Basic Education Students' Attitudes in the Sultanate of Oman towards Learning Mathematics (Geometry) Using GeoGebra

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Abstract

Background: Developing positive student attitudes towards mathematics is a central goal of contemporary mathematics education, given the well-established link between attitudes and achievement. In the Sultanate of Oman, ongoing curriculum reforms in basic education emphasize active learning, problem solving, and the integration of educational technology in classroom practice. Within this context, dynamic mathematics software such as GeoGebra offers promising opportunities to make geometry more visual, interactive, and meaningful for learners.

Purpose: This study aimed to investigate Grade Ten basic education students' attitudes towards learning geometry using GeoGebra and to examine the relationship between these attitudes and students' achievement in circle geometry.

Methods: The study employed a descriptive–correlational design embedded within a broader quasi-experimental study. The sample consisted of Grade Ten female students enrolled in basic education schools in the Sultanate of Oman. An attitudes towards learning geometry with GeoGebra scale was developed and validated, and administered after a GeoGebra-based instructional unit on circle geometry. Students' achievement was measured using a researcher-developed test focusing on conceptual understanding and problem solving in circle geometry. Descriptive statistics, reliability analysis, and correlation coefficients were used to analyze the data.

Results: Findings indicated that students held generally positive attitudes towards learning geometry with GeoGebra across affective, cognitive, and behavioral dimensions. Students reported increased enjoyment, perceived usefulness, and confidence when working with geometric constructions and problems in the GeoGebra environment. The analysis also revealed a strong positive association between students' attitudes and their achievement scores in circle geometry, suggesting that more favorable attitudes are linked to higher performance.

Conclusion: The results support the integration of GeoGebra as an effective tool for enhancing Omani students' attitudes towards learning geometry and for supporting better learning outcomes in basic education. The study recommends ongoing professional development for mathematics teachers in the pedagogically sound use of GeoGebra, as well as further research on attitudes in different mathematical domains and grade levels.

Keywords:

GeoGebra; attitudes towards mathematics; geometry education; basic education; circle geometry; Oman.

الملخص

الخلفية: تُعدّ تنمية الاتجاهات الإيجابية نحو تعلّم الرياضيات هدفًا محوريًّا في تعليم الرياضيات المعاصر، نظرًا لارتباطها الوثيق بالتحصيل الدراسي والاستمرارية في تعلّم المادة. وفي سلطنة عُمان تشهد مناهج التعليم الأساسي تطويرًا مستمرًّا يركّز على التعلّم النشط، وحل المشكلات، وتوظيف التقنيات التعليمية داخل الصف. وفي هذا الإطار يوفّر برنامج جيوجبرا بوصفه برنامجًا ديناميكيًّا للرياضيات فرصة واعدة لجعل تعلّم الهندسة أكثر تفاعلية وبصرية وارتباطًا بخبرات الطلبة.

الهدف: هدفت هذه الدراسة إلى الكشف عن اتجاهات طالبات الصف العاشر في مرحلة التعليم الأساسي في سلطنة عُمان نحو تعلّم الهندسة باستخدام برنامج جيوجبرا، وإلى فحص العلاقة بين هذه الاتجاهات والتحصيل الدراسي في موضوع هندسة الدوائر.

المنهجية: اتّبعت الدراسة منهجًا وصفيًّا ارتباطيًّا في إطار تصميم شبه تجريبي أوسع. تألفت العينة من طالبات صف عاشر في مدارس التعليم الأساسي الحكومية. طوّر الباحث مقياسًا لقياس الاتجاهات نحو تعلّم الهندسة باستخدام جيوجبرا، جرى التحقّق من صدقه وثباته، وطُبِّق بعد انتهاء تدريس وحدة "هندسة الدوائر" في بيئة تعتمد على جيوجبرا. كما تم قياس التحصيل الدراسي من خلال اختبار تحصيلي بنائي في مفاهيم هندسة الدوائر وحلّ مشكلاتها. استُخدمت الإحصاءات الوصفية وتحليل الثبات ومعاملات الارتباط لتحليل البيانات.

النتائج: أظهرت النتائج أن لدى الطالبات اتجاهات إيجابية عمومًا نحو تعلّم الهندسة بواسطة جيوجبرا على المستويات الوجدانية والمعرفية والسلوكية، حيث عبّرن عن قدر أكبر من المتعة، والإحساس بالفائدة، والثقة عند التعامل مع الأشكال الهندسية وحلّ المسائل داخل بيئة البرنامج. كما بيّنت النتائج وجود ارتباط إيجابي قوي بين درجة الاتجاهات ودرجات التحصيل في هندسة الدوائر، بما يشير إلى أن الاتجاهات الأكثر إيجابية تقترن بتحصيل أعلى.
الخلاصة: تدعم نتائج الدراسة إدماج برنامج جيوجبرا في تدريس الهندسة بوصفه أداة فعّالة لتحسين اتجاهات طلبة التعليم الأساسي في سلطنة عُمان نحو تعلّم الرياضيات ودعم تحصيلهم الدراسي. وتوصي الدراسة بتعزيز برامج التنمية المهنية لمعلّمي الرياضيات حول التوظيف التربوي السليم لجيوجبرا، وإجراء دراسات إضافية حول الاتجاهات في مجالات رياضية مختلفة وفي صفوف دراسية أخرى.
الكلمات المفتاحية: جيوجبرا؛ الاتجاهات نحو الرياضيات؛ تعليم الهندسة؛ التعليم الأساسي؛ هندسة الدوائر؛ سلطنة عُمان.

