overall all p value 0.054 is greater than 0.05. This result shows that there were no statistically differences between experimental group and control group in studying quadratic functions. That is, the results imply that there have been no statistically significant differences in the dimensions regarding the learning of the students in the experimental as well as the control groups prior to the use of the GeoGebra software. The achievement levels of the students have been considered as linear functions and that has been compared prior to the training of using the GeoGebra software. The results give us a basis to argue for or against the use of GeoGebra software in teaching and learning thereafter.

As it was stated above, students were divided into two equivalent groups- control and experimental. One group learnt using a traditional method of teaching and learning (control group) and the other was exposed to GeoGebra (experimental group). This process took place over a period of three weeks. The same content was covered in each lesson for the four classes, the only difference being that the control groups did not use GeoGebra. At the end of the experiment, all classes sat for the same assessment including class work activities, quizzes and assignments. The results are summarized in Table 3 below.

Table 3:Post-Test Results on Students' Understanding of Quadratic Functions Related to Group Variable

Variables (Post-Test Composite Items)	Group	N	Mean	Std. Dev.	t	df	Sig. (2-tailed)
Interpret and use the vertex form of a quadratic function	Experimental	40	3.73	1.617	1.919	83	0.058
	Control	45	3.07	1.543			
Interpret and use the standard form of a quadratic function	Experimental	40	4.18	1.678	2.565	83	0.012
	Control	45	3.31	1.427			
	Control	45	17.56	5.655			
Interpret and use the graph of a quadratic function	Experimental	40	11.08	3.058	3.052	83	0.003
	Control	45	9.09	2.937			
Graph transformations of function $f(x) = x^2$	Experimental	40	7.40	2.639	2.300	83	0.024
	Control	45	6.02	2.856			
Interpret a quadratic function in a real-life context	Experimental	40	1.40	.841	5.601	83	0.000
	Control	45	.47	.694			
Demonstrate an understanding of quadratic equations	Experimental	40	5.38	1.890	3.050	83	0.003
	Control	45	4.22	1.594			
Post total	Experimental	40	22.10	5.363	3.789	83	0.000
	Control	45	17.56	5.655			

The results from the table are intriguing. It was found that the p-values of the groups studying vertex form, standard form, and use of graphs of a quadratic are 0.058, 0.012 and 0.003 respectively (two-tailed-test). At the standard critical region (α= 0.05), it seems the teaching with or without software was not statistically different in studying vertex form of quadratic function (p-value= 0.058). This suggests that they may be other compounding variables as suggested by Zhang, et al.(2017). These compounding variables may include the level of intelligence for the students and also gender. The other two groups have p- values of 0.012 and 0.003 < 0.05 indicating a statistically difference between those studying with software and those without in studying quadratic functions in standard form and using graphs. A similar argument can be used on the remaining p-values of 0.00, 0.003 and 0.024. Overall, despite confounding variables, the tests show that teaching and learning using interactive software is engaging and effective compared to traditional methods of teaching. Thus, it can be argued that the performance of the students of grade 10 in graphing quadratic functions in the selected Al-Ain school had been effective due to the adoption of GeoGebra software.

4.4 Reliability of the Tests Performed

Prior to the analysis, the researcher has established the reliability of the test and used Cronbach's alpha to measure internal consistency of the collected datasets This test reveals that when the entire data has been presented the Cronbach's alpha coefficient was calculated and recorded to be 0.95, that is greater than 0.70 (Bonett & Wright, 2015). This has thus been sufficient for the sake of performing the present study.

4.5 Summary of Results

This chapter focused on reporting the main findings of the study. At the beginning, the Difficulty and Discrimination Coefficient were considered appropriate. Secondly, the statistical investigation done on both experimental and control groups showed that the samples are homogeneous as the results of the pretest showed that the mean and the standard deviation of scores for both groups were insignificant. As observed the experimental group score (M= 12.05, SD= 3.012) was slightly higher when compared to those of the control group (M= 10.80, SD= 2.873) and the independent t-test value was found to be 1.957 which lies within the accepted range of –1.9861 and +1.9861. Next, results of students' performance in the posttest were presented and observed, in the experimental group, teaching through GeoGebra was found effective in enhancing all the learning outcomes except interpret and use the vertex form of a quadratic function compared to the control group, which followed the traditional teaching. The posttest result showed that the experimental group achieved a higher mean (M= 22.10, SD= 5.363) score than the control group (M= 17.56, SD= 5.655) on the overall score, in which (t-test= 3.789) result showed a significant difference between the two groups.

Chapter 5: Discussion, Conclusions and Recommendations

5.1 Chapter 5 Overview

The main purpose of this study was to determine if there was a statistically significant difference in students' academic performance in graphing quadratic functions between 10th grade students who used GeoGebra software and students who did not. This chapter outlines and discusses the findings of the study, its implications and limitations, and makes recommendations for better practices to reform mathematics teaching-learning by using technological tools, such as GeoGebra. In addition, it relates the study results to the literature review presented earlier in Chapter 2. The chapter concludes with suggestions for future research on the integration of mathematical software GeoGebra into the teaching and learning of mathematics.

5.2 Discussion of the Results

5.2.1 Students' Overall Mean Total Scores in the Pre- and Post-Test

The results of the analysis of the t-test on the performance of students taught using GeoGebra and those taught using the traditional method of instruction (talk-and-chalk) indicated a significant difference in results in favor of the students taught with GeoGebra. These results were based on the performance of 85 students on a 40- item content test administered twice: as a pre-test before teaching and then after the implementation of the GeoGebra as a post-test. Results from the pre-test showed that there was no statistically significant difference between the performance of the two groups in terms of the total score on the test ($p= 0.054$). This implies that both groups were homogenous in terms of understanding of the test objects.

The comparison between the experimental and the control groups' performances on the post-test results, which took place after teaching the experimental group with GeoGebra revealed that students who were exposed to GeoGebra achieved a higher average score (M= 22.10, SD= 5.363) on the overall score compared to the achievement of students in the control group (M= 17.56, SD= 5.655). An independent samples t-test analysis revealed that the difference in their achievements to be statistically significant t (83)= 3.789, p =0.000.

