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The effectiveness of the GeoGebra Programme in the development of academic achievement and survival of the learning impact of the mathematics among secondary stage students

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Abstract
The objective of this research is to identify the effectiveness of the GeoGebra program in developing academic achievement and ensuring survival of the learning impact of the mathematics among female secondary stage students. To achieve this objective, an experimental approach was applied. This consisted of a quasi-experimental design comprising an experimental group and control group with pre, post, and deferred assessments for both groups. The research was conducted with a random sample of 60 female third grade of secondary stage divided into two groups: an experimental group comprising 30 students who studied using the GeoGebra program and a control group comprising 30 students who studied in the traditional manner. The measurement tool consisted of an achievement test on scientific concepts in a polar coordinates and complex numbers unit at different cognitive levels (Application-Analysis). This was pre-applied to both groups in the second term of 2020. At the end of the experiment, the post application was conducted, and the deferred test was applied 10 days later. The results revealed that the experimental group were superior to the control group in achievement scores and survival of learning impact. Based on the findings, the researchers recommend the inclusion of GeoGebra program in mathematics curricula at various stages of education. They further recommend including this program in mathematics in general, and in polar coordinates geometry and complex numbers in particular.

Keywords Mathematics · GeoGebra program · Academic achievement · Survival of the learning impact · Secondary stage

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1 Introduction

Modern technologies, including educational technical applications, have helped to create an interactive learning environment that has had a positive impact on students' understanding of scientific concepts and levels of mathematical achievement.

Emphasizing the importance of such educational applications, the National Council of Teachers of Mathematics (NCTM) in the USA (2008) issued the principles and standards of school mathematics. Technology was included as a fundamental principle on which mathematics is based. This principle states that technology is a vital tool for teaching mathematics in the twenty-first century and all schools must ensure that their students are able to use it. An effective teacher is the one who maximizes the role of technology when developing the student's mathematics knowledge and raises their level of mathematical ability. Technology becomes acceptable for all students when it is used properly and purposefully in teaching mathematics.

The use of technology in teaching mathematics is also important because it makes learning fun and enables students to practice self-learning through educational conversation and dialogue with educational software. It reduces the learning time by about 30% compared to traditional learning. Furthermore, it provides an appropriate structure to use movement, sound, and graphics, and to achieve the capability of simulation and modulation (Al-Hadi 2005).

The computer provides an environment of communication and interaction between learners during the process of learning and education. This creates positive attitudes among learners towards the computer as an educational method and towards the subjects they study. This increases their motivation to learn, enhances their achievement in mathematics, and develops positive trends towards mathematics (Al-Dayel 2011).

A study by Ishaq (2018) revealed the superiority of students who studied through the use of the GeoGebra program in an achievement test. Similarly, Abu Thabet (2013) confirmed that the use of the GeoGebra program in teaching a "Circle" unit in mathematics resulted in an increase in the overall score achieved on the post-achievement test as well as the direct and deferred achievement tests in favor of the experimental group.

The researchers therefore argue that technology must be integrated into the teaching of mathematics. This research aims to identify the effectiveness of the GeoGebra program in developing academic achievement in the mathematics among female third grade of secondary stage.

1.1 Identifying the problem

The researchers conducted an initial survey of 10 female teachers of secondary stage mathematics at The Eastern Province. The questions are as follows:

1- What is the teaching method that you follow in teaching mathematics?
2- What is the most effective method of teaching mathematics in your opinion?
3- To what extent do you include technology while teaching mathematics?
4- Do you think that the use of technology contributes to raising the achievement level of female students?

5- Do you think that the use of technology contributes to the survival of the learning effect of the students?

The results of the initial survey interviews showed that seven teachers used the traditional teaching method, which is represented by the use of the pen and the board in the process of writing, explaining and solving exercises and the textbook, without the diversity in their teaching methods, and they also showed negative trends towards technology, because they think it requires prior training and takes longer to implement it. While three teachers showed positive trends towards the diversity of teaching methods and the use of technology, because they have previous experience and practice, which was reflected in the students' achievement level.

In addition, when the follow-up records of female students were reviewed, the researchers noticed that the average grades of female students who were taught through the traditional method did not exceed a very good grade compared to female students who were taught through modern teaching methods (technology), as their average grades reached an excellent.

There is therefore a need to address this gap by investigating the effectiveness of changing from a traditional method of teaching to a more technical one. After reviewing the literatures about the effectiveness of the GeoGebra program, which specializes in mathematical concepts based on international standards of mathematics, this research was conducted to identify the effectiveness of the program in the development of academic achievement and survival of learning impact of the mathematics for female secondary stage students.

1.2 Research problem

Most international tests have identified a significant drop in academic achievement in mathematics in Arab countries compared with other countries. These tests include the TIMSS, which was developed by the International Association for the Evaluation of Educational Achievement (IEA).

For instance, Education and Training Evaluation Commission reports documented on the Ministry of Education website (2019) reveal that indicators of academic achievement in mathematics for fourth primary grade and second middle grade students in KSA reflect a poor level of academic achievement compared with their peers from other countries. TIMSS test courses conducted from 2003 to 2015 revealed that the KSA was ranked below average level amongst the participating countries (paragraphs 6–10).

The research problem becomes even more apparent when considering the position of Saudi Arabia in the TIMSS test that was published on the MOE's website in 2019. There is clearly a low level of achievement in mathematics among primary and intermediate stage students. This problem will thus move to the secondary stage unless it is resolved. The Ministry of Education has recommended reconsidering classroom practices with a view to taking advantage of new pedagogical tools and technologies, including assistive devices and teaching tools. The aim is to help students gain mathematical and scientific skills which they can transfer and employ in different situations in order to solve this problem (Paragraph 11).

Al-Enezi (2012) stated that geometric topics in mathematics are among the topics students do not like. This reflects an apparent drop in students' academic achievement in mathematics in general, and geometry in particular. Ateeq (2016) stated that the reason for this drop is the abstract presentation of lessons, which makes students feel that the course is complex and difficult, resulting in them developing negative attitudes towards mathematics.

The focus of this research revolves around the low level of academic achievement in mathematics among female secondary grade students as a result of traditional education practices.

1.3 Research objectives

This research aimed to:

1- Reveal the effectiveness of teaching the Polar Coordinates & Complex Numbers chapter using the GeoGebra program in enhancing academic achievement among female third grade of secondary stage.
2- Reveal the effectiveness of teaching the Polar Coordinates & Complex Numbers chapter using the GeoGebra program in ensuring survival of the learning impact for female third grade of secondary stage.

1.4 Hypotheses

The specific hypotheses that were tested are as follows:

1. There are no statistically significant differences at (0.05) between average achievement scores (pre-test and post-test) for the control group.
2. There are no statistically significant differences at (0.05) between average achievement scores (pre-test and post-test) for the experimental group.
3. There are no statistically significant differences at (0.05) between average post-test achievement scores for both control and experimental groups.
4. There are no statistically significant differences at (0.05) between average post-test and deferred test achievement scores (Survival of Learning Impact) for the control group.
5. There are no statistically significant differences at (0.05) between average post-test and deferred test achievement scores (Survival of Learning Impact) for the experimental group.
6. There are no statistically significant differences at (0.05) between average achievement scores on the deferred test for both control and experimental groups.