Introduction

Students' attitudes toward mathematics are widely recognized as a key factor shaping their engagement, persistence, and long-term success in the subject. When learners perceive mathematics as meaningful, enjoyable, and within their reach, they are more likely to participate actively in lessons, invest effort in homework and problem solving, and consider further study in mathematics-related fields. In contrast, negative attitudes are often associated with avoidance, anxiety, superficial learning strategies, and low achievement. This affective dimension becomes particularly important in geometry, where abstract reasoning, spatial visualization, and precise language can pose significant challenges for many students.

Attitude is a complex construct that combines emotions, beliefs, and behavioral tendencies toward a particular object or activity. In the context of learning mathematics, students' attitudes include how much they like the subject, how useful they believe it is for their current and future lives, and how confident they feel when dealing with mathematical tasks. Positive attitudes are not just "nice to have"; they are closely linked to students' willingness to engage with challenging problems, to persevere in the face of difficulty, and to develop deeper conceptual understanding rather than relying on rote memorization.

At the same time, the growing integration of digital technologies in education has opened new possibilities for reshaping students' experiences and attitudes toward mathematics. Dynamic mathematics software such as GeoGebra allows learners to manipulate geometric objects, explore patterns, and visualize relationships in ways that are not possible with static textbooks and traditional board work. In geometry in particular, the ability to drag points, observe how angles and lengths change, and test conjectures interactively can make abstract ideas more concrete and accessible. Many classroom experiences and research findings from different contexts suggest that such tools can increase students' interest, enjoyment, and perceived relevance of mathematics, and can help reduce feelings of fear or boredom associated with the subject.

In the Sultanate of Oman, educational reforms in recent years have been guided by Oman Vision 2040, which emphasizes developing human capital, building a knowledge-based society, and integrating digital technologies into teaching and learning. The vision calls for a high-quality education system that equips students with future-oriented skills, including critical thinking, creativity, and digital competence. Parallel to this, the Ministry of Education has launched initiatives related to digital transformation, such as the introduction of e-learning platforms, smart classrooms, and the use of educational software across subjects, including mathematics.

Despite these ambitious directions and investments, international assessments such as TIMSS have indicated that Omani students' performance in mathematics remains below the international benchmark, with geometry identified as one of the challenging content areas. While achievement data receive substantial attention, less focus has been placed on the affective side of learning: how students feel about mathematics, how they perceive its value, and how technology-supported approaches may influence these attitudes. In particular, there is a shortage of empirical studies in the Omani context that examine students' attitudes toward learning mathematics – especially geometry – using dynamic software such as GeoGebra, even though such tools are increasingly available in schools and are encouraged in teacher training and curriculum development.

The doctoral research from which the present article is derived implemented GeoGebra in teaching the "Circle Geometry" unit to Grade Ten basic education students and included a specific attitude scale to measure students' perceptions and feelings about learning mathematics using GeoGebra. The results showed generally positive attitudes, but these findings have not yet been presented and discussed in a focused, standalone article. There is therefore a need to document and analyze Omani students' attitudes towards GeoGebra-based geometry learning in depth, and to situate these findings within the broader discussion on attitudes toward mathematics and technology-enhanced learning.

Accordingly, this article focuses specifically on basic education students' attitudes in Oman toward learning mathematics (geometry) using GeoGebra. It aims to describe the overall level of these attitudes, explore their cognitive, affective, and behavioral components, and examine whether attitudes differ according to students' levels of academic achievement in mathematics. By doing so, the study seeks to provide evidence that can inform classroom practice, teacher professional development, and policy decisions related to the integration of dynamic software in mathematics education in the Sultanate of Oman.

Problem Statement

Although the Omani education system has invested in curriculum reform and digital transformation, many students still experience mathematics—especially geometry—as difficult and disconnected from real life. International and local reports highlight concerns not only about achievement, but also about students' limited engagement and persistence in mathematics learning. At the same time, dynamic software such as GeoGebra is increasingly available in schools and has been shown in other contexts to support more engaging, visual and exploratory approaches to geometry.

However, the success of such technological interventions ultimately depends on how students perceive and experience them. If students view learning mathematics with GeoGebra as enjoyable, meaningful and supportive of their understanding, they are more likely to embrace it; if they see it as confusing, burdensome, or irrelevant, its potential impact may be greatly reduced. Despite this, there is little empirical evidence from the Omani context concerning students' attitudes toward learning mathematics (geometry) using GeoGebra.

This lack of localized, curriculum-aligned research creates a gap between national policies that promote educational technology and the day-to-day experiences and perceptions of students in Omani classrooms. The present study seeks to address this gap by systematically examining the attitudes of Grade Ten basic education students towards learning geometry with GeoGebra, using data derived from a quasi-experimental implementation of the software in North Al Batinah Governorate.

Research Questions

This study seeks to answer the following questions:

1. What is the overall level of Grade Ten basic education students' attitudes toward learning mathematics (geometry) using GeoGebra?
2. What are the levels of the cognitive, affective, and behavioral components of students' attitudes toward learning mathematics (geometry) using GeoGebra?
3. Are there statistically significant differences in students' attitudes toward learning mathematics (geometry) using GeoGebra according to their level of academic achievement in mathematics?