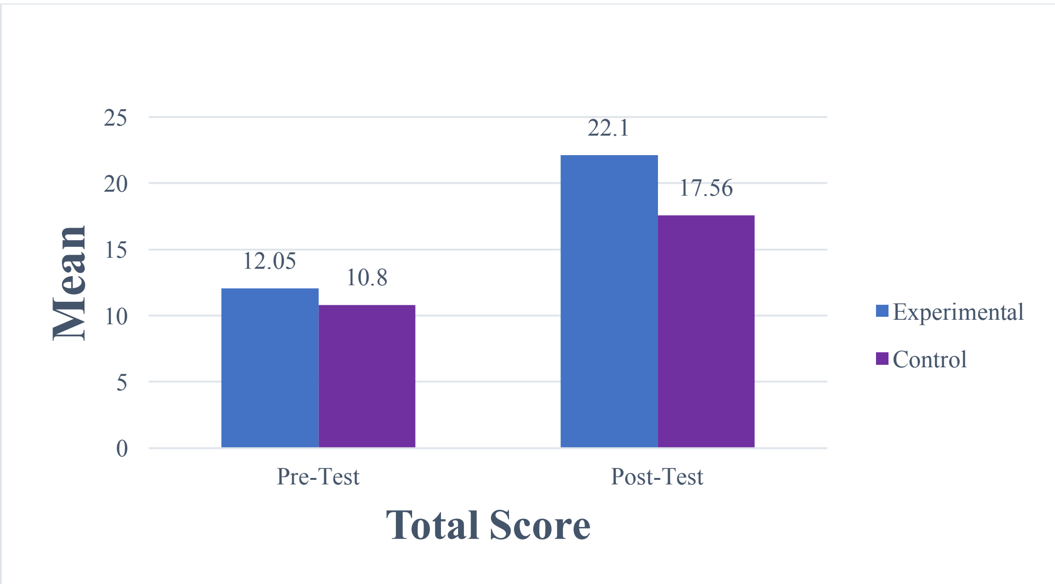

Figure 1: Students' Overall Mean Total Score in the Pre- and Post-Test

The test reveals for the fact that there have been some statistically significant differences between two groups at (α= 0.05) due to grouping variable. There have been statistically significant differences in the total score as well as all the other dimensions except that of the interpret and use the graph of a quadratic function post factor.

Thus, it can be clearly interpreted that the performance of the students of grade 10 in Graphing Quadratic Functions in the selected school in Alain have been enhanced due to the adoption of GeoGebra software.

It can be depicted from these results that GeoGebra had a positive impact on students' achievement in learning quadratic functions. The possible reasons for this finding could be that GeoGebra enabled students in the experimental group to check the correctness of their methods and the accuracy of their work. Being able to check one's own work goes a long way in determining achievement levels. Because GeoGebra is dynamic, students in the experimental group had opportunities of re-examining their work and see how changing any parameter could affect the graph, while those in the control group could not do the same. In the control group, teaching was limited to a few examples, because drawing many diagrams on the whiteboard consumed both time and space.

In addition, the production of good-quality sketches requires competence in technical drawing skills, which not all students possess. GeoGebra-generated sketches are neat and accurate and reflect the characteristics of quadratic functions; it allowed students in the experimental group real-time exploration opportunities. Consequently, this improved the learning process in terms of speed and quality (Ljajko & Ibro, 2013). When students learn using GeoGebra they spend less time drawing diagrams (sketches) and making calculations; this allows them to have more time to explore the characteristics of quadratic functions. All of these factors could have contributed to the greater achievement of the experimental group. It is virtually impossible to have passive students when computer technology such as GeoGebra is used in the teaching and learning process. GeoGebra changes the role of the student from an observer to an independent explorer, it also modifies the role of a teacher from the center of learning to a director and monitor of students' work. Moreover, mathematical concepts and procedures learnt using GeoGebra are long-lasting and better incorporated into students' cognitive structure, which makes them easier to apply (Ljajko & Ibro, 2013). Another element that could have added to the better achievement is the level of the interaction.

5.2.2 Students' Overall Mean Score in Learning Outcome 1: Interpret and Use the Vertex Form of a Quadratic Function

The results related to the first learning outcome in the post-test showed that the average score of the experimental group taught with GeoGebra was (M= 3.73, SD= 1.617) compared to the average score in the control group (M= 3.07, SD= 1.543). Despite that, the difference is not statistically significant as the independent t-test value is t (83)=1.919, p=0.058. As stated earlier, questions that measured this learning outcome were questions: 1, 2, 3, 4, 9, 10 and 35 in the test.

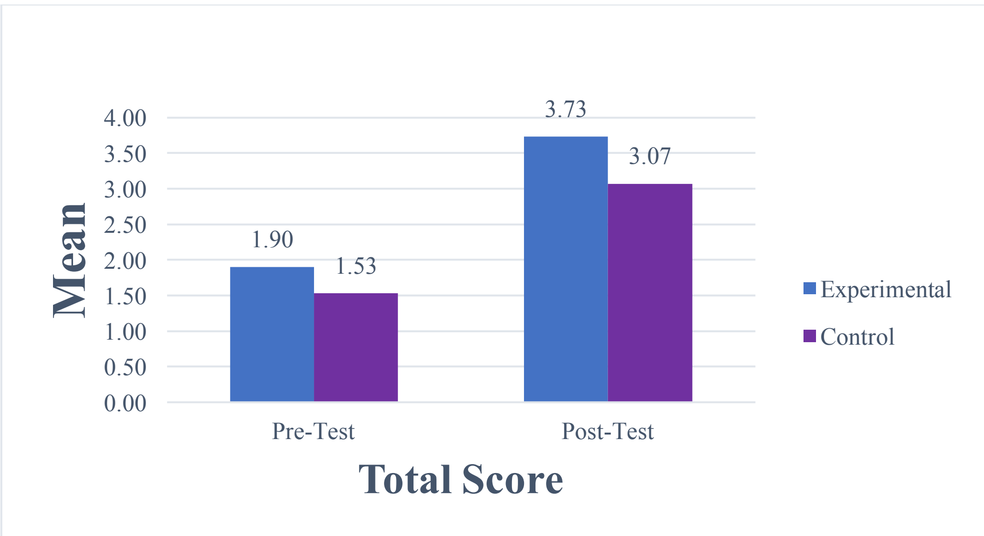

Figure 2: Students' Overall Mean Score in Learning Outcome 1

This result can be comprehended by the fact that a vertex form visibly outlines some features of a quadratic function as the vertex, the axis of symmetry, the stretch factor and the maximum or minimum value of the function. The vertex form $f(x) = a(x - h)^2 + k$ clearly tells that the vertex of the quadratic function is (h, k) and the axis of symmetry is $x = h$, while a represents the stretch or compression factor. The direction of opening of the quadratic function is related to the value of a, when a is positive the function is open upward and consequently it has a minimum value= k, if a is negative a student can identify that function is open downward and has maximum value= k. A student can easily memorize how to locate these characters of the quadratic function from its vertex form without the need to graph this function. Using GeoGebra for teaching this basic level of learning outcomes did not affect students' performance in both groups as students in experimental group scores were not related the instrument as much as to their ability to recall these facts. Another possible factor that led to such results in this domain is the type of questions students are exposed to in their classes on a daily basis. Each time the researcher wrote a quadratic function in the vertex form with the control group, he asked students to mention the characteristics of this function and graph the function on the board.

5.2.3 Students' Overall Score in Learning Outcome 2: Interpret and Use the Standard Form of a Quadratic Function

Results related to the second learning outcome in the post-test exposed that the experimental group outperformed the control group; the average scores of both groups were (M= 4.18, SD= 1.678) and (M= 3.31, SD=1.427) respectively.

A statistically significant difference was found in the independent t-test implemented to compare both groups' scores, t (83)= 2.565, p=0.012.