1.5 Research importance

Theoretical importance: This research is important as it adopts a modern teaching method based on learners' practice and interaction with the GeoGebra program, which makes the learning environment more vital and active. Additionally, it further enhances understanding of mathematical content and leads to a more durable educational experience, which will be positively reflected in learners' achievement and progress.

Practical importance: Firstly, the results will be of value to those involved in mathematics teaching, including curriculum supervisors, educators, teachers and researchers. Specifically, it will provide them with feedback and help them plan the curriculum and become acquainted with the latest methods of presenting mathematical content through the use of the GeoGebra program. Secondly, the results will be of value to students as it will encourage them to practice self-learning in mathematics through interaction with the GeoGebra program and create positive perceptions towards this technology. Thirdly, the results will provide researchers with field indicators regarding the effectiveness of the GeoGebra program in enhancing academic achievement and survival of the learning impact for students. Finally, the research keeps pace with global and local trends that advocate the need to benefit from the use of computer technologies in the field of education.

1.6 Research delimitations

Objective Delimitation: This research was applied to certain topics in the second term (polar coordinates and complex numbers unit, which have the following topics: Polar coordinates, and their representation, polar form and Cartesian form of equations, and complex numbers and De Moivre's theorem) on mathematics course-6 for secondary education stage - Courses System - Natural Sciences Track, Edition 2020.

Temporal Delimitation: The researchers chose to conduct the field research in the second term of the academic year 2019–2020.

Spatial Delimitation: This research was conducted in two secondary schools in Al-Dhahran city.

Population Delimitation: The sample comprised 30 female students in the third grade of secondary stage (control sample) and 30 female students in the third grade of secondary stage (experimental sample). However, the study.

could have included male students if there were no restrictions of time.

1.6.1 Research terms

Effectiveness Effectiveness refers to the ability to influence and achieve objectives and inputs in order to realise the expected results as much as possible (Zaytoon 2009). The researchers defined effectiveness as the impact of GeoGebra on students' post and deferred achievement on the mathematics course.

GeoGebra Programme This is a dynamic educational method used in teaching and learning Algebra and Geometry through which graphical algebraic concepts and expressions are connected (Ishaq 2018). The researchers defined GeoGebra as an educational mathematical program designed according to Mathematical International Standards. It creates a conceptual environment that makes it easier for students to acquire geometrical and mathematical concepts in a simple and interesting way. This aligns with a constructive learning curve, as students continually build on their previous learning. It was used in the experimental group to support the teaching and learning of a polar coordinates and complex numbers unit for third grade of secondary stage.

Survival impact of learning This refers the learning output retained in memory, which is measured by the score the student obtains in the subject when he/she is retested. This may be directly applied after completion, with an appropriate period of time between both tests (Al-luqani and Al-Jamal 2003, p. 10). Procedurally, the researchers define this term as the extent to which participants (third grade of secondary stage from both control and experimental groups) retain information related to the Polar Coordinates and Complex Numbers unit after studying it for 10 days. It is measured through the score students obtain on the deferred test. (Based on the study of Abu Thabet (2013), who measured the effectiveness of the GeoGebra program and educational aids in the direct and deferred achievement of ninth grade students in mathematics, within 10 days; In addition, this study was carried out during the beginning of the Corona pandemic, which is a transitional period in education in the Kingdom of Saudi Arabia from face-to-face education to e-learning across platforms, therefore, 10 days was the maximum period we are allowed to conduct Survival test).

Polar coordinates The polar coordinate system is a two-dimensional coordinate system in which each point on a plane is determined by a distance from a reference point and an angle from a reference direction.

Complex numbers A complex number is a number with a real part and an imaginary part usually represented in algebraic form: $Z = a \pm jb$ where 'a' is the real part, 'b' is the imaginary part and 'j' represents $\sqrt{-1}$ (where in mathematics, 'i' is in mathematical notation, and in engineering context, 'j' is engineering notation). The word complex numbers may have sounded difficult and alien to some students hearing it for the first time because complex means complicated or hard to understand (Livingstone 2008). More unknown terms such as imaginary, conjugate, phasors and Argand diagram (a coordinate plane where horizontal axis is denoted as real axis and vertical axis is denoted as imaginary axis, also known as a complex plane) introduced were too much to the students' dismay. The j-notation was introduced when the squared root of a negative number has no solution (Ahmad and Shahrill 2014).

2 Theoretical framework and literature review

The first section presents the theoretical frameworks for this study, and the second section provides the previous research in the areas relating to this study.

2.1 The first section: Theoretical framework

2.1.1 GeoGebra Programme

Al-Alawi (2017) defines this as an electronic programme prepared by the GeoGebra site that contains a set of tools that provide students with mathematical skills. It is helpful for the teachers, but it is not a substitute for them.

Al-Noaimi (2016) defined GeoGebra as a software for mathematic education specializing in three main topics (Algebra, Geometry, and Math). It is based on creating an interactive conceptual environment for students. This can be classified into two systems: the first is related to Computer Algebra System (CAS), as it includes algebraic and conceptual processes involving equations and coordinates; the second is related to Dynamic Geometry Software (DGS), as it includes geometric concepts such as point, line, 2D shapes, and 3D objects. It also provides students with information on interrelations between concepts (p. 47).

Al-Balawi (2012) states that GeoGebra is an educational computer program that includes a set of tools which help students acquire mathematical skills in an easy and interesting way. It is a program based on international mathematical standards supporting the curricula of the ministry of education, but it is not a substitute for them. GeoGebra is designed to enable students to acquire an in-depth understanding of mathematical theories and facts through exploration and practice of these concepts (p. 24).

The researchers were enthusiastic about this program precisely because it is based on international standards of mathematics and is considered supportive of the curriculum, especially the mathematics course. It includes a set of tools that provide superior and interesting learning, enabling students to build on what they have learnt in the past. This is advocated by Crown Prince Mohammed bin Salman through his ambitious 2030 vision and is fully compatible with the constructive learning curve.

2.1.2 Programme philosophy and objectives

The program philosophy is based on the fact that students can learn mathematics better if they are given the opportunity, through perfect problem-solving practice, to use GeoGebra to absorb and interrelate mathematical concepts. This is known as the "learn by practice" approach, where students learn using their personal abilities, and is one of the most important foundations on which the theory of constructivism is based.

Al-Balawi (2013) explained that this program was built on the fact that all students can learn mathematics whenever they are given a sufficient opportunity, and can solve problems in a way that is commensurate with their capabilities and speed. It is based on scientific pillars that advocate practice, as the nature of mathematics requires perfection, comprehension, and the ability to build associations between both concepts and skills. (p. 698).

The GeoGebra program aims to help students perceive and embody concepts in a concrete way. It is based on the interrelation of mathematical concepts and their relationship to mathematical tasks. The program develops self-learning skills and thinking skills, and builds self-confidence by providing students with an opportunity to fully demonstrate their efforts (Abu Thabet 2013).