Research Hypotheses

To answer these questions, the following null hypotheses will be tested:

- **H☐1:** There is no statistically significant difference between the mean total score of students' attitudes toward learning mathematics (geometry) using GeoGebra and the neutral midpoint of the attitude scale.
- **H☐2:** There are no statistically significant differences between the mean scores of the cognitive, affective, and behavioral components of students' attitudes toward learning mathematics (geometry) using GeoGebra.
- **H☐3:** There are no statistically significant differences in students' attitudes toward learning mathematics (geometry) using GeoGebra attributable to their level of academic achievement in mathematics.

Objectives of the Study

The study aims to:

1. Describe the overall level of Grade Ten basic education students' attitudes toward learning mathematics (geometry) using GeoGebra.
2. Examine the levels of the cognitive, affective, and behavioral components of these attitudes.
3. Investigate whether students' attitudes differ according to their academic achievement level in mathematics.
4. Provide empirical evidence that can guide teachers, curriculum developers, and policymakers in effectively integrating GeoGebra into geometry instruction in Oman.

Significance of the Study

This study is significant at several levels:

- At the student level, it sheds light on how learners actually experience and perceive the use of GeoGebra in geometry lessons, going beyond achievement scores to capture their feelings, beliefs, and behavioral intentions.
- At the teacher level, the findings can help mathematics teachers understand whether and how GeoGebra improves students' interest, confidence and willingness to participate, thereby informing decisions about lesson design and classroom practices.

- At the policy and curriculum level, the study provides locally grounded evidence supporting the integration of dynamic software in mathematics education, in line with Oman Vision 2040 and national digital transformation initiatives.
- At the research level, it contributes to the relatively limited body of literature on students' attitudes toward mathematics in Arab contexts, particularly in relation to GeoGebra, and may serve as a reference point for further studies examining the affective impact of technology-enhanced learning.

Definition of Key Terms

1 Attitudes toward Learning Mathematics (Geometry) Using GeoGebra

Theoretical definition. :Attitude is generally defined as a psychological tendency expressed by evaluating a particular entity with some degree of favor or disfavor. In mathematics education, attitudes toward mathematics are often conceptualized as a combination of emotions, beliefs, and values related to mathematics and its learning, including enjoyment, perceived usefulness, and self-confidence.

Operational definition :In this study, *attitudes toward learning mathematics (geometry) using GeoGebra* refer to Grade Ten students' cognitive, affective, and behavioral responses to learning geometry with GeoGebra. These attitudes are measured by a researcher-developed Likert-type scale that captures students' beliefs about the usefulness of GeoGebra, their feelings (e.g., enjoyment, interest, anxiety reduction) when using it, and their behavioral intentions (e.g., willingness to use GeoGebra in future learning).

2 GeoGebra

Theoretical definition :GeoGebra is a free, open-source dynamic mathematics software that integrates geometry, algebra, calculus and statistics in a single interactive environment, allowing users to construct, manipulate, and explore mathematical objects dynamically.

Operational definition:In this study, *GeoGebra* refers to the specific version of the software used by Grade Ten students and their teacher to learn the "Circle Geometry" unit. The software was installed on computers in the school's computer laboratory and used during lessons to support visualizations, constructions, and exploratory activities related to angles, arcs, chords, tangents, and related properties.

3 Mathematics (Geometry) Learning

Theoretical definition :Geometry is a branch of mathematics concerned with the properties and relationships of points, lines, angles, surfaces and solids. In school curricula, it involves conceptual understanding of geometric objects, reasoning about their relationships, and solving problems involving geometric figures.

Operational definition :In this study, *mathematics (geometry) learning* refers specifically to students' engagement with the Grade Ten "Circle Geometry" unit in the Omani basic education curriculum, including lessons on circle elements, angles, chords, tangents, and associated theorems, taught using GeoGebra in the experimental implementation from which the data are drawn.

4 Basic Education Students

Theoretical definition :Basic education typically denotes the compulsory stages of schooling that provide foundational knowledge, skills, and values for all learners within a national system.

Operational definition :In this study, *basic education students* refers to Grade Ten students enrolled in public basic education schools under the supervision of the Ministry of Education in the Sultanate of Oman, in the North Al Batinah Governorate.

5 Academic Achievement in Mathematics

Theoretical definition :Academic achievement is the extent to which a learner has attained intended learning outcomes in a particular subject, typically reflected in performance on standardized or teacher-made assessments.

Operational definition :In the context of this derived article, *academic achievement in mathematics* refers to students' scores on a researcher-developed geometry achievement test for the "Circle Geometry" unit, used to categorize students into different achievement levels when examining differences in their attitudes toward learning mathematics using GeoGebra.

2. Theoretical Framework

Attitudes toward learning mathematics are generally viewed as multidimensional constructs that include cognitive, affective, and behavioral components. The cognitive component reflects students' beliefs and perceptions about mathematics (for example, whether they see it as useful, logical, or excessively difficult). The affective component involves emotions such as enjoyment, interest, anxiety, or boredom. The behavioral component relates to students' tendencies to engage with or avoid mathematical tasks, such as their willingness to participate in class, do homework, or choose mathematics-related courses. This tripartite view of attitudes is widely adopted in social psychology and mathematics education and provides a conceptual basis for measuring students' attitudes toward learning mathematics using specific tools such as GeoGebra.

In mathematics education, attitudes are closely related to students' motivation, self-efficacy, and achievement. Learners who believe that mathematics is meaningful and attainable are more likely to invest effort and to persevere when faced with challenging problems. Conversely, students who perceive mathematics—especially geometry—as abstract, disconnected, or "only for the smart" often develop negative emotions and avoidant behaviors. Geometry, in particular, requires spatial reasoning, visualization and deductive thinking; if these demands are not supported by appropriate teaching methods and representations, students may feel frustrated and lose confidence. Therefore, any attempt to improve students' experiences in geometry should consider not only cognitive outcomes but also their attitudes toward the subject.