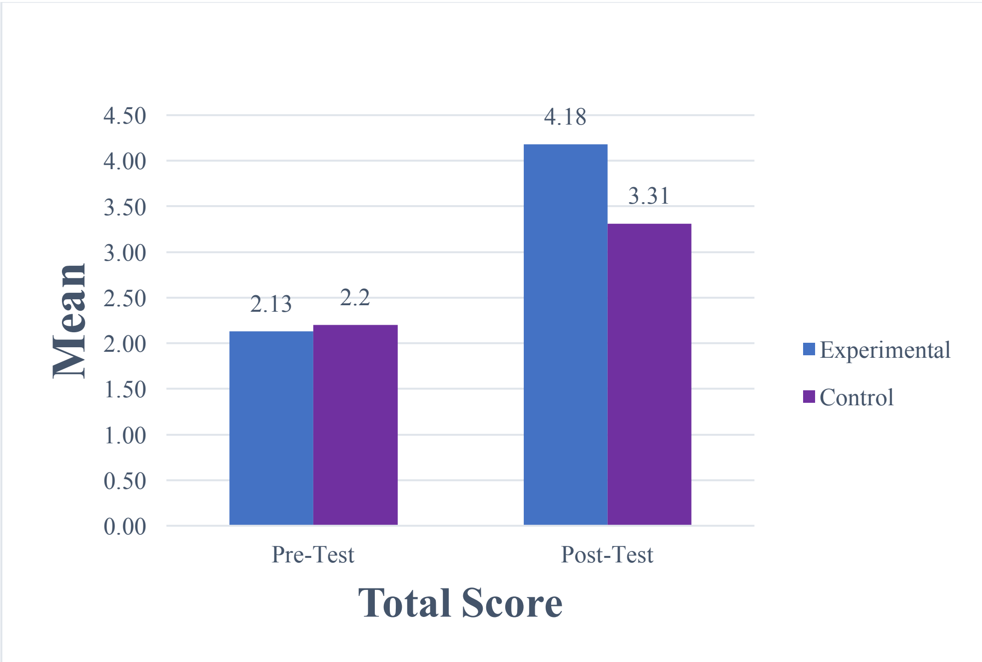

Figure 3: Students' Overall Mean Score in Learning Outcome 2

A standard form of the quadratic function is $f(x) = ax^2 + bx + c$ and questions related to this learning outcome where 11, 14, 15, 16, 33, 36, 39 and 40 in the post-test. To understand these results, the type of questions presented should be investigated: students were asked to identify the vertex in different situations, the y-intercept, the opening direction, match the correct function with its graph, identify the characteristics of the graph of a quadratic function and determine the solutions of the quadratic equation using the graph of the related function. GeoGebra enhanced students' ability to: understand the features of the quadratic function, match the quadratic function in its standard form with the correct graph and understand how to locate the solutions of the quadratic equation to yield the most important effects of teaching students with GeoGebra. The graphing tool instrument supported students in connecting the graph of the quadratic function with its features and students were able to identify all the components of the parabola.

5.2.4 Students' Overall Score in Learning Outcome 3: Interpret and Use the Graph of a Quadratic Function

Eighteen questions measured students' performance related to this learning outcome and compared their scores in both groups. The average scores of both groups were: (M= 11.08, SD= 3.058) for the experimental group, while the control group average score was (M= 9.09, SD= 2.937). The independent t test indicated that the difference between the experimental group who used the GeoGebra instrument and the other group who were taught using traditional method was statistically significant in favor of the GeoGebra group, t (83)= 3.052, p = 0.003.

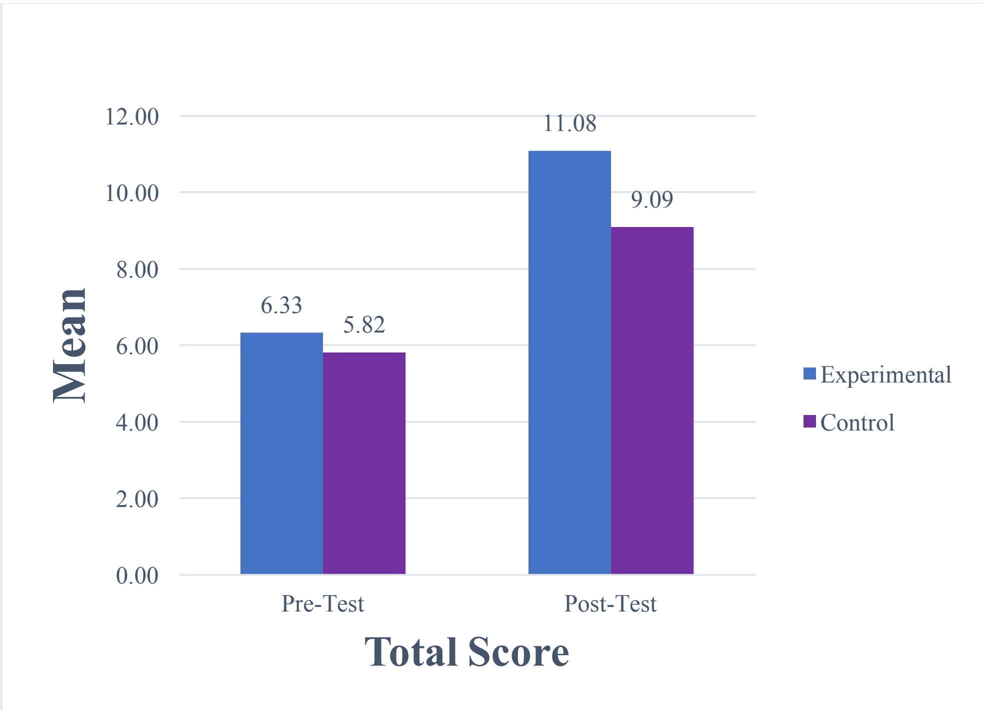

Figure 4: Students' Overall Mean Score in Learning Outcome 3

The following questions in the posttest: 4,9,12, 13, 16, 17, 18, 19, 20, 22, 23, 25, 26, 27, 28, 35, 36 and 40 highlighted the students' ability to link the graph of the quadratic function to its characteristics and vice versa, students were forced to imagine the graph in some questions to respond correctly, while in other questions they had to understand the relation between the graph given and its elements. The difference between the two means of students' scores (11.08 and 9.09) signified the importance of the graphing application and its role in training students to recognize the quadratic functions components from its graph. On the other hand, GeoGebra had a positive impact in leading the students to uncover the features of the quadratic function without visualizing its graph.

5.2.5 Students' Overall Score in Learning Outcome 4: Graph Transformation of $f(x) = x^2$

The researcher believes that this learning outcome is the most important product of using the graphing application GeoGebra in teaching quadratic functions. Graphing transformations in quadratic functions were measured by the following questions: 3, 5, 6, 7, 8, 9, 14, 29, 30, 31, 32, 33, 35 and 39. The study results showed that GeoGebra group (M= 7.40, SD= 2.639) outperformed the none - GeoGebra group (M= 6.02, SD= 2.856), results were statistically significant t (83)= 2.300, p= 0.000.