Therefore, it is necessary to use the GeoGebra program in teaching mathematics, as it reflects information in a way that gives students numerous mathematical and personal skills that will help them develop their capabilities, improve the quality of their conceptual understanding, and sustain the impact of their learning to achieve the expected objectives.

2.1.3 Practical access

GeoGebra can be defined as a tool that has various practical capabilities. It has three main practical capabilities as a program for the teaching and learning of mathematics. First, Kadir and Al-Zahrawi (2015) explain that it is a tool of description and representation, encompassing algebraic representation, geometric representation, numerical representation, and dynamic representation, and links between these. Second, GeoGebra is a modeling tool because it is a dynamic construction and facilities a method of learning through exploration and experimentation. Third, it is a writing tool as it is used in building and sharing materials among the Internet Community and in scientific research on learning and teaching.

These capabilities enable the teacher to use different teaching methods and achieve learning through multiple mathematical representations that enable students to solve and share mathematical problems, thus achieving the desired goals according to their capabilities and preferred method of learning.

2.1.4 Working mechanism inside mathematics classroom

Al-Jasser (2011) explained the GeoGebra working mechanism as follows: Student learning takes place individually or collectively to accomplish the exercise assigned by the teacher. The role of the teacher is limited to providing assistance when the students fail to understand the required task; however, the teacher should not give them the solution. If students fail to reach the solution, the teacher shall provide proper assistance and direct them to carry out exercises related to the one they failed to accomplish. The teacher corrects the exercises daily and returns them to the students on the following day so that they can rectify their mistakes and save the exercises in their files. Students' progress is monitored on a daily basis and recorded in their follow-up files (p. 37).

Therefore, it becomes clear that both teachers and students have specific roles when using the GeoGebra program. The students' role is primarily one of self-learning and building knowledge by themselves or in cooperation with colleagues. The teacher's role is limited to guiding and assisting the students when needed, as well as monitoring students' progress to give them feedback and help them correct their mistakes.

2.1.5 GeoGebra from an international background

The International Society for Technology in Education (ISTE), which is a US organization for education leaders and educators that aims to improve teaching by developing the effective usage of technologies, has published regular policy briefs on the role that technology plays since 2008. They first published a report on technology and student accomplishment in 2008 with the title 'The indelible link'. It indicated that technology had a positive effect on the academic achievement levels of students. It was reported by ISTE (2008) that effectively integrating technology into teaching and learning processes was positively impacting students' achievement levels via increased test results and their ability to acquire modern skills (which are necessary for students to achieve success when leaving school).

A particular result that emerged from the First International GeoGebra Conference held in Linz, Austria on July 14–15, 2009 was related to activities pertaining to the organization of regional conferences in in Spain, Turkey, Argentina, South America, and Norway. With the aim of engaging groups of mathematicians, educators and software developers in debates regarding the opportunities to apply technology in the teaching and learning of mathematics, the First North-American GeoGebra conference (GeoGebra-NA 2010), held on July 28–29, 2010 in Ithaca, NY, paved the way for successive conferences in North America and consequently to this conference in Canada, the idea is to hold annual conferences interchangeably in the US, Canada and Mexico (Martinovic et al. 2014).

The intellectual benefit of GeoGebra and its scientific objective is in attempting to accomplish the following goals:

1. The identification of an agenda of critical research and development requirements in the discipline; collective exploration of questions surrounding research processes with respect to GeoGebra and similar types of software.
2. The creation of synergies among developers, mathematics experts, educationalists and teachers/practitioners that will affect research into how education is supported by technology.
3. Investigating methods of reaching and engaging with a variety of communities to promote mathematics; developing a publicly available resource of quality teaching methods and materials to facilitate the integration of GeoGebra into mathematics education (Martinovic et al. 2014, p.iii).

It was contended by Hohenwarter and Preiner (2007) that mathematics teachers around the world are starting to believe that GeoGebra can potentially transform the teaching of mathematics. Hence, Milner-Bolotin (2014) stated that an area worthy of investigation is the manner in which prospective teachers' technology experiences effect their teaching in the initial period after they graduate. This has particular importance due to the fact that GeoGebra has numerous benefits when used in the classroom. For example, Furner and Marinas (2014) claimed that GeoGebra is motivational in terms of mathematics learning and can reduce anxiety related to the subject. Real-life images incorporated in GeoGebra facilitate the process of observing relations between distinct and similar shapes.

2.1.6 Polar coordinates

Prior to being recognized as a general geometrical instrument, polar coordinates were employed for particular purposes as well as studying specific curves (Mi et al. 2013). They were first used by Bonaventura Cavalieri for finding the area inside an Archimedean spiral by correlating it with the area outside a parabola. A similar transformation was utilized by Pascal for the purpose of calculating a parabolic arc's length. Although Roberval had previously proposed a solution to this problem, its validity was not universally recognized. An analogous transformation between two separate curves was performed by James Gregory in which there was a relation between the areas, while the transformation utilized by Pierre Varignon for studying spirals had slight differences.

Newton was the first scholar to view polar coordinates as a way of fixing any point in the plane (Coolidge 1952). Nevertheless, he only studied them with respect to Cartesian, bipolar and other systems, with his sole focus on demonstrating how it was possible to determine the tangent when the curve's equation was given in one or the other system. Jacob Bernouilli investigated this further by writing the expression for the radius of curvature when the curve's equation was written in polar form. Clairaut was the first scholar to consider polar coordinates in 3-space, although he only mentioned that such a thing was possible. They were not actually developed until Euler achieved this, who was the originator of polar and radio-angular coordinates. These were subsequently modified by Ossian Bonnet (Coolidge 1952).

2.1.7 Challenges experienced by students with polar coordinates

Polar coordinates are crucial for studying calculus, complex numbers and modelling all systems that incorporate radial symmetry or motion around a central point. Even though polar coordinates have significant importance in high schools, current researchs (Montiel et al. 2008; Montiel et al. 2009; Sayre and Wittman 2007; Paoletti et al. 2013) indicates that students' understanding of polar coordinates remains limited, where particular problems are related to problematic links with the Cartesian coordinate system (CCS). For example, it was determined by Montiel et al. (2008) that the knowledge that students have of polar coordinates is commonly linked to their activity within the CCS (e.g., the application of the vertical line test in the polar coordinates). These findings reveal the overall necessity to improve students' understanding of how polar coordinates are constructed. Despite the fact that both CCS and polar coordinates are utilized for the purpose of representing relationships, they have distinct conventions that must be constructed and coordinated by students if the polar coordinates are to be used in a productive manner (Paoletti et al. 2013).

2.1.8 The polar coordinates in GeoGebra

Technology has assumed a pivotal role in people's daily lives and computers can now be found in all locations, particularly in developed nations. Moreover, standards for technology are now being developed by educational institutions (Lawless and Pellegrino 2007) with the aim of promoting the integration of technology into teaching and learning processes. For instance, one of the six principles for school mathematics stipulated by the National Council of Teachers of Mathematics' (NCTM) Principles and Standards for School Mathematics is technology: "Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning." (NCTM 2000, p. 11). A software program called GeoGebra has recently been used in numerous mathematics classrooms (e.g., Aydos 2015; Öçal 2017; Shadaan and Leong 2013; Tatar and Zengin 2016). The use of GeoGebra fosters the students' meaningful and conceptual understanding of targeted mathematics subjects. For example, Alves (2014) presented and explained various examples of how integrals can be applied in polar coordinates. He discovered that GeoGebra facilitates the process of describing complex regions in the plane.