Within this broader attitudinal framework, educational technology can be conceptualized as both a mediating tool and a context that shapes students' experiences and emotions. Dynamic mathematics software such as GeoGebra allows learners to construct and manipulate geometric objects, observe how changes in one element affect others, and test conjectures in real time. From a constructivist perspective, these interactive experiences support active knowledge construction: students do not simply receive definitions and theorems but explore relationships, discover patterns, and justify their findings. This can strengthen their cognitive beliefs about mathematics as a meaningful, coherent discipline rather than a set of arbitrary rules.

At the same time, technology can influence the affective component of attitudes. When students work with visual, responsive, and exploratory tools, they often report increased enjoyment, curiosity, and interest. Tasks that might feel tedious on paper can become more engaging when represented dynamically. For some learners, the use of software can also reduce anxiety, because they can experiment and make mistakes in a more private and flexible environment, with immediate visual feedback rather than public correction on the board. These experiences may enhance their sense of competence and control, which in turn supports more positive attitudes.

The behavioral component is also central in technology-rich environments. Students who experience GeoGebra as helpful and accessible may be more willing to use it beyond mandatory lessons—for example, to explore new examples, review concepts, or work on assignments. Their behavioral intentions (such as wanting to use GeoGebra again in future learning) are important indicators of the sustainability of technology integration: if students themselves are inclined to use the tool, the long-term impact is more likely to be positive.

In the Omani context, these theoretical considerations intersect with national aspirations for education. Oman Vision 2040 and related policy documents emphasize digital transformation, learner-centered pedagogy, and the development of higher-order thinking skills. Integrating GeoGebra into geometry lessons can be seen as a concrete expression of these principles at the classroom level. However, the extent to which this integration is successful depends in part on students' attitudes: if they perceive learning geometry with GeoGebra as supportive, enjoyable and worthwhile, the reform goals stand on firmer ground. If, on the contrary, they perceive it as confusing, technically difficult, or irrelevant, the intended benefits may not materialize.

Thus, the theoretical framework for this study combines:

1. A tripartite model of attitudes (cognitive, affective, behavioral).
2. A constructivist and technology-as-tool perspective on mathematics learning.
3. The Omani educational reform context, which positions digital tools like GeoGebra as levers for improving both the quality of learning and students' relationship with mathematics.

Within this framework, students' attitudes toward learning mathematics (geometry) using GeoGebra are not viewed as a simple "like–dislike" measure, but as a nuanced construct that reflects what they think and feel about this mode of learning, and how likely they are to engage with it in meaningful ways.

3. Review of Related Studies

3.1 Studies on Students' Attitudes toward Mathematics and Geometry

A substantial body of research has examined students' attitudes toward mathematics in general, highlighting consistent links between attitudes, motivation, and achievement. Meta-analytic work has shown that more positive attitudes are associated with higher performance in mathematics, and that this relationship is reciprocal: success tends to foster positive attitudes, and positive attitudes support further success. Many studies have also reported that students' attitudes towards mathematics become less positive as they progress through schooling, especially when teaching approaches remain heavily procedural and examination-oriented.

Specific to **geometry**, several studies have documented that students often perceive this branch as abstract, demanding and sometimes disconnected from real life. Difficulties in visualizing three-dimensional relationships, understanding proofs, or connecting algebraic and geometric representations can contribute to negative feelings. Research has suggested that teaching approaches which emphasize memorization of theorems and routine exercises, with limited use of visual and dynamic representations, may reinforce these attitudes. In contrast, more active and exploratory approaches, including the use of manipulatives and dynamic geometry environments, have been associated with improvements in both understanding and attitudes.

3.2 Studies on Attitudes toward Learning Mathematics Using Technology

With the increasing availability of computers, tablets, and educational software, many researchers have investigated how technology-enhanced learning affects students' attitudes toward mathematics. Studies involving graphing calculators, computer algebra systems, and dynamic geometry software generally indicate that technology can have a positive impact on students' enjoyment of mathematics, their perception of its relevance, and their confidence in handling complex tasks—provided that the technology is integrated thoughtfully into pedagogy, rather than used as a superficial add-on.

Dynamic mathematics software such as GeoGebra has received particular attention. Several international studies have reported that students taught geometry or functions using GeoGebra express higher levels of interest and satisfaction compared with peers taught through traditional methods. Students often mention the visual and interactive features, the possibility to experiment freely, and the immediate feedback as reasons for liking the software and feeling more engaged. Some studies also point out that technology can help shift classroom dynamics toward more student-centered, inquiry-based learning, which in turn influences attitudes.

In the Arab context, a number of studies have explored students' attitudes toward technology in mathematics classes, including the use of GeoGebra. These studies, conducted in different countries and at various educational stages, generally report positive attitudes toward learning with dynamic software. Students frequently indicate that such tools make abstract concepts clearer, increase their motivation to participate, and help them overcome fears associated with mathematics. Some research specifically on GeoGebra in geometry units has found that students not only improve their achievement, but also report more favorable feelings toward the subject and greater willingness to explore mathematical ideas independently.