Students were asked to recognize the effects of changing the quadratic function parameters on its graph such as dilation, translations and reflection with respect to the parent function $f(x) = x^2$.

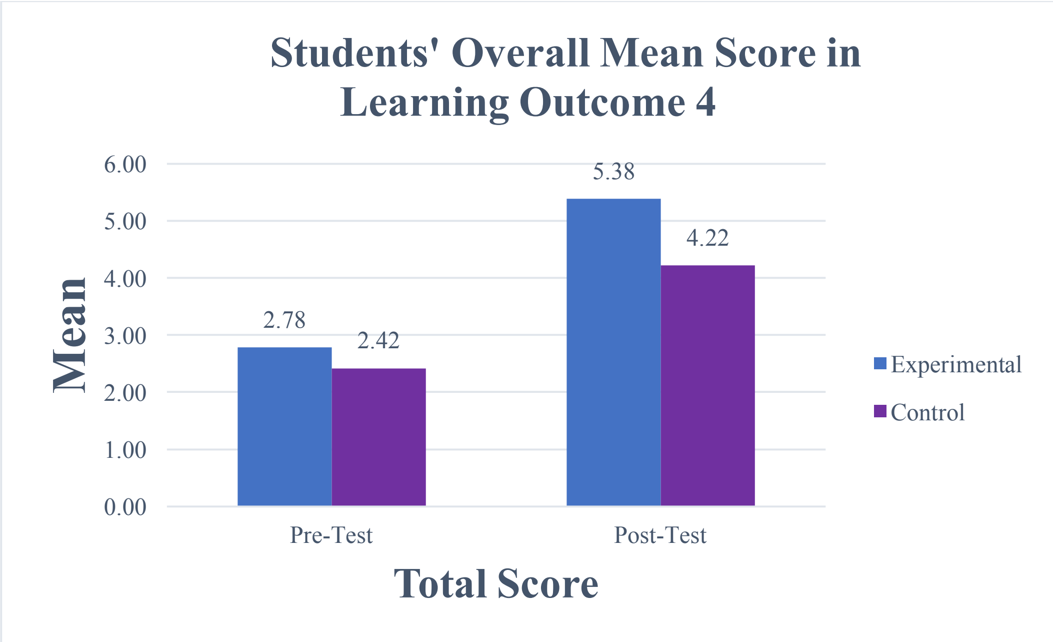

Figure 5: Students' Overall Mean Score in Learning Outcome 4

Students' capability of understanding transformations of the quadratic functions is increased by using the graphing application because they were able to see these effects at the time it was completed. Students in the experimental group were asked to change these parameters and present their conclusions about what was happening to the graph of the function. Learning by doing was a solid method to build and memorize knowledge as seen by the researcher from students in following topics in mathematics.

5.2.6 Students' Overall Score in Learning Outcome 5: Interpret a Quadratic Function in a Real-Life Context.

Linking real life situations that are related to parabolas were discussed and measured in questions: 21, 34, and 40 to study the impact of GeoGebra on students' capability to utilize their skills in quadratic functions. The t test showed that students in the experimental group (M= 1.40, SD= 0.841) outclassed their counterparts in the control group (M= 0.47, SD= 0.694), results were statistically significant t (83)=5.601, p= 0.000.

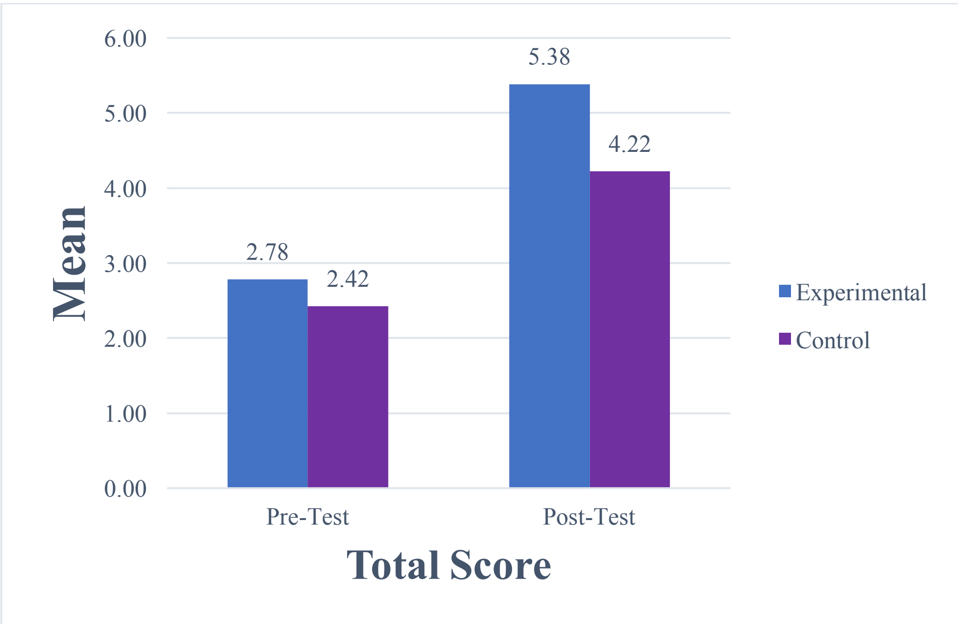

Figure 6: Students' Overall Mean Score in Learning Outcome 5

In the post-test questions, students were expected to answer questions related to the use of quadratic functions in real life contexts such as the projectile motion that takes the shape of a parabola and calculate the maximum height of the object thrown, or to find the distance from the highest point of a parabolic arch sculpture to the ground. Students in general try to avoid word problems, choose their answers randomly and in many times leave these questions unanswered; this could explain the huge difference between the two groups. Students have a negative attitude towards type of questions that include real life situations as noted by the researcher but using the graphing application made it easier to students to visualize and approach these situations with much comfort.

5.2.7 Students' Overall Score in Learning Outcome 6: Demonstrate an Understanding of Qadratic Equations

Quadratic equations are an important type of equations that need to be understood and solved. When equations are related to the graph of a function, it is much easier for students to visualize the geometrical meaning of a solution of an equation. In this study, one important learning outcome that was measured is the ability of students to understand quadratic equation and its solutions in relation to different situations of the graph of the related quadratic function. Questions: 17, 18, 19, 22, 24, 25, 37, 38, 39, 40 attempted to explore the impact of the graphing application GeoGebra on students' performance associated with this domain. It was found that students' achievement in GeoGebra group (M= 5.38, SD= 1.890) was higher than the achievement of other students who did not use the instrument (M= 4.22, SD= 1.594); the difference was statistically significant t (83)=3.050, p=0.003 and was due to GeoGebra implementation in their learning process.