2.1.9 Complex numbers

It is undeniable that the emergence of complex numbers has triggered a revolution in the field of advanced mathematics, and it can certainly be stated that their utility in various different topics and applications has prepared the ground for multiple new innovations and discoveries (Dempsey 2010). As noted by the French mathematician Jacques Hadamard (1865–1963), "The shortest path between two truths in the real domain passes through the complex domain." (Berlinghoff and Gouvêa 2002, p. 146). Hence, the comprehension of the complex number system, along with the ability to perform arithmetic operations using complex numbers as well the representation of complex numbers and their operations on the complex plane form a specific standard in the subject of Mathematics for high school students emphasized in the Common Core State Standards Initiative (CCSSI 2010 Appendix 1, p. 60). In order for students to meet all the criteria necessary for this subject, it is important that teachers have a comprehensive understanding of how to teach complex numbers.

2.1.10 History of complex numbers

According to an article published by Steven Strogatz, mathematicians have had an ongoing obsession with calculating the roots of polynomial equations for over two and a half millennia. The story of their attempts to discover the "roots" of equations that have become increasingly complex represents one of the most important aspects in the history of human thinking (Strogatz 2010). Prior to the 1700s, it was believed by mathematicians that negative numbers had no square roots. In their opinion, these numbers could not exist due to the fact that all numbers multiplied by themselves produce a non-negative result. However, it is important to note that even until the seventeenth century, renowned mathematicians like John Wallis were skeptical about negative numbers. To understand why they were so suspicious, readers are referred to the interesting book by Nahin (Nahin 2005, p. 14). The notion that negative numbers had square roots was clearly perceived to be absurd and illogical.

In the initial period of the history of mathematics, when a mathematician was required to take the square root of a negative number when attempting to solve an equation, he/she would merely terminate the process as this type of expression had no meaning. An example of this occurred in 50 AD, when Heron of Alexandria was investigating a truncated pyramid's volume (defined as the frustrum). Nevertheless, in this era, negative numbers had neither been "discovered" and nor where they utilized (Chavez 2014).

2.1.11 Traditional approach in teaching complex numbers

In the ttraditional approach, the teacher has all control and is responsible in the classroom. This generally involves giving lectures in which the students are required to follow all classroom rules and procedures stipulated by the teacher. The notion of complex numbers is introduced by the teacher who explains the facts. For example, students are instructed to add the complex numbers $+3i$ and $2+7i$. They are taught to add the real and imaginary parts individuals in order to acquire the result $6+10i$. With regard to multiplication, in the process of multiplying the complex numbers $1+2i$ and

$-5+3i$, students must perform the necessary expansion and subsequently simplify the result. Although this standard algebraic approach taken to complex numbers is strictly regimental, it is advantageous for presenting and instructing the basic operations on complex numbers (Chavez 2014).

The Common Core State Standards do not recommend the traditional approach. In this method, the Argand diagram for showing complex numbers in graphical form as a point in rectangular coordinates on the plane is introduced. Due to the fact that students will have previous experience of plotting ordered pairs in a coordinate plane, they will have minimal problems with using the Argand diagram. Although it has similarities to the topics they covered in Algebra 1, in this context, the real and imaginary axes replace the x and y axes. The representation comprises the identification of complex number a + bi by the point (a, b) on the plane. With regard to the complex number a + bi, a and b are defined as the real and imaginary parts, respectively. The point (a, b) on the plane represents this complex number. On the other hand, it is possible to identify any point (a, b) on the plane via the complex number a + bi. This explains why the plane is defined as the complex plane in this situation. When the real part is positive, the number will move to the right along the real axis, whereas when it is negative, the movement will be to the left of the real axis. Furthermore, where the imaginary part is positive, it moves up along the imaginary axis, whereas the movement is down when it is negative (Chavez 2014).

2.1.12 Students' difficulties with complex numbers and the use of technology

Students and the general public often experience significant challenges when attempting to learn complex numbers (Bagni 2001; Nesbitt and Bright 1999). The different challenges experienced by students include "(i) accepting the existence of the number i that satisfies $i2=-1$, (ii) overcoming the anxieties created by the unfortunate choice of words such as "imaginary" and "complex" in reference to certain numbers, (iii) mixing the ideas from algebra, geometry and trigonometry and (iv) being unaware of the origin, history, and usefulness of complex numbers" (Chavez 2014, p.47). Matzin et al. (2013) noted that an interesting online article was published by Egan (2008) related to teaching complex numbers, with a focus on comprehending the perceptions and challenges experienced by students when they are first confronted by complex numbers. According to Egan, it is likely that the arithmetic of complex numbers represents the first subject that students will encounter in which the strength of their mathematical education will surpass the strength of their imagination. The process of learning about complex numbers boosts the significant capacity of abstract thinking as well as the mathematical instruments by which it is facilitated. Furthermore, he noted that the introduction of complex numbers not only builds on the student's previous comprehension of arithmetic, but it also shows them that their previous knowledge only provided a one-dimensional perspective of a world that is actually two-dimensional,

Nevertheless, mathematics teachers are now beginning to exploit the benefits of technology to motivate the students to choose this subject and to improve the overall learning experience (Wong 2009). Technology facilitates the development of interactive learning (Flores and Montoya 2016). The emergence of information and communication technologies (ICT) "as an educational tool represents a turning point in the way in which learning […], breaking with rigid schemes and traditional teaching has been done, to adopt other ways of building, managing and transmitting knowledge" (Millán-Rojas et al. 2016. P. 86). Technological applications such as GeoGebra offer improved content, power and efficiency when plotting or manipulating mathematical content (Araujo 2007).

2.2 The second section: Literature reviews

2.2.1 First Axis: The effectiveness of GeoGebra Programme in the development of academic achievement in mathematics

Saha et al. (2010) conducted a study to measure the effectiveness of using the GeoGebra program on student achievement in Kuala Lumpur, Malaysia, by extending their learning of geometric coordinates. This study adopted a quasi-experimental approach. The sample consisted of 53 secondary school graders, who were divided into two groups based on their spatial abilities (high spatial ability and low spatial ability). The experimental group comprised low spatial ability students who used the GeoGebra program while the control group comprised high spatial ability students who used the traditional method of education. Achievement tests and spatial ability measurement were applied to both groups. The results showed that the academic achievement of low spatial ability students had improved, and thus their spatial abilities had increased.

Ries and Ozdemir (2010) conducted a study that revealed the effectiveness of employing the GeoGebra program in enhancing student achievement while teaching parabola. The sample consisted of twelfth graders who were divided into two equivalent groups: a control group comprising 102 students who used the traditional method of education; and an experimental group comprising 102 students who used the GeoGebra program. The results revealed high achievement on the parabola unit among the experimental group students compared with the control group. The interaction between experimental group students in the class increased and they felt that studying the parabola had become easier and more enjoyable.