3.3 Studies on Attitudes toward GeoGebra in the Omani and Regional Context

Regionally, a smaller subset of research has focused directly on students' attitudes toward using GeoGebra in school mathematics. These studies typically employ attitude scales with cognitive, affective, and behavioral components, similar to the approach used in the present article. Their findings suggest that when GeoGebra-based instruction is carefully planned and aligned with curriculum goals, students tend to view the software as useful and enjoyable, and many express a desire to continue using it in future learning.

In contexts similar to Oman—both culturally and in terms of curriculum structure—research has highlighted that technology can play a role in reducing the perceived difficulty of geometry, especially when students feel that the dynamic environment allows them to "see" relationships rather than relying solely on symbolic manipulation. Some studies also note that students' initial attitudes toward technology can vary: those with prior positive experiences are often enthusiastic, while others may feel hesitant until they become familiar with the software.

Within Oman itself, the doctoral work underlying this article included a detailed measurement of Grade Ten students' attitudes toward learning mathematics (geometry) using GeoGebra. The findings indicated generally positive attitudes across cognitive, affective, and behavioral dimensions, suggesting that students valued the role of GeoGebra in clarifying concepts, found lessons more interesting, and were willing to use the software again. However, these results were embedded within a broader study that also examined achievement and critical thinking; they have not yet been fully elaborated and discussed as a primary focus.

4. Synthesis and Commentary on Previous Studies

The review of related studies reveals several consistent themes:

1. Attitudes matter: There is broad agreement that students' attitudes toward mathematics are strongly linked to their engagement and achievement, and that negative attitudes can act as a barrier to success, particularly in challenging domains such as geometry.
2. Technology has potential: Research on technology-enhanced mathematics education, including the use of dynamic geometry software like GeoGebra, indicates that well-designed technological interventions can improve students' experiences. Students often report higher interest, perceived usefulness, and confidence when technology is integrated meaningfully into lessons.
3. GeoGebra is promising in geometry: Studies from different countries and some Arab contexts show that GeoGebra can support both cognitive gains (improved understanding and achievement) and affective gains (more positive attitudes toward learning mathematics), especially in geometry units that involve visual and relational thinking.

4. Contextual gaps remain: Despite positive international and regional findings, there is a relative shortage of localized studies in Oman that focus specifically on students' attitudes toward learning mathematics (geometry) using GeoGebra, rather than treating attitudes as a secondary variable alongside achievement. The few available works suggest promising trends, but they do not yet provide a comprehensive picture.

In light of these points, the present study seeks to make several contributions:

- It focuses explicitly and in depth on Grade Ten Omani students' attitudes toward learning geometry with GeoGebra, rather than treating attitudes as an ancillary outcome.
- It adopts a multidimensional view of attitudes (cognitive, affective, behavioral), allowing a more nuanced understanding of how students think and feel about learning with GeoGebra, and how likely they are to continue using it.
- It draws on data generated in the authentic context of implementing GeoGebra in the "Circle Geometry" unit of the national curriculum, thereby providing evidence that is directly relevant to policy and practice in Oman.

By addressing these gaps, the study positions itself as a bridge between broad international research on attitudes and technology in mathematics education and the specific needs and realities of Omani basic education classrooms.

3. Methodology

3.1 Research Design

This study adopts a quasi-experimental design with a descriptive orientation, drawing on data collected from the experimental group of a larger intervention that integrated GeoGebra into the teaching of circle geometry for Grade Ten students in the Sultanate of Oman. The present paper focuses specifically on students' attitudes toward learning mathematics (geometry) using GeoGebra after completing the instructional unit, and on possible differences in attitudes according to their level of academic achievement in circle geometry. The design is therefore both **post-intervention descriptive** (to determine the level and direction of attitudes) and **comparative** (to examine differences in attitudes across achievement levels).

3.2 Population and Sample

The population of the original study comprised all Grade Ten students enrolled in government schools under the Ministry of Education in North Al Batinah Governorate during the first semester of the 2023/2024 academic year, totaling 11,119 students (5,618 males and 5,501 females).

From this population, a purposive sample **of** 272 female students was selected from **four basic education schools**. The sample was distributed equally into two groups:

- **Experimental group:** 136 Grade Ten students in four classes from two schools, who learned the circle geometry unit using GeoGebra according to a teaching plan and teacher guide prepared by the researcher.
- **Control group:** 136 Grade Ten students in four classes from two other schools, who studied the same unit using traditional instructional methods.

For the purposes of this article, the analysis of attitudes is limited to the experimental group (136 students), because only these students experienced learning mathematics (geometry) using GeoGebra and completed the attitude scale.

3.3 Instrument

3.3.1 Attitude Towards Learning Mathematics (Geometry) Using GeoGebra Scale

To measure students' attitudes towards learning mathematics (specifically circle geometry) using GeoGebra, the researcher developed an attitude scale based on the work of Al-Bay (2018), Al-Zahrani (2012), and Atiq (2016) on attitudes toward learning with educational software and GeoGebra.

The scale was designed to capture the **affective component** of students' attitudes toward:

- learning mathematics using GeoGebra,
- learning circle geometry concepts with GeoGebra, and
- their motivation and enjoyment when using the software.

The final version of the scale consisted of:

- **25 items** under a **single dimension** (unidimensional scale),
- **21 positively worded items** and **4 negatively worded items** (items 10, 15, 19, and 23).

A five-point Likert format was used with the following response options:

- **5 = Strongly Agree**
- **4 = Agree**

- 3 = Neutral
- 2 = Disagree
- 1 = Strongly Disagree

For positively worded items, responses were scored from 5 to 1 as listed above. For negatively worded items, scoring was reversed (1 to 5). Thus, the total score on the scale could range from 25 to 125, where higher scores indicate more positive attitudes toward learning mathematics using GeoGebra.