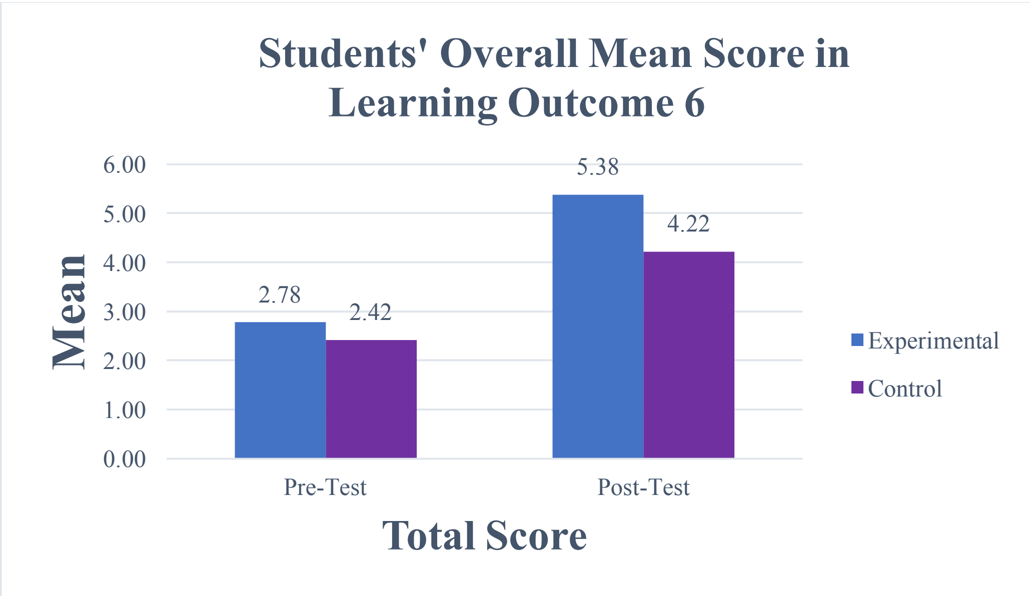

Figure 7: Students' Overall Mean Score in Learning Outcome 6

In the post-test, students were asked to answer questions that tackled number of solutions of a quadratic equation when the graph crossed the $x - axis$ 2 times, touched it one time or was completely above or below the $x - axis$. In addition, students were expected to link the graph of a quadratic function to the value of the discriminant of the quadratic equation. Furthermore, they were requested to identify the solutions of the quadratic equation from the graph, or link the graph with the corresponding equation given in standard or factored form. In general, students in the experimental group were more capable of conceptualizing the geometrical meaning of a root of a function and link it to the algebraic meaning of a solution of an equation. They were able to construct the connection needed by mathematics between Algebra and Geometry.

5.3 Discussion of the Results in Relation to the Literature Review

Learning mathematics with old methods should be investigated and reviewed. Technology is not any more an accessory component inside classes; on the contrary, it is an essential element that can be employed efficiently. In this section, the researcher will discuss the impact of the graphing application GeoGebra on students and its possible outcomes in relation to teachers and the mathematical knowledge.

Students nowadays are confronting many challenges in learning mathematics; one of these is their role in the learning process. They were viewed as compulsive receivers where they have no share in building their own understanding and experience. When students used the graphing application, they were more engaged in their own learning, more confident of their ability in the construction of mathematical awareness.

In addition, students' motivation to learn in the group of GeoGebra clearly increased as seen by the researcher when this study was administered, students were excited to practice new situations where they were going to investigate the effects taking place when changing the parameters' values in a quadratic function. Using the graphing application provides them with an instantaneous feedback on their responses to questions, which added an internal stimulus for learning. Students experienced the support provided by the application to modify their understanding when needed, or ensure their learning is on the right track.

Students were able to graph more quadratic functions when GeoGebra was used; this was due to the time-consumed factor. It was obvious that students had saved extra time that enabled them to encounter more exercises and situations, which added more to their experience. A major problem is the variety of exercise that can be seen when learning any topic in mathematics; students are always under the pressure of the massive content and the diverse problems they need to approach. GeoGebra gave the students the opportunity to encounter different cases in quadratic functions, which increased the probability of mastering the desired learning outcomes.

In another dimension related to students, high level of corporation was visible among students as they were helping each other most of the time. Working in groups and the degree of interaction between learners are huge benefits of using technology, students were passionate to demonstrate their skills and transfer their recent experience to their colleagues. Students in many occasions are better teachers; they can communicate with each other and positively interfere to clarify some misconceptions or vague points. In a study conducted by Shadaan and Leong (2013), they measured the effectiveness of using GeoGebra on students' understanding in learning circles and found that not only student scores were increased, but the software created an energetic classroom environment that was full of clear values of cooperation and collaboration among learners.

As for teachers, technology is a challenge in its self for many of this community. Many teachers are still not familiar with the proper use of technology inside their classes; in fact, some of them are opposing any technology use in their teaching. Training teachers to the best utilizing of effective applications in teaching mathematics is an essential component prior to using this software. GeoGebra is an easy application that can be handled by teachers who have the minimum level of computer skills; still teachers are confronted by the challenge that many schools are not equipped with infrastructure required for running technology. In this study, ATHS students and teachers have access to the Internet and can use their laptops and iPads in learning and teaching process, which made it easier on the researcher to conduct his study. One main disadvantage of technology in classes as many studies highlighted is the distraction that it could bring to some students. Teachers need to be vigilant when students are asked to use the Internet, unfortunately some students consider this as a chance to play games or look for irrelevant practices.

Teachers as mentioned before are required to overcome many difficulties, for example pacing, students' engagement, students' performance are daily concerns that must be addressed. Using the graphing application had a positive influence on these domains as perceived by this study. The support purpose of GeoGebra in the teacher's instruction is not negotiable; it saved time for teachers to move forward with their material. Furthermore, teachers could use the time spared to focus on struggling students with extra practice inside the class while other students are working on higher levels of questions. It also could give teachers a chance to move forward with their curriculum and use this time in other topics in mathematics that need more time and effort from both students and teachers. In summary, teachers should be grateful for these graphing applications for its efficient support for leading to a better and fruitful learning environment.

Moving to the most significant domain, mathematical knowledge is the main focus of this study as the research was exploring the impact of the graphing application GeoGebra on students' performance. In fact, results of students reflected the positive instantaneous impact of GeoGebra on their learning of quadratic functions, its transformations and applications; still there is a prolonged positive effect that appears when learning new topics in mathematics.

As for the direct influence, students were able to link both algebra and geometry together in one window; students in general cannot observe the hidden connection between the two fields. The features of the application gave them the opportunity to visualize the solid connection that they missed in many occasions as many programs teach them unconnectedly. In addition, students' cognitive ability was enriched by the use of GeoGebra. In their study, Karadag and McDougall (2011) highlighted GeoGebra as an important cognitive tool that support the endless interaction between the physical and the mental types of mathematical activities, where GeoGebra can be used as a medium to "create mathematical objects, to manipulate them, and to interact with them". They suggested that teachers can implement GeoGebra in their teaching "to explain, to explore, and to model mathematical concepts and the connections between these concepts". Students understanding begins when they are asked to graph a quadratic function where they see its algebraic representation, then they graph it using the software to establish a strong visual link between the two representations, and investigate the simultaneous effects of interacting with its parameters. It is understandable that students need to be trained in advance on using the software; nevertheless, students are the best reward for them is that they construct and perceive their own knowledge.

