GEOGEBRA AS A TOOL FOR ENHANCING MATHEMATICAL UNDERSTANDING IN STUDENTS: INCLUSION IN CURRICULUM

By

Yamuna Shri KY

(23PMA024)

Supervisor

Dr. C. Antony Crispin Sweety

Thesis submitted to

Avinashilingam Institute for Home Science and Higher Education for Women Coimbatore – 641 043

In Partial Fulfillment of the Requirements for the Degree of Master of science in Mathematics

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Signature of the Director

28/04/25

Signature of the Supervisor

DECLARATION

I declare that the thesis **"GeoGebra as a Tool for Enhancing Mathematical Understanding in Students: Inclusion in Curriculum"** was submitted by me for the degree of **Master of Science (M. Sc.)** is the record of work carried out during the period from December 2024 to April 2025 under the guidance of **Dr. C. Antony Crispin Sweety., Ph.D., Assistant Professor, Department of Mathematics,** Avinashilingam Institute for Home Science and Higher Education for women, Coimbatore, and has not formed the basis for the award of any Degree, Diploma, Associateship, Fellowship. Titles in this institute or any other University or other similar institution of Higher Learning.

Signature of the Candidate

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ABSTRACT

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This research investigates the effectiveness of using GeoGebra in enhancing the understanding of geometric concepts among Class VII students through a mixed-methods approach. The study involves two groups: a Conventional Group taught using traditional methods and an Experimental Group instructed with GeoGebra-based interventions. A quasi-experimental design is employed, incorporating pre-tests and post-tests to quantitatively assess students' achievement. The mean and standard deviation of test scores are calculated and subjected to hypothesis testing to determine statistical significance.

Alongside the quantitative data, the study incorporates qualitative insights collected through open-ended questions posed to mathematics teachers. This was done to explore their perceptions, experiences, and challenges while integrating GeoGebra into the classroom. Furthermore, a Likert-scale based questionnaire was administered to gather broader feedback on the usefulness and feasibility of using GeoGebra in regular classroom instruction. The reliability of the questionnaire was also calculated to ensure consistency of responses.

The findings indicate a marked improvement in the performance of students in the Experimental Group compared to the Conventional Group. Additionally, the teachers' responses reflect a generally positive attitude toward the use of GeoGebra, highlighting its effectiveness in visualizing geometric concepts and increasing student engagement. However, concerns regarding infrastructure limitations and the need for proper training were also noted. The study concludes that GeoGebra can be a valuable tool in mathematics education when supported with adequate resources and teacher preparedness.

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CHAPTER I

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1.1 INTRODUCTION

Teachers and students have a great potential to enhance the teaching and learning process with the use of information and communication technology (ICT).

Numerous studies indicate that technology has been widely incorporated into the classroom. At the educational level, ICT is an effective tool for both instruction and learning. ICT use is rapidly growing in a number of countries. ICT is thought to be the most important factor in bringing industrialized and emerging countries together. India claims that their objective for NEP 2020 is "Technology Usage and Integration" in order to give students a route to developing India into a globally recognized knowledge economy and digitally empowered society. People who live in remote areas of the country can now access education because of ICT integration. Mathematical literacy is essential to scientific progress. Many kids are afraid of mathematics since it is thought to be the most difficult subject in the world. A few math teaching programs, such as Matlab, GeoGebra, and Mathematica. Many students regarded geometry to be a difficult subject in school. GeoGebra is a much more important mathematics program that illustrates geometric concepts using a figure. It's Free and Open-Source Software (FOSS).

GeoGebra is a free program that anyone can use. It can help pupils improve their mathematical comprehension and was developed with educational goals in mind (Hohenwarter and Printer, 2007). GeoGebra is an open-source program that is gaining popularity worldwide. Teachers can design dynamic learning environments that promote experimentation and discovery learning in their students by allowing them to engage graphically with geometry, algebra, calculus, and statistics. It is an effective teaching tool for math teachers. Geogebra is a dynamic software application for all educational levels that combines geometry, algebra, spreadsheets, statistics, and calculus. It was constructed in 2001 as part of Markus Hohenwarter's master's thesis in mathematics education and computer science at the University of Salzburg in Austria.