The scale was originally prepared in Arabic, ensuring linguistic appropriateness and cultural relevance to the Omani educational context.

3.4 Validity of the Attitude Scale

Multiple forms of validity evidence were collected to ensure the appropriateness of the attitude scale for Grade Ten students in Oman.

3.4.1 Content and Face Validity

The initial pool of items was drafted after reviewing the theoretical literature on attitudes and technology-enhanced mathematics learning, as well as previous instruments measuring attitudes towards learning with GeoGebra and educational software.

The preliminary version of the scale was then submitted to a panel of experienced judges, including university faculty members and specialist supervisors in mathematics education. They evaluated:

- the relevance of each item to the construct,
- clarity and linguistic accuracy of wording,
- appropriateness of items for Grade Ten students in the Sultanate of Oman, and
- adequacy and clarity of directions and response format.

Based on their feedback, minor modifications were introduced, such as revising item wording and replacing certain terms to better fit students' language (e.g., replacing "subject" with "topics" in one item), while no items were deleted. The scale thus remained at 25 items in its final form.

3.4.2 Internal Consistency (Item–Total Correlations)

To establish construct validity through internal consistency, the scale was piloted with a tryout sample of 76 Grade Ten students from Asma bint Omar Basic Education School, which was not included in the main study sample.

Pearson correlation coefficients were calculated between each item and the total score of the scale. The results showed that:

- all item–total correlations were positive,
- all correlations were statistically significant at $\alpha = 0.05$ or $\alpha = 0.01$,
- the coefficients ranged from 0.24 to 0.75.

These results indicate satisfactory internal consistency and support the construct validity of the scale.
Table 1 below summarizes the main indicators used as evidence of validity.

Table 1:Summary of Validity Evidence for the Attitude Towards Learning Mathematics Using GeoGebra Scale

Aspect	Procedure	Evidence / Result
Content / Face Validity	Expert review by university staff and mathematics supervisors	Minor wording changes; no items deleted; scale judged appropriate for Grade Ten in Oman
Internal Consistency Validity	Item–total Pearson correlations on pilot sample (n = 76)	All correlations positive and significant ($\alpha \leq 0.05$); coefficients ranged from 0.24 to 0.75
Structural Decision	Retained all 25 items as one unidimensional scale	Final scale: 25 items, 21 positive, 4 negative (items 10, 15, 19, 23)

3.5 Reliability of the Attitude Scale

Reliability was examined using two complementary methods on the same pilot sample of 76 Grade Ten students:

1. Internal Consistency (Cronbach's Alpha):
   Cronbach's alpha was calculated using SPSS to estimate the internal consistency of the scale. The coefficient reached 0.93, which is considered a high and acceptable level of reliability for research purposes.
2. Test–Retest Reliability:
   The scale was re-administered to the same 76 students after a two-week interval under similar conditions. The Pearson correlation coefficient between the two administrations was 0.97, indicating very high temporal stability.

These coefficients demonstrate that the attitude scale is highly reliable and suitable for use with the target sample.

Table 2 :Reliability Coefficients for the Attitude Towards Learning Mathematics Using GeoGebra Scale

Reliability Method	Pilot Sample (n)	Coefficient Value	Interpretation
Internal Consistency (α)	76	0.93	High internal consistency; items measure same construct
Test–Retest (Pearson r)	76	0.97	Very high stability over two-week interval

3.6 Procedures

The procedures related to the attitude scale were conducted as part of the broader intervention using GeoGebra to teach the circle geometry unit:

1. Preparation and Training Phase
   - The researcher coordinated with school administrators, mathematics supervisors, and Grade Ten teachers in the four participating schools to explain the aims and requirements of the study.
   - A training program was implemented during September 2023 to equip the experimental-group teachers with the pedagogical and technical skills necessary to use GeoGebra in teaching circle geometry.
2. Implementation of Instruction Using GeoGebra
   - Students in the experimental group studied the circle geometry unit (Cambridge syllabus, Grade Ten) using GeoGebra over approximately 16 class periods during the first semester of the 2023/2024 academic year.
   - Lessons followed a teacher guide and student activities prepared by the researcher, emphasizing dynamic exploration, visualization, and student interaction using GeoGebra.
3. Administration of the Attitude Scale
   - After completing the instructional unit, the attitude scale was administered in paper form to all students in the experimental group (n = 136) during regular mathematics periods.
   - Students were informed that responses would be used strictly for research purposes and would not affect their grades.
   - Completed scales were collected, checked for completeness, and scored according to the scoring scheme described earlier (reverse scoring for negative items).
4. Linking Attitude Scores with Academic Achievement
   - Students' academic achievement in circle geometry was determined using the researcher-developed posttest used in the original quasi-experimental study.
   - For the present paper, students were categorized into achievement levels (e.g., high, medium, low) based on their posttest scores to test differences in attitudes according to academic achievement level, as formulated in the study hypotheses.

3.7 Data Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS). The following procedures were adopted:

1. Descriptive Statistics
   - Means, standard deviations, and frequencies were calculated to describe students' attitudes towards learning mathematics (geometry) using GeoGebra at the item and total scale levels.
   - The overall mean attitude score was compared to the theoretical midpoint of the scale (3.00 on a 5-point Likert scale) to determine whether attitudes were generally positive, neutral, or negative.
2. Inferential Statistics
   - One-sample t-tests were used to test whether the mean attitude scores differ significantly from the neutral midpoint.
   - One-way ANOVA (or equivalent non-parametric tests, where necessary) was employed to examine differences in attitudes according to students' academic achievement level in circle geometry.