Additional result of using the graphing application with quadratic functions is its impact on other topics. In the following semesters in high school, students are going to study different topics: polynomial functions, rational functions, exponential and logarithmic functions, trigonometric functions and conic sections. Students will be expected to graph various types of the previously mentioned. Thus, students' understanding of transformations in quadratic functions graphs is considered as an essential element in understanding the techniques that would lead them to a powerful learning of the new topics. When students learn transformations of functions, they are required to describe what is really happening to the graph in words and the corresponding algebraic notation before sketching, this procedure applies to all types of graphs mentioned earlier. Pfeiffer (2017) found in his study that GeoGebra presented an excellent opportunity to better understanding of functions transformation; students demonstrated a deep abstracted conceptual understanding when moving forward in learning new functions and graphs.

Solving equations is a fundamental theme in mathematics; different categories of equations are confined within algebraic perspective. Students only solve equations without understanding the geometrical meaning; the solutions of a quadratic equation are the $x - intercepts$ of the related quadratic function graph. It is essential to link the graph to the number of solutions of the equation, as graphs enable students to classify quadratic equations and their determinants into three piles: equations with 2 solutions, 1 solution or no real solutions. Some equations' solutions are not integers, so students can estimate or identify these solutions from the graphs' geometrical characteristics. In the following topics, students are asked to solve polynomial equations from a higher degree; a student can easily locate solutions by graphing both sides of the equations and looking for the intersections of the two graphs.

5.4 Recommendations and Suggestions for Further Research

As proved by many studies, GeoGebra implantation in classes was productive for all elements of the learning and teaching process. Literature review showed that countless numbers of teachers and students valued its positive effects in terms of building a learning environment that stress on the facilitating role of a teacher to guide and help students build and construct their own knowledge. In addition to its positive impact on students' achievement, it encouraged students to inquire, explore, discover and learn to create a deep and abstract understanding of mathematical concepts in a class setting full of engagement, independent learning and collaboration. The researcher underlines the weight of the dynamic visualization factor that the graphing application offers for students to see the direct effect of manipulating the parameters to a quadratic function graph; it gave the students the advantage of learning by doing with their own hands.

In light of the previous results, the following recommendations and suggestions may be considered:

Teachers are advised to utilize the graphing application GeoGebra in their classes. Mathematics teachers are urged to reconsider their perceptions and attitudes towards technology implementation in classes as many studies advocated for its use in teaching to enhance student' understanding of mathematical concepts. One eventual goal in education is provide students with the best opportunities that can raise their independence in learning. On one hand, GeoGebra increases the level of confidence within a student where he can trust himself to be responsible for his own learning. On the other hand, it can give space and time needed by teachers to finish their curriculum, ensure that their lessons' objectives are achieved and practice a different role in a class from being the center of the learning process to be an organizer of effective instructional lessons who supports and guides his students to reach the desired learning outcomes.

Schools should be equipped with the necessary services and equipment to use GeoGebra in classes. It is not feasible to adopt technology in schools without providing the required infrastructure. Although many schools around the world nowadays have open access to the Internet, it is still limited to few of its users or certain disciplines with regards to many sites; also, the local intranet provider may block several educational websites. Furthermore, schools ought to promote using technology by providing iPads or graphing calculators to students, or allow them to bring their own devices. Moreover, expert users should offer effective professional development for teachers via conducting training sessions in advance.

Graphing applications should be embedded within the mathematics' curricula from early grade levels. Students' exposure to such applications at an early age would definitely open horizons later on in their studies; it also triggers their creativity as well as gives them the opportunity to have diverse way of learning. For example, teaching Euclidian Geometry using GeoGebra in elementary levels would shift the learning environment form basic arithmetic and boring study of shapes to an attractive setting full of well-designed dynamic activities where a student can learn through playing, exploring and constructing.

Incorporating graphing applications into students' assessment system. When the mathematics' curriculum is built, it is highly advised that extra attention should be given to include individual projects which are based on graphing applications usage within the content related. It is important to set aside time in the weekly planning for these tasks, in addition to assigning a weight for students' performance in their final evaluation.

Using GeoGebra and 3D printing technology to investigate some mathematical concepts. GeoGebra new-implemented features enable its users to construct 3D digital models that can be exported to printable files. This provides students with an opportunity to study important concepts in mathematics such as volume and solids of revolution. This domain could be a possible field to further research in the future.

It is also recommended to investigate the effectiveness of using GeoGebra in teaching mathematics per gender (male and female students). This further investigation could clarify if gender would make a difference in students' engagement and achievement or not when GeoGebra software is implemented in teaching different topics in mathematics for specific grade levels.

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Appendix

Pre-test/Post-test

Quizizz

Pre-test Study

Name : ____________________

Class : ____________________

Date : ____________________

1. The graph of the quadratic function $y = 2(x - 1)^2 + 3$

☐ a) has a vertex of (1 , 3) and opens upward.

☐ b) has a vertex of (3 , 1) and opens upward.

☐ c) has a vertex of (1 , 3) and opens downward.

☐ d) has a vertex of (3 , 1) and opens downward.

2. The graph of the function $y = 4(x - 3)^2 + 2$ has an axis of symmetry

☐ a) x= - 3

☐ b) x= 3

☐ c) x= 4

☐ d) x= 2

3. The graph of $y = 3(x + 2)^2 - 6$ is a stretch of $y = x^2$ by a factor of

☐ a) 2

☐ b) 6

☐ c)3

☐ d) ⅓

4. The graph of the function $y = 4(x - 2)^2 - 3$ has

☐ a) a maximum value = 3

☐ b) a maximum value = - 3

☐ c) a minimum value = 3

☐ d) a minimum value = - 3

5. Which function graph of the following is a reflection of $y = x^2$ across the x-axis

☐ a) $y = 3x^2$

☐ b) $y = -3x^2$

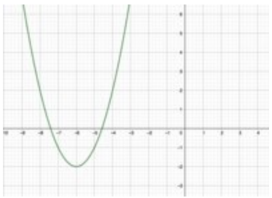
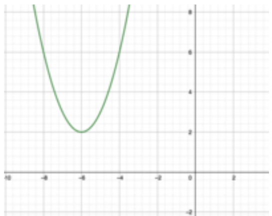
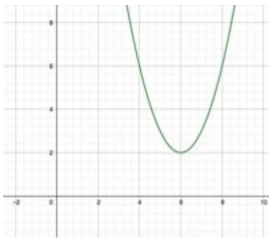
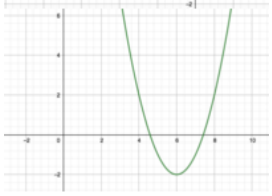
☐ c) $y = \frac{1}{3}x^2$

☐ d) $y = (x - 3)^2$

6. What steps transform the graph of $y= x^2$ to the graph of $y = 2(x-1)^2 + 3$.

- ☐ a) Stretch by the factor 2, translate 1 unit to the left and 3 units up.
- ☐ b) Stretch by the factor 2, translate 3 units to the left and 1 unit up.
- ☐ c) Stretch by the factor 2, translate 1 unit to the right and 3 units up.
- ☐ d) Stretch by the factor 2, translate 3 units to the right and 1 unit down.