Furkan et al. (2012) aimed to determine the impact of using the GeoGebra program on student achievement in the teaching of trigonometry. The sample consisted of 51 secondary graders. The researchers employed the experimental approach in its quasi-experimental design. All participants completed an achievement test, the results of which revealed that the academic achievement of the experimental group was superior to their counterparts in the control group.

Al-Alawi (2017) conducted a study to identify the impact of using the GeoGebra program in geometry teaching on academic achievement and geometric anxiety reduction among first secondary graders. The sample consisted of 55 first secondary graders. The researcher employed the experimental approach in its quasi-experimental design. All completed an achievement test and an anxiety scale. The results revealed that the experimental group who used the GeoGebra program were superior to the control group on both the achievement post-test and anxiety scale. The findings also revealed a statistically significant correlation between academic achievement levels and geometric anxiety.

Ishaq (2018) conducted a study to reveal the effectiveness of using the GeoGebra program in developing visual thinking skills and achievement in mathematics among middle school students at the Educational Directorate in Sabia, Saudi Arabia. The sample consisted of 99 first middle graders. The researcher employed the experimental approach in its quasi-experimental design. The research tools consisted of an achievement test and visual thinking test. The results revealed that the experimental group who used the GeoGebra program achieved scores superior to the control group on both tests. The results also revealed no statistically significant differences in all fields of the study tool. This is because the pedagogical competencies of mathematics teachers are usually attributed to the impact of study grade, academic qualification, and years of experience.

Ali (2019) conducted a study to identify the effectiveness of a proposed strategy based on the GeoGebra program to develop mathematical communication skills in geometry and academic achievement among fifth primary graders. The researcher adopted an experimental approach. The sample consisted of 66 fifth primary graders from two different schools. These were divided into two groups: an experimental group comprising 33 pupils from Al-Eman Primary School and a control group comprising 33 pupils from Kafr Mansour Primary School. The research tools consisted of a teacher's guide, a test to measure mathematical communication skills, and a test to measure academic achievement in geometry. The results revealed that the experimental group was superior to the control group in terms of both mathematical communication skills and academic achievement.

2.2.2 Second Axis: Studies on the effectiveness of the GeoGebra program on survival of the learning impact of mathematics

Al-Ghamdi (2011) conducted a study to assess the impact of using GeoGebra Geometry Panel in the teaching of vectors on survival of the learning impact for normal second secondary graders. The sample consisted of 62 normal second secondary graders. The researcher applied a quasi-experimental design based on control and experimental groups with immediate and deferred prior and post evaluation. The research tools consisted of a proposed module and an achievement test. The results revealed that the experimental group was superior to the control group on the deferred achievement post-test.

Abu Thabet (2013) conducted a study to compare the teaching of a "Circle Unit" using the GeoGebra program with traditional teaching tools and their impact on the direct and deferred achievement of ninth graders in the Nablus district. The sample consisted of 188 ninth grade male and female students from public schools in Nablus. These were divided into two groups: an experimental group comprising 96 students; and a control group comprising 92 students. The researcher employed a quasi-experimental approach. The study tool consisted of an achievement test. The results revealed the superiority of the experimental group in scores on the achievement post-test and direct and deferred achievement tests.

2.2.3 Similarities between the literature and this research

In terms of the independent variable: This research is consistent with all literature reviews in terms of handling the GeoGebra program variable, but differs from Abu

Thabet's (2013) study in terms of dealing with teaching tools and traditional method variables.

In terms of the dependent variable: This research is consistent with (Ishaq 2018; Al-Alawi 2017; Abu Thabet 2013, Al-Ghamdi 2011) in terms of dealing with the academic achievement variable. It is also consistent with Abu Thabet (2013) and Al-Ghamdi (2011) in terms of dealing with the survival of deferred learning impact.

However, it differs from Ali (2019) in terms of dealing with the mathematical communication variable, Ishaq (2018) in terms of dealing with the visual thinking variable, and Al-Alawi (2017) in terms of dealing with the anxiety reduction variable.

In terms of the research methodology: This research employs an experimental approach comprising a quasi-experimental design and is thus consistent with all the literature reviewed.

In terms of research population: This research is consistent with Al-Alawi (2017), Furkan et al. (2012) and Al-Ghamdi (2011) in selecting secondary schoolgirls as the study population. However, it differs from Ali (2019), who focused on the primary stage, and Ishaq (2018) and Abu Thabet (2013), who both focused on the middle stage.

In terms of research tool: This research is consistent with all previous literature in terms of the test selected as the research tool. However, it differs from Ali (2019), who also used a teacher's guide and a mathematical communication skills test. It also differs from Ishaq (2018) who used a visual thinking test, Al-Alawi (2017) who used an anxiety scale, and Al-Ghamdi (2011) who built the proposed module.

What distinguishes this research from the existing literature The researchers contend that this research is distinct because it is the only study to have addressed the effectiveness of the GeoGebra program in the teaching of polar coordinates and complex numbers and its impact on academic achievement and survival of learning impact in Saudi Arabia.

Aspects drawn from the literature reviews:

- Drawing on the pedagogical literature, literature reviews, and adopted scientific methodology to form the theoretical framework used in this research.
- Identification of the research methodology and tools appropriate for this research.
- Reviewing the statistical methods employed and adopting them as appropriate for this research.

3 Research questions

The main research question is as follows:

How effective is the GeoGebra program in the development of academic achievement and survival of the learning impact of the mathematics for female secondary stage students?

This can be broken down into the following sub-questions

1. How effective is the GeoGebra program in developing academic achievement in mathematics among female secondary stage students?
2. How effective is the GeoGebra program in ensuring survival of the learning impact of the mathematics for female secondary stage students?

4 Research methodology

Sample, tools, intervention information, methods of analysis, etc),

To achieve the research objectives, the researcher employed the experimental approach in its quasi-experimental design. This involved the use of a quasi-experimental design consisting of both experimental and control groups. Obaidat et al. (2011) define this as a deliberate and controlled change of the specific conditions of the actuality or phenomenon that form the subject of the study, and then noting the effects of this change on that actuality or phenomenon.

4.1 Research population and sample

Al-Assaf (2012) define the research population as “whatever the research results may be circulated to, whether individuals, groups, books, etc., according to the subject area of the research problem” (p. 95). The population of this research comprised all third grade of secondary stage who studied in the second semester, 2019–2020 in all 687 schools of the Dhahran district, as reported by the Dhahran Educational Supervision Bureau.

Al-Bassam (2015) defined the research sample as “a subset of vocabulary of population of the study in question, to be selected properly to represent the study population” (p. 12). The sample for this research comprised 60 female students enrolled in the third grade of secondary stage in two public schools; Al-Khansa Secondary School and the Second Secondary School in Dhahran district. The experimental group comprised 30 students in Al-Khansa Secondary School and the control group comprised 30 students in the Second Secondary School. The sample was purposively selected from among schools equipped with the devices and tools needed to conduct the research.