GeoGebra is used to help students visualize different figures in order to teach geometry in an easy-to-understand manner. Numerous scholarly studies have found that GeoGebra is an effective teaching tool that improves students' ability to study mathematics at the secondary school level. Many of the topics covered in Basic and Higher Education Mathematics are made

easier by GeoGebra, which also offers engaging learning opportunities. The effectiveness of GeoGebra in comprehending diagrammatic problems has been studied by fewer scholars.

This research examines how well GeoGebra software teaches geometry to students in all categories. It also describes how the pupils advance in geometry. The main finding of this research described the research group's performance. Furthermore, the subject matter and experimental environment are different from those of earlier research. pupils who don't understand the basics of geometry. When using the GeoGebra application, this article can help you better understand geometry concepts.

In addition, a survey was given to instructors regarding the inclusion of GeoGebra instruction in the curriculum.

Using Geogebra:

GeoGebra is a mathematics program that provides six distinct perspectives on mathematical things. The Graphics View, the Algebra View, and the Construction Protocol are the three new views in GeoGebra.

The views in the GeoGebra window, which includes different views of the GeoGebra software, are displayed below the figure. Therefore, the toolbar and standard menu bar are present in the Geogebra window. As we can see, the tool bar in the window's upper right corner contains a variety of construction tools, including point, line, line segment, polygon, angle, and more. With the aid of these resources, we can visually explain geometry ideas to

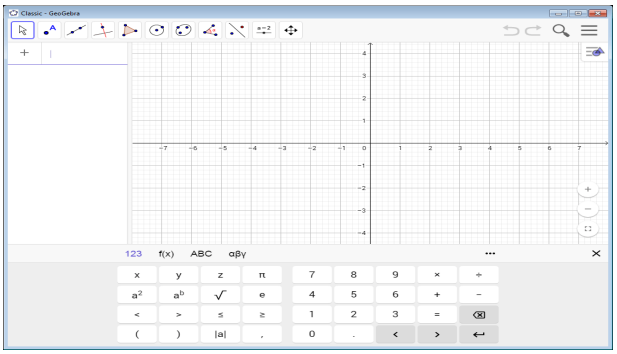


Fig 1.1 Geogebra window

the kids. With the help of this window, students can readily grasp the idea. The figure's equation is displayed in the algebraic perspective, while the graphical view displays.

Significance of the research:

A lot of pupils think that math issues are difficult to solve. Since the pandemic, children's math proficiency has been poor since the majority of them lack a basic understanding of math principles. It has an effect on all students' knowledge and learning, not just those who perform below average. Therefore, math teachers need to be aware of their students' psychology as well as the atmosphere in the classroom. Within the structure of our nation, mathematics is regarded as a necessary subject from grade I to grade X.

The use of ICT is growing in many different fields these days. Researchers, math teachers, students, and policy experts will all benefit from this research's understanding of the technological tools employed in math education. ICT resources at the school level were investigated in this research. Students' performance on all levels (below average, average, and above average) could be improved by using GeoGebra, a free and open-source program, to teach geometry.

The usage of ICT in education is examined in this research. This research will help to motivate teachers and students throughout the teaching and learning process. GeoGebra is used in geometry instruction to help visualize geometrical concepts. When teaching geometry, GeoGebra can help children become more proficient in mathematics, which benefits parents, teachers, and students alike.

This research encourages school administrators to manage dynamic math software, such as GeoGebra. In terms of their professional and career development, other researchers, volunteers, and students all gain a great deal from this research. Additionally, it helps another researcher learn how to utilize the GeoGebra program.

Objective of the research:

This research's main goal is to assess how well GeoGebra helps students with different academic performance levels grasp geometrical ideas. The following goals will be used to accomplish this:

- The process of choosing pupils with varying performance levels (High, Average, and Low achievers).
- Splitting the class into two groups: one that uses GeoGebra for research and the other that uses traditional teaching techniques.

- ➢ Examining how the research group and the traditional group performed differently academically.
- ➢ Evaluating GeoGebra's effects on various student groups.
- ➢ Surveying educators to find out how they feel about adding GeoGebra to the curriculum.

Examination of Hypothesis:

A population-based assumption that may or may not be true is called a hypothesis. Developing a hypothesis aids in establishing the direction of the research and confirming its conclusions.

A Hypothesis for Research:

This research looks at how well students of different academic performance levels learn basic geometrical concepts using the graphical program GeoGebra.