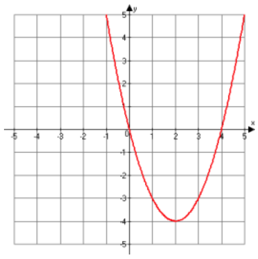
7. Using the graph of $f (x)= x^2$ as a guide, graph the function $g(x) = (x + 6)^2 - 2$.

- ☐ a) 
- ☐ b) 
- ☐ c) 
- ☐ d) 

8. The parent function f(x) is reflected across the x-axis, vertically stretched by a factor of 10, and translated right 10 units to create g(x). Use the description to write the quadratic function in vertex form.

- ☐ a) $g(x) = - 10 (x - 10)^2$
- ☐ b) $g(x) = 10 (x - 10)^2$
- ☐ c) $g(x) = 10 (x + 10)^2$
- ☐ d) $g(x) = - 10 (x + 10)^2$

9. What is the vertex form of this quadratic Function graph?



- ☐ a) $f(x) = -(x + 2)^2 - 4$
- ☐ b) $f(x) = (x - 2)^2 + 4$
- ☐ c) $f(x) = (x - 2)^2 - 4$
- ☐ d) $f(x) = -(x - 2)^2 - 4$

10. What is the vertex of

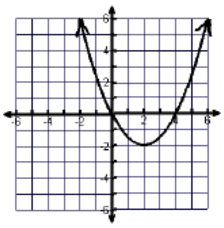
$f(x) = 2(x - 5)^2 + 12$

- ☐ a) (-5, -12)
- ☐ b) (5,-12)
- ☐ c) (5, 12)
- ☐ d) (-5, 12)

11. The graph of the quadratic function $y=3x^2 + 6x - 5$ has a vertex with x - coordinate

- ☐ a) x= - 2
- ☐ b) x= 6
- ☐ c) x= - 1
- ☐ d) x= 2

12. What is the range of this function?



- ☐ a) All real numbers.
- ☐ b) All real numbers greater than or equal to 0.
- ☐ c) All real numbers greater than or equal to -2.
- ☐ d) All real numbers greater than or equal to 2.

13. A parabola has a vertex at (-3,2). Where is the axis of symmetry?

- ☐ a) y = -2
- ☐ b) x = 3
- ☐ c) x = -3
- ☐ d) y = 2

14. What is the y intercept for the equation:

$y = -8x^2 + 3x - 7$

- a) (0, -8)
- b) (0, 3)
- c) (-8, -7)
- d) (0, -7)

15. Find the vertex of

$f(x) = -x^2 - 4x + 12$

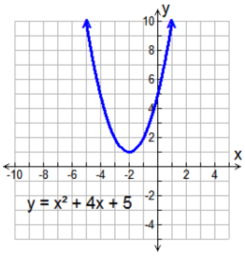
- a) (-2, 16)
- b) (2, 0)
- c) (2, 4)
- d) (-2, 4)

16. What direction is the following equation opening?

$y=-3x^2-7x+8$

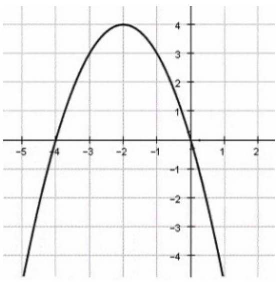
- a) Up
- b) Down
- c) Left
- d) Right

17. How many solutions does this graph have?



- a) one
- b) two
- c) no solutions
- d) cannot be determined

18. How many solutions does this graph have?



- a) one
- b) two
- c) no solutions
- d) cannot be determined

19. The solutions to a quadratic function, or "zeros" are said to be where the graph crosses

- ☐ a) the x-axis
- ☐ b) the y-axis
- ☐ c) the center
- ☐ d) the line

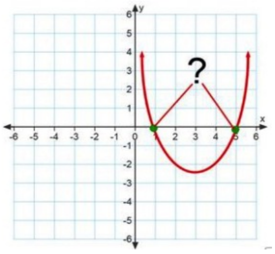
20. What is the axis of symmetry?

- ☐ a) the slope of the graph
- ☐ b) the dividing line for a parabola
- ☐ c) the y -axis
- ☐ d) the x-axis

21. Ahmed hits a fly ball. You can track the height of the ball using the equation: $h(t) = -16t^2 + 160t + 2$ where t is time in seconds. When does the ball reach its maximum height?

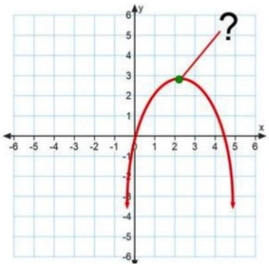
- ☐ a) at t = 2 seconds
- ☐ b) at t = 3 seconds
- ☐ c) at t = 4 seconds
- ☐ d) at t = 5 seconds

22. What are the green dots called?



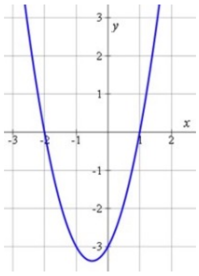
- ☐ a) axis of symmetry
- ☐ b) vertex
- ☐ c) parabola
- ☐ d) roots or x-intercepts

23. What is the green dot on the parabola called?



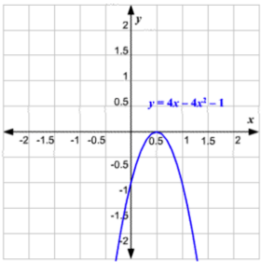
- [ ] a) maximum
- [ ] b) minumum
- [ ] c) roots
- [ ] d) zeros

24. What is the equation for this parabola in factored form?



- [ ] a) y=(x+2)(x-1)
- [ ] b) y=(x-2)(x+1)
- [ ] c) y=(x-2)(x-1)
- [ ] d) y=(x+2)(x+1)

25. How many solutions does this graph have?



- [ ] a) one
- [ ] b) two
- [ ] c) no solutions
- [ ] d) cannot be determined

26. The axis of symmetry line passes through which point in the graph of a quadratic function?

- [ ] a) y-intercept
- [ ] b) any random point
- [ ] c) vertex
- [ ] d) the function zeros.