4.2 Research variables

These were as follows

- Independent Variable: The use of the GeoGebra program.
- Dependent Variable: Development of academic achievement and survival of learning impact.
- External Variables:

A. Chronological Age: To verify the homogeneity of ages for both samples, the researchers reviewed students’ ages as per school records. The ages of both groups were equal and the average age was 17–18 years.

B. Gender: In accordance with the education system in Saudi Arabia, the sample comprised female students only, representing control of the gender variable.
C. Previous achievement in mathematics among the sample students: the equality of academic achievement was investigated through a pre-test completed by both groups.
D. Sample Teachers: The sample teachers were selected on the basis of their outstanding academic performance in realizing equality in education.

4.3 Research tool

The research tool was an achievement test on the polar coordinates and complex numbers unit (please see Appendix 1), for which the researchers followed the stages set out below:

4.3.1 Test objective

This test aims to assess the application and analysis skills of third grade of secondary stage on the polar coordinates and complex numbers unit.

Formulation of test paragraphs The researchers reviewed the pedagogical literature and mathematics curriculum. They also examined samples of achievement tests supplied by the National Center of Assessment to use when drafting the test paragraphs. Questions were objectively designed in a multiple choice format comprising ten questions on different cognitive skills, as shown in Table 1:

Test Instructions Test instructions were drafted on a separate paper in short and clear sentences that explained the details to each student. These demonstrated how to answer and where to put the answers to the test. According to the answer scheme of the test paragraphs, participants were informed that one mark is given for a correct answer and zero for an incorrect answer.

Test Validity After the initial preparation, the test was presented to a group of arbitrators specializing in curriculum and teaching methods as well as a group of mathematics teachers. In view of their comments, the researchers amended the research title and thus the test was finalized.

Pilot Study Using facilities provided by General Directorate of Education in the Eastern Province, the researchers applied the final form of the test on polar coordinates

Table 1 Distribution of test paragraphs to application and analysis skills

Application Skill	Paragraphs (1,2,4,7,8)
Analysis Skill	Paragraphs (3,5,6,9,10)

Table 2 Pearson correlation coefficients between each question and the total mark for the skill under which the question falls

Analysis		Application	
Pearson Correlation	Question	Pearson Correlation	Question
.681**	Third Question	.830**	First Question
.712**	Fifth Question	.788**	Second Question
.754**	Sixth Question	.830**	Fourth Question
.890**	Ninth Question	.707**	Seventh Question
.856**	Tenth Question	.551**	Eighth Question

**Correlation is significant at 0.0

**Correlation is statistically significant at 0.01

and complex numbers to a random sample of 30 third grade of secondary stage from Dhahran schools.

This sample had the same characteristics as the original population of the study (not the study sample) in the second term of the academic year 2019–2020. The pilot study was used to calculate the validity and reliability coefficient of the test, the difficulty coefficient, and the discrimination coefficient.

Test Validity & Reliability Coefficient The internal consistency validity of the test was assessed by calculating Pearson Correlation coefficients between each question and the total mark for the skill under which the question falls, as shown in the following table:

Table 2 shows that all correlation coefficients between each question and the total mark for a skill under which the question falls are statistically significant at 0.05. This means that the test has internal consistency validity.

Reliability Calculation: The reliability of the test was verified through two methods: Alpha Cronbach Coefficient and split-half reliability (Spearman-Brown). The results are presented in Table 3:

The results of both tests demonstrate that reliability is 0.835 and 0.921, respectively. This indicates high reliability and thus confirms the appropriateness of the test for application.

Table 3 Alpha Cronbach coefficient and split-half reliability calculations results

Skills	Question count	Cronbach's Alpha	Split-half
Application	5	0.795	0.878
Analysis	5	0.832	0.838
Test	10	0.835	0.921

Table 4 Shapiro-Wilk test for normality distribution

		Statistic	Df	Sig.
Scores	Control	.881	30	.003
	Experimental	.901	30	.009

Null Hypothesis: data follows normal distribution

Alternative Hypothesis: data does not follow normal distribution

Table 4 shows that the Shapiro-Wilk Significance level is less than 0.05 and therefore the null hypothesis is rejected. This means that the data are not normally distributed and thus non-parametric tests must be used.

Difficulty & Discrimination Coefficient in Table 5:

Table 5 shows that the value is generally acceptable and that the ease coefficients of cognitive test ranged from 30% to 70%. This indicates that the cognitive test is moderately easy. The difficulty coefficients of the test ranged from 70% to 30%. This indicates that the test is moderately difficult. The coefficients approached 0.5, suggesting that the cognitive test terms are appropriate given that the previous value was medium. They also reflect the balance of the cognitive test in terms of simplicity and difficulty.

Equivalence of Both Groups: Before embarking on the experiment, the researchers verified the equivalence of both groups by determining whether the differences between the average scores of the control and experimental groups on the pre-measurement test were significant.

Table 6 shows that the test significance level is above 0.05, thus the null hypothesis is accepted, which states there are no statistically significant differences between the two groups in pre measurement. Therefore, there was equivalence between both groups in terms of pre-measurement.

Table 5 Calculation of difficulty & discrimination coefficient

	Discrimination	High	Low	Total Marks	Difficulty
Question 1	77.78%	9	2	22	64.71%
Question 2	77.78%	9	2	20	58.82%
Question 3	77.78%	9	2	20	58.82%
Question 4	88.89%	9	1	22	64.71%
Question 5	66.67%	8	2	18	52.94%
Question 6	77.78%	8	1	16	47.06%
Question 7	77.78%	9	2	24	70.59%
Question 8	44.44%	7	3	22	64.71%
Question 9	66.67%	7	1	11	32.35%
Question 10	66.67%	9	3	13	38.24%

Table 6 Mann-Whitney- U test results to determine the significance of the difference between the experimental and control groups in the pre-measurement test

Group	Count	Arithmetic Mean	Standard Deviation	Ranks Average	Mann-Whitney U	Significance Level
Control	30	4.2333	1.43078	28.47	389.000	.360
Experimental	30	4.6667	1.98847	32.53		

4.3.2 Statistical methods

The researchers conducted the following combination of statistical analyses on SPSS:

Arithmetic Mean and Standard Deviation.
Shapiro-Wilk Test to reveal the normality distribution.
Mann-Whitney- U Test for Independent Samples to identify differences between the averages of independent samples.
Wilcoxon Test of Related Samples to identify differences between the averages of related samples.
Eta Squared Coefficient to calculate the size of the GeoGebra program's effect on academic achievement and survival of learning impact.

This was based on the following equation:

$$\eta^2 = \frac{t^2}{df + t^2}$$

Where T = t value calculated in T-Test, and df = Degrees of Freedom.
Effect size is significant if $\eta^2 \geq 0.14$.
Effect size is intermediate if $0.06 \leq \eta^2 < 0.14$.
Effect size is small if $0.06 > \eta^2 \geq 0.01$.

5 Results and discussion

First Hypothesis There are no statistically significant differences between the average achievement scores (pre-test and posttest) for the control group.