- Effect sizes were reported alongside p-values to provide information about the practical significance of any differences detected.

These analyses were aligned with the study questions and hypotheses regarding (a) the overall level of students' attitudes toward learning mathematics (geometry) using GeoGebra and (b) the extent to which such attitudes differ according to academic achievement level.

4. Results

4.1 RQ1: What is the overall level of students' attitudes towards learning mathematics (geometry) using GeoGebra?

To answer this question, the attitude scale towards learning mathematics (circle geometry) using GeoGebra was administered to the experimental group only (n = 136 Grade Ten female students). The instrument consisted of 25 items on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree), with a maximum possible total score of 125.

The analysis showed that students' attitudes were overall positive and high. The general mean of the attitude scale was M = 4.07 (SD = 0.54) on the 5-point scale, corresponding to a high level of positive attitude. This indicates that, on average, students agreed or strongly agreed with the majority of positive statements about learning geometry using GeoGebra.

Table3: Descriptive statistics for overall attitudes towards learning mathematics (circle geometry) using GeoGebra (n = 136)

Variable	N	Mean	SD	Interpretation
Attitude towards learning mathematics (circle geometry) using GeoGebra – item mean (1–5)	136	4.07	0.54	High
Attitude total score (0–125)	136	101.74	13.44	High

(Data derived from the original dissertation analyses of the attitude scale.)

These results suggest that the implementation of GeoGebra in teaching circle geometry was accompanied by a generally favourable affective response among Grade Ten students in the Omani basic education context.

4.2 RQ2: What patterns emerge at the item level in students' attitudes?

To gain a more nuanced understanding of students' attitudes, descriptive statistics were examined at the item level. The means for individual items ranged from 3.62 to 4.37, all within the high or very high range after reversing the negatively worded items.

Some of the highest-rated items were:

- "I feel that learning mathematics using GeoGebra increases my achievement." (M = 4.37, SD = 0.57, very high).
- "Learning by using GeoGebra helps me understand circle geometry theorems." (M = 4.29, SD = 0.92, very high).
- "Using GeoGebra stimulates my motivation to learn mathematics." (M = 4.29, SD = 0.89, very high).

These items highlight the strong perceived usefulness of GeoGebra in enhancing achievement, conceptual understanding, and motivation.

Items reflecting engagement, enjoyment, and cognitive activation also obtained high means:

- "I do not feel bored when learning mathematics using GeoGebra." (M = 3.76, SD = 0.98, high).
- "I enjoy studying mathematics using GeoGebra." (M = 4.16, SD = 0.94, high).
- "Learning mathematics using GeoGebra helps me think and predict results." (M = 4.22, SD = 0.91, very high).

Even the lowest-rated item, which is negatively phrased ("I am afraid of failing when learning mathematics using GeoGebra because it is a new method I am not used to"), had a mean of 3.62 (SD = 0.97) after reverse scoring, still representing a high positive attitude.

Overall, all 25 items reflected positive attitudes with degrees ranging from high to very high, confirming that students welcomed the use of GeoGebra for learning geometry.

4.3 RQ3: What is the relationship between students' attitudes and their academic achievement in circle geometry?

To address this question, Pearson's correlation coefficient was computed between the students' scores on the post-test of academic achievement in circle geometry and their total attitude scores. The analysis was conducted for the experimental group (n = 136).

As shown in the original dissertation, the mean of the achievement test was M = 17.15 (SD = 5.15), while the mean total attitude score was M = 101.74 (SD = 13.44). The correlation between achievement and attitude was:

- $r = 1.00$, $p < .01$ (two-tailed), indicating a perfect positive correlation at the 0.01 significance level.

According to the classification used in the dissertation, a correlation of 1.00 reflects a perfect positive relationship. This means that students who achieved higher scores in the circle geometry post-test also reported more positive attitudes towards learning mathematics using GeoGebra, and vice versa.

Table 4:Correlation between academic achievement and attitudes towards learning mathematics (circle geometry) using GeoGebra (n = 136)

Variable 1	Variable 2	r	p	Interpretation
Achievement in circle geometry	Attitudes towards learning mathematics using GeoGebra	1.00	< .01	Perfect positive relation

5. Discussion

5.1 Overall positive attitudes in the Omani basic education context

The findings demonstrate that Grade Ten students in Omani basic education schools hold highly positive attitudes toward learning mathematics (circle geometry) using GeoGebra. The overall mean of 4.07 (on a 5-point scale) and the consistently high item means indicate that GeoGebra was not perceived as an imposed technological burden; rather, it was received as a supportive, motivating, and enjoyable learning tool.

From a local perspective, these results are encouraging for the ongoing educational reforms in Oman, which emphasise the integration of digital resources to support active learning and higher-order thinking in mathematics. The students' responses suggest that when technology is thoughtfully integrated into the curriculum—aligned with learning objectives, accompanied by teacher guidance, and supported by classroom infrastructure—students are ready and willing to engage with it. This aligns with international literature reporting that dynamic mathematics software such as GeoGebra can enhance students' engagement and attitudes towards mathematics learning (e.g., Arbain & Shukor, 2015; Rajagopal et al., 2015; Zengin et al., 2012).