27. Quadratic equations take the shape of a________when graphed.

- a. U
- b) straight line
- c) wavey line/snaked
- d) circle/elliptical

28. What is the domain of the quadratic function $y = -3x^2 + 6x - 2$?

- a. All Real Numbers
- b) No Solution
- c) $y \geq -2$
- d) 6

29. Describe the transformations of $g(x)= x^2 + 5$ when compared to the parent function $f(x) = x^2$.

- a. horizontal shift right 5 units
- b. horizontal shift left 5 units
- c. vertical shift up 5 units
- d. vertical shift down 5 units

30. Describe the transformations of $g(x) = (x+7)^2$ when compared to the parent function $f(x) = x^2$.

- a. horizontal shift left 7 units
- b. horizontal shift right 7 units
- c. vertical shift up 7 units
- d. vertical shift down 7 units

31. In the equation $f(x)= 5 (x+3)^2-10$, what effect does the 5 do when compared to the parent function $f(x) = x^2$?

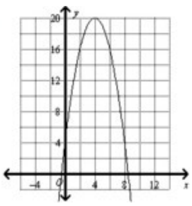
- a. Vertical stretch by a factor of 5
- b. Vertical shrink/compress by a factor of 5
- c. Reflect over x-axis
- d) Vertical shift up 5 units

32. Which of the following describes the transformations done to the quadratic parent function $f(x) = x^2$ to obtain $g(x) = 2x^2 + 4$?

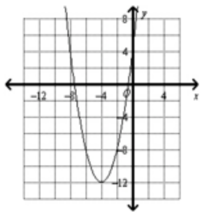
- ☐ a. Vertical Stretch by a factor of 2 and vertical shift up 4 units
- ☐ b. Vertical Shrink/Compress by a factor 2 and vertical shift up 4
- ☐ c. Vertical Stretch by a factor of 2 and horizontal shift left 4 units
- ☐ d. Vertical Shrink/Compress by a factor of 2 and horizontal shift right 4 units

33. What is the graph of $y = x^2 + 8x + 4$?

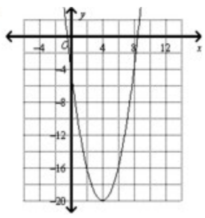
- ☐ a. D.



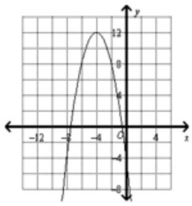
- ☐ b) C.



- ☐ c) B.



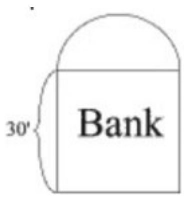
- ☐ d) A.



34. A parabolic arch sculpture is on top of a city bank. A model of the arch is $y = -0.005x^2 + 0.3x$ where x and y are in feet.

a. What is the distance from the highest point of the arch to the ground?

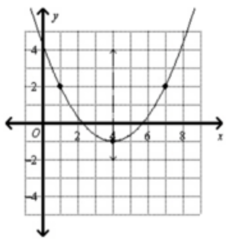
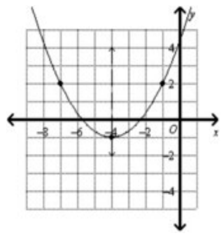
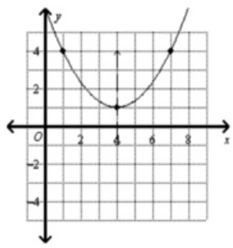
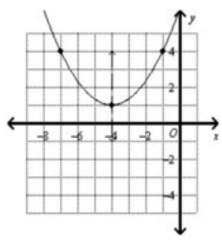
b. What is the width of the bank?



- [ ] a) a. 34.5 feet
  b. 60 feet
- [ ] b) a. 4.5 feet
  b. 60 feet
- [ ] c) a. 4.5 feet
  b. 30 feet
- [ ] d) a. 34.5 feet
  b. 30 feet

35.

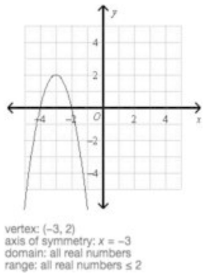
What is the graph of $f(x) = \frac{1}{3}(x-4)^2 - 1$?

- [ ] a. 
- [ ] b) 
- [ ] c) 
- [ ] d) 

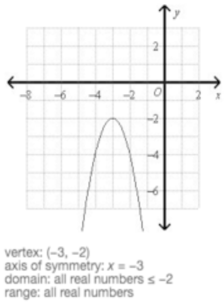
36. **Graph the quadratic function. Identify the axis of symmetry, the vertex, and the domain and range of the function.**

$y = -2x^2 + 12x - 16$

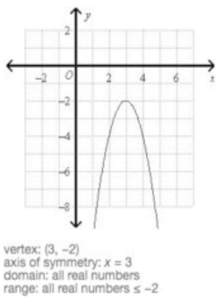
☐ a.



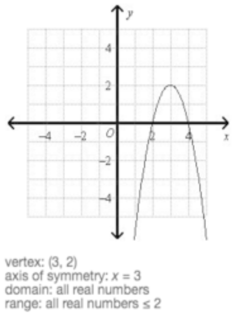
☐ b)



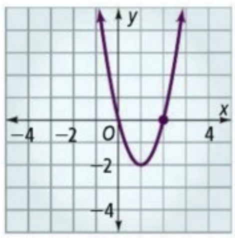
☐ c)



☐ d)



37. The graph represents the quadratic function f(x). When solving the quadratic equation f(x)=0 the value of the discriminant Δ is?

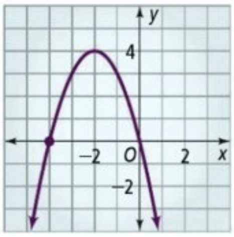


☐ a. positive

☐ b) negative

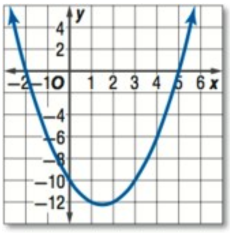
☐ c) zero

38. The quadratic equation that represents the graph is



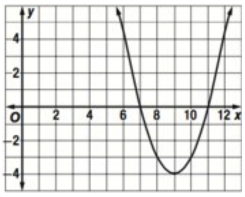
- [ ] a) x (x + 4) = 0
- [ ] b) x (x - 4) = 0
- [ ] c) (x + 4) (x+ 2) =0
- [ ] d) (x + 4) (x- 2) =0

39. **Use the graph related to the equation** $x^2 - 3x - 10 = 0$ **to determine its solutions.**



- [ ] a) 5, 2
- [ ] b) 5, -2
- [ ] c) 5 , - 2 , -10
- [ ] d) 2 , -5

40. Ali is a computer programmer. He needs to find the quadratic function of this graph for an algorithm related to a game involving dice. Provide such a function.



- [ ] a) $f(x)= x^2 - 18x + 77$
- [ ] b) $f(x)= x^2 + 18x + 77$
- [ ] c) $f(x)= x^2 - 18x - 77$
- [ ] d) $f(x)= x^2 + 18x + 77$

Answer Key

1. a
2. b
3. c
4. d
5. b
6. c
7. a
8. a
9. c
10. c
11. c
12. c
13. c
14. d
15. a
16. b
17. c
18. b
19. a
20. b
21. d
22. d
23. a
24. a
25. a
26. c
27. a
28. a
29. c
30. a
31. a
32. a
33. b
34. a
35. a
36. d
37. a
38. a
39. b
40. a