Table 7 reveals statistically significant differences ($p = 0.019$) between the average academic achievement scores of students within the control group in favor of the post-test. Thus, the traditional method of education made a difference in terms of academic achievement. Furthermore, the Eta Squared Coefficient reveals a high effect size of 0.18, greater than the Cohen Standard of 0.14.

Second Hypothesis There are no statistically significant differences between the average cognitive achievement scores (pre-test and post-test) for the experimental group.

Table 8 reveals statistically significant differences ($p = 0.000$) between the average academic achievement scores of the experimental group in favor of the post-test.

Table 7 Wilcoxon test results to determine the significance of the difference between the pre and post measurements for the control group

Group	Count	Arithmetic Average	Standard Deviation	Ranks Average	Differences		Wilcoxon (Z)	Significance Level
Pre	30	4.2333	1.43078	10.50	Negative	8	−2.343	.019
Post	30	5.3667	2.56614	14.83	Positive	18		

Therefore, the use of the GeoGebra program made a difference in terms of academic achievement. Furthermore, Eta Squared Coefficient reveals a high effect size of 0.42, greater than the Cohen Standard of 0.14. Moreover, this effect size is stronger than that for the traditional method.

Third Hypothesis There are no statistically significant differences between the average post measurement of achievement scores for both control and experimental groups in the achievement post-test.

Table 9 reveals that the significance level is less than 0.05. Therefore, the null hypothesis is rejected, which states there are no statistically significant differences between both groups in post measurement. This means that the use of the GeoGebra program made a difference in post achievement in favor of the experimental group.

The results for the first three hypotheses are identical to those of (Saha et al. 2010; Ries and Ozdemir 2010; Furkan et al. 2012; Al-Alawi 2017; Ishaq 2018; Ali 2019). These studies measured the effect of an independent variable (i.e. using the GeoGebra program) on a variety of dependent variables such as visual thinking skills, mathematical communication skills in geometry, geometry anxiety reduction, and achievement. The results of all these studies reflected the superiority of the experimental group over the control group.

The results of the pre-test revealed that both groups were equivalent in their level of achievement regarding the topics to be addressed and assessed (polar coordinates and complex numbers). Any change in the dependent variable (achievement) is therefore a result of the processes developed in the independent variable, i.e., the use of a GeoGebra Programme to teach the experimental group and a traditional method to teach the control group.

The results of the three hypotheses on achievement at the level of application and analysis when using the GeoGebra program demonstrated the superiority of the experimental group students over their peers in the control group. This is because in the traditional approach, the board and pens are used by the teacher to explain and solve the exercises in the textbook without using any strategy or technology in the teaching.

Table 8 Wilcoxon test results to determine the significance of the difference between the pre and post measurements for the experimental group

Group	Count	Arithmetic Average	Standard Deviation	Ranks Average	Differences		Wilcoxon (Z)	Significance Level
Pre	30	4.6667	1.98847	7.83	Negative	6	−3.564	.000
Post	30	7.6000	2.71141	16.32	Positive	22		

Table 9 Mann Whitney U test results to determine the significance of the difference between the experimental and control groups in the post measurement

Group	Count	Arithmetic Average	Standard Deviation	Ranks Average	Mann-Whitney U	Significance Level
Control	30	5.3667	2.56614	22.97	224.000	.001
Experimental	30	7.6000	2.71141	38.03		

With regard to the experimental group, the teacher used the GeoGebra program on her tablet that connected to the data show, by explaining and drawing the polar coordinates directly on the program in a clear way, and then the students practicing what they learned by using their tablets, the exercises book and other exercises from the Qiyas Center of the Ministry of Education.

As we know that the polar coordinates is critical to the study of calculus and complex numbers, and many researchers such as (Montiel et al. 2008; Montiel et al. 2009; Sayre and Wittman 2007; Paoletti et al. 2013) indicates students hold limiting understandings of the polar coordinates. Some students their issues stem from problematic connections with the Cartesian coordinate system (CCS), because students' understandings of the polar coordinates are often tied to their activity within the Cartesian coordinate system (CCS). Therefore, we need as teachers to use GeoGebra in our mathematics classrooms, because as we found in this study that GeoGebra facilitated the process of describing complex regions in the plan, and this is consistent with Alves (2014).

In regard to the complex numbers, as we see that the results of the initial survey interviews showed that seven teachers of ten follow the traditional teaching method. Actually, although the traditional method is frequently employed by teachers in Saudi Arabia, mathematics education specialists do not recommend that it be used. Such a teaching approach is completely insufficient when performed in isolation due to the fact that it does not build the mind's eye or increase the motivation of students to learn the subject. It also does not assist students with understanding how to multiply and divide complex numbers. This is consistent the Common Core State Standards who do not recommend the traditional approach (Chavez 2014). Therefore, we can see from the results in this current study that the superiority of the experimental group students over their peers in the control group.

Some students try to mix the ideas from algebra, geometry and trigonometry and being unaware of the origin and usefulness of complex numbers. In addition, when the teacher started to teach the complex numbers, we think that the first thing the students will come across where the power of their mathematical training will exceed the power of their imagination, and this is consistent with Egan (2008) who wrote an interesting online article regarding the teaching of complex numbers, he mentioned that by introducing complex numbers, it is not simply adding on an extra piece to students' prior understanding of arithmetic, it is to show that the prior understanding only gave a one-dimensional picture of a two-dimensional world. Therefore, we need to use technological tools to provide better content, power and efficiency at the time of

Table 10 Wilcoxon test results to determine the significance of the difference between the post and deferred measurements for the control group

Group	Count	Arithmetic Average	Standard Deviation	Ranks Average	Differences		Wilcoxon (Z)	Significance Level
Post	30	5.3667	2.56614	19.00	Negative	18	−2.703	.007
Deferred	30	3.6000	2.14315	8.45	Positive	11		

plotting or manipulating mathematical content, we can find this in GeoGebra, and this is consistent with (Araujo 2007).

Fourth Hypothesis There are no statistically significant differences (0.05) between the average post-test and deferred post-test achievement scores (Survival of Learning Impact) in the control group.

Table 10 reveals a statistically significant difference ($p = 0.007$) between the average academic achievement scores of students within the control group in favor of the post-test. This means that the traditional teaching method made a difference in terms of academic achievement, but not in favor of deferred achievement.

Fifth Hypothesis There are no statistically significant differences (at a significance level of 0.05) between the average post-test and deferred post-test achievement scores (Survival of Learning Impact) of the experimental group.

Table 11 reveals no statistically significant differences ($p = 0.084$) between the average academic achievement scores of students in the experimental group in either the post-test or the deferred test. This means that the use of the GeoGebra program maintained the same level of academic achievement.

Sixth Hypothesis There are no statistically significant differences between the average deferred measurement scores for both control and experimental groups on the academic achievement test.

Table 12 reveals that the value of the significance level of the test was less than 0.05. Thus, the null hypothesis is rejected, which states that there are no statistically significant differences between both groups in terms of deferred measurement. This means that the use of GeoGebra program made a difference in deferred achievement in favor of the experimental group.