5.2 Patterns of attitudes: usefulness, motivation, and affective safety

The highest-rated items focused on perceived academic benefits (improved achievement and understanding of circle theorems), increased motivation, and enhanced concentration and prediction of results. Students seemed to see GeoGebra not just as a "nice extra" but as a tool that helps them learn better and succeed. This echoes findings from similar studies where GeoGebra was associated with clearer conceptual understanding and better performance in geometry and other topics (e.g., Saha, 2010; Arbain & Shukor, 2015).

At the same time, items related to enjoyment, reduced boredom, and a sense of autonomy ("I do not feel bored…", "I enjoy studying mathematics using GeoGebra", "I feel independent when I study using GeoGebra") also received high ratings. This combination suggests that GeoGebra contributed both to cognitive engagement (understanding, problem solving) and affective engagement (enjoyment, reduced anxiety, increased confidence).

Interestingly, even items expressing potential concerns about failure or anxiety when using a new learning method had, after reverse scoring, high positive means. This indicates that while some students might initially have been cautious about using a new technology, their overall experience with GeoGebra remained favourable. This may be attributed to the way the intervention was designed: students received explicit training on how to use GeoGebra, they worked through well-structured activities, and they had continuous support from their teachers, which likely reduced the technological barrier and strengthened their sense of competence.

5.3 Attitudes and achievement: a mutually reinforcing relationship

The perfect positive correlation ($r = 1.00$) between achievement in circle geometry and attitudes towards learning with GeoGebra is a striking result. It suggests that, within this sample, students who performed better academically also reported more positive attitudes, and that performance and attitudes moved almost in parallel.

This result can be interpreted in light of the broader literature that views attitudes and achievement as reciprocally related: positive attitudes can increase effort, persistence, and engagement, which in turn can improve achievement; higher achievement can then reinforce positive beliefs and feelings about the subject (e.g., Kinzie, 2000; McLeod, 2013). The current findings are consistent with this theoretical perspective and with previous work showing positive relationships between attitudes and mathematics achievement in technology-rich environments (e.g., Rajagopal et al., 2015; Mthethwa et al., 2020).

In the specific context of this study, the strong association might be explained by how GeoGebra was implemented:

- Lessons were designed so that concept discovery, visualisation, and problem solving took place in the GeoGebra environment, allowing students to see immediate feedback and to adjust their reasoning.
- Collaborative tasks and classroom discussions encouraged students to share strategies, test conjectures, and explain their solutions, which may have fostered both understanding and positive social-emotional experiences.
- Teachers used WhatsApp groups and other communication channels to support students outside class time, further reinforcing both learning and attitudes.

Thus, it is likely that the pedagogical design around GeoGebra, rather than the software alone, created a learning environment in which achievement and attitudes strengthened each other.

6. Recommendations

6.1 Recommendations for educational practice

Based on the results and their interpretation, several recommendations can be proposed for the Omani educational context and similar settings:

1. Institutionalise the use of GeoGebra in Grade Ten geometry
    - The high and very high attitude levels suggest that GeoGebra can be integrated more systematically into the Grade Ten geometry curriculum—especially in units such as circle geometry that benefit from dynamic visualisation.
2. Provide sustained professional development for mathematics teachers
    - Teachers need ongoing training not only on the technical aspects of GeoGebra but also on didactical design: how to structure tasks, guide exploration, manage classroom discussion, and assess learning in technology-rich lessons. This echoes recommendations in the original dissertation to support teachers with targeted professional development.
3. Equip schools with adequate infrastructure
    - For GeoGebra to be effectively implemented, schools should ensure sufficient computers or tablets, reliable internet access when needed, and suitable projection facilities. Dedicated mathematics labs or well-equipped classrooms can help institutionalise technology-enhanced teaching.
4. Encourage student-centred, inquiry-based use of GeoGebra
    - The positive attitudes observed here were associated with activities that required students to explore, conjecture, and justify. Teachers should be encouraged to move beyond demonstration-only uses of GeoGebra and design tasks that promote inquiry and critical thinking.
5. Integrate formative assessment within GeoGebra-based lessons
    - Short quizzes, immediate feedback, and reflective prompts embedded in GeoGebra activities can help maintain motivation, support learning, and further strengthen the link between positive attitudes and achievement.

6.2 Recommendations for future research

To extend and deepen the insights of this study, the following directions for future research are suggested:

1. Broader and more diverse samples
    - Replicate the study with male and mixed-gender samples, different grade levels, and schools from various governorates in Oman to examine whether the pattern of positive attitudes and strong achievement–attitude relationships holds across contexts.
2. Longitudinal studies on attitude stability
    - Conduct longitudinal research that follows students over several units or school terms to examine whether positive attitudes towards GeoGebra are sustained over time and how they evolve as students encounter more advanced mathematical content.
3. Comparative studies of different digital tools
    - Compare GeoGebra with other digital platforms (e.g., learning management systems, other dynamic geometry software) to explore whether similar attitude patterns emerge, and to identify which design features most strongly support positive attitudes and achievement.
4. Qualitative investigations of student experience

- Use interviews, focus groups, and classroom observations to explore why students develop such positive attitudes—capturing their voices regarding what they find enjoyable, challenging, or empowering when learning with GeoGebra.

5. Mediators and moderators of the attitude–achievement relationship
    - Investigate variables such as self-efficacy, prior achievement, teacher practices, and classroom climate as potential mediators or moderators of the relationship between attitudes and achievement in technology-rich mathematics instruction.

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