Table 11 Wilcoxon test results to determine the significance of the difference between the post and deferred measurements for the experimental group

Group	Count	Arithmetic Average	Standard Deviation	Ranks Average	Differences		Wilcoxon (Z)	Significance Level
Post	30	7.6000	2.71141	10.19	Negative	18	−1.729	.084
Deferred	30	8.5667	2.28463	12.97	Positive	11		

Table 12 Mann Whitney U test results to determine the significance of the difference between the the control and experimental groups in the deferred measurement

Group	Count	Arithmetic Average	Standard Deviation	Ranks Average	Mann-Whitney U	Significance Level
Control	30	3.6000	2.14315	17.68	65.500	.000
Experimental	30	8.5667	2.28463	43.32		

The results of the final three (fourth, fifth and sixth) hypotheses when using the GeoGebra program to teach the (polar coordinates and complex numbers unit are identical to those of Al-Ghamdi (2011) and Abu Thabet (2013).

These studies measured the effect of an independent variable (i.e. using the GeoGebra program) on various dependent variables such as deferred academic achievement. The results of all these studies reflected the superiority of the experimental group over the control group. The results of the current research also show statistically significant differences ($p = 0.007$) between the average achievement scores in the control group in favor of the post-test. This means that the traditional method made a difference in academic achievement; however, this was not in favor of deferred achievement, which indicates poor survival of the learning effect when subjects are taught using traditional methods.

The results also revealed no statistically significant difference ($p = 0.084$) between the average achievement scores in the experimental group on the post-test and deferred test. This means that the use of the GeoGebra program helped maintain learning impact for a longer time. The value of the level of statistical significance of the deferred test for both control and experimental groups was less than 0.05. This means that the use of the GeoGebra program made a difference in deferred achievement in favor of the experimental group.

This indicates that the nature of the GeoGebra program - which is based on providing an interactive visual environment that encompasses equations, coordinates, practical learning, experiment, and discovery - increases academic achievement among students and enabled the learning impact to survive. Consequently, the experimental group outperformed the control group. Therefore, we advise all teachers to use the GeoGebra in the classroom, particularly in the polar coordinates and complex numbers unit. Internationally, we can see that technology is becoming more and more important tool particularly in developed countries. For instance, the International Society for Technology in Education based in the US, documented the fact that the effective integration of technology into teaching and learning was having a positive impact on increasing student achievement through test scores and the acquisition of twenty-first century skills (ISTE 2008). In addition, in an attempt to engage the communities of mathematicians, mathematics educators, and software developers in discussions around the potential of technology for learning and teaching of mathematics, the First North-American GeoGebra conference (GeoGebra-NA2010), held on July 28–29 (Martinovic et al. 2014). This has particular importance due to the fact that GeoGebra has numerous benefits when used in the classroom (e.g. Furner and Marinas 2014; Hohenwarter and Preiner 2007).

6 Summary

This research assessed the effectiveness of using the GeoGebra program in developing academic achievement and ensuring survival of the learning impact of the mathematics among female secondary school students. The key findings were as follows:

1- There were statistically significant differences ($p = 0.019$) between the average achievement scores of the control group in favor of the post-test.
2- There were statistically significant differences ($p = 0.000$) between the average achievement scores of the experimental group in favor of the post-test.
3- The significance level of the test was less than 0.05. Thus, the null hypothesis is rejected as there were statistically significant differences between both groups in terms of post measurement.
4- There were statistically significant differences ($p = 0.007$) between the average achievement scores of the control group in favor of the post-test.
5- There were no statistically significant differences ($p = 0.084$) between the average achievement scores of the experimental group on both the post-test and deferred test.
6- The significance level of the test was less than 0.05. Thus, the null hypothesis is rejected as there were statistically significant differences between both groups in terms of deferred measurement.

7 Recommendations

In view of the findings, the researchers recommend the following:

1- The GeoGebra program must be included in mathematics curricula at various stages of education.
2- The programme should be included in mathematics in general, and in teaching polar coordinates geometry and complex numbers in particular.

8 Suggestions

The researchers suggest conducting further research in the following areas:

1. Conduct similar studies with other school grades to further identify the impact of using GeoGebra to teach the mathematics curriculum.
2. Conduct similar studies to identify the impact of other interactive program, such as Advanced Editing Program and Sketchpad Program, on teaching the mathematics curriculum.
3. Conduct further studies to identify the difficulties and obstacles hindering use of the GeoGebra program in teaching the mathematics curriculum.
4. Conduct a study to identify the effectiveness of the GeoGebra program in improving female students' results on national achievement tests, which are carried out by the National Center for Assessment.

Appendix 1

10

Choose the correct answer (one answer only)

1) The polar form of equation $x^2 + y^2 - 6y = 0$ is: A) $r = 6\sin\theta$ B) $r = 6\cos\theta$ C) $r^2 = 6\sin\theta$ D) $r^2 = 6\cos\theta$	………… (1
2) Write the Cartesian equation $x^2 + y^2 - 2x = 0$ in polarity form: A) $r = 2\sin\theta$ B) $r = \cos 2\theta$ C) $r^2 = 2\sin\theta$ D) $r = 2\cos\theta$	…………(2
3) Write the Cartesian equation $x^2 + y^2 = 5y$ in polarity form: A) $r = \cos 5\theta$ B) $r = \sin 5\theta$ C) $r = 5\cos\theta$ D) $r = 5\sin\theta$	…………(3
4) Write the polar equation $r = 3$ in Cartesian form: A) $x^2 - 9 = 0$ B) $x^2 + y^2 - 9y = 0$ C) $x^2 + y^2 = 9$ D) $xy = 9$	…………(4
5) Write the polar equation $r^2 - 2r\sin\theta = 0$ in Cartesian form: A) $x + y - 2 = 0$ C) $x^2 + y^2 - 2y = 0$ B) $x^2 + y^2 - 2x = 0$ D) $x = 2y$	………… (5
6) The equation $r = 12\sin\theta$ is written in Cartesian form as: A) $y = 12x$ C) $x^2 + y^2 - 12y = 0$ B) $x^2 + y^2 - 12x = 0$ D) $x = 12y$	…………(6
7) Write the polar equation $r = 5$ in Cartesian form: A)$x^2 - y^2 = 25$ B) $x^2 + y^2 = 25$ C)$x = 5$ D) $y = 5$	…………(7
8) What is the polar form of the equation ($x^2 + (y - 2)^2 = 4$: A) $r = \sin\theta$ B) $r = 4\sin\theta$ C) $r = 2\sin\theta$ D) $r = 8\sin\theta$	…………(8
9) Write down the Cartesian equation $(x - 7)^2 + y^2 = 49$ in polar form: A) $r = 14\cos\theta$ B) $r = 14\sin\theta$ C) $r = 7\cos\theta$ D) $r = 7\sin\theta$	…………(9
10) Find a cube root of the number i: A) $\frac{\sqrt{3}}{2} - \frac{1}{2}i$ B) $\frac{-\sqrt{3}}{2} - \frac{1}{2}i$ C) $\frac{\sqrt{3}}{2} + \frac{1}{2}i$ D) $\frac{1}{2} + \frac{\sqrt{3}}{2}i$	………. (10

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