Statistical Hypothesis:

Null Hypothesis (H_0): Students taught GeoGebra and students taught with traditional methods do not significantly vary in their mean scores.

Alternative Hypothesis (H_1): Students who were taught GeoGebra had significantly higher post-test mean scores than students who were taught using traditional methods.

Research questions:

In order to accomplish the goal of this research, the following research questions were developed.

- ➢ In comparison to traditional teaching techniques, how does the use of GeoGebra affect students' comprehension of geometrical concepts?
- ➢ Does the academic achievement of pupils who use GeoGebra to learn geometry differ significantly from that of students who do not?
- ➢ Do students with high, average, and poor performance levels have distinct experiences with GeoGebra's effectiveness?

- ➢ How do educators feel about GeoGebra's inclusion in the curriculum and how do they feel about utilizing it to teach geometry?

Delimitation of the research:

- ➢ The research was carried out in two schools located in the districts of Bharath Vidya Nikkethan and Siwalik school. This research's experimental period lasted one month at two public schools.
- ➢ GeoGebra was used to teach the research group, while the standard technique was used for conventional instruction.
- ➢ The experimental research design served as the foundation for this investigation.
- ➢ This research collected data using a questionnaire, pre-test, and post-test.

Definition:

Conventional Approach: This method of instruction uses chalk, board and a blackboard to teach the material.

Research Group: The set of pupils who received instruction using GeoGebra, a geometry software program.

Conventional Group: Students in the conventional group receive education using the conventional teaching methods.

1.2 LITERATURE REVIEW

A review of the literature directs and aids the researcher in achieving the research's goal. A literature review is a written summary of books, journals, articles, and other materials that explains the current state of knowledge regarding the research's issue. Because there is so much information available, it can be difficult to find quality research study material (Creswell, 2012). As a result, reviewing related literature entails methodically selecting, locating, and assessing material that addresses our selected issue. The research's conceptual framework, theoretical literature, and empirical literature are all represented in this chapter.

Awaji, Bakri Mohammed A (2021) Examining how well pupils' mathematical skills are affected by utilizing GeoGebra software. PhD dissertation, Glasgow University. This research of the literature looked at twenty studies on the use of GeoGebra in secondary mathematics

training spanning a variety of subjects, including geometry, algebra, calculus, and trigonometry. According to 80% of the reviewed research, GeoGebra improved students' interest in and understanding of mathematics, particularly geometry. However, 20% of the research found no appreciable change between the experimental and control groups, indicating that the effectiveness of GeoGebra may depend on how it is used. The assessment emphasizes the importance of effective integration strategies and the need for further research into the applications of GeoGebra beyond geometry.

The impact of GeoGebra software on students' engagement and mathematical achievement is examined in the study "Effectiveness of GeoGebra towards Students' Active Learning, Performance and Interest to Learn Mathematics" by Nzaramyimana et al. (2021), with a focus on exponential and logarithmic functions. The research, which involved 34 Grade 11 students in Rwanda, used an experimental design in which participants used GeoGebra to learn these mathematical concepts over a predetermined amount of time. Group discussions and attitudinal surveys were used in the study to gauge students' opinions and experiences. The results showed that students' enthusiasm in mathematics, active involvement, and comprehension were all greatly improved by the use of GeoGebra. In order to promote self-directed learning and enhance academic results, the authors support the wider integration of GeoGebra into mathematics curriculum.

Aydos (2015) investigated the impact of teaching mathematics with GeoGebra on conceptual understanding. Investigating the effects of teaching limits and continuity concepts in a GeoGebra-supported environment on students' conceptual understanding was the goal of the research. For the research, the researcher chose an experimental and control group. The data were analysed with a t-test on gain score for the control and experimental groups as part of the research design, which also included pre-test and post-test for the examination of the data. Also, the mean, median, and standard deviation were employed by the researcher to analyse the data. The survey also discovered that students' perceptions of studying mathematics through technology have changed. The research's findings suggest that GeoGebra could be a useful teaching and learning tool.

Acharya (2015) research on "Effectiveness of GeoGebra software on mathematics achievement". The report's goal was to assess the relationship between elite perceptions in learning circles using GeoGebra and student accomplishment in mathematics using GeoGebra. Two secondary schools in the Kathmandu district were chosen by the researcher as the

experimental group and control group. Out of 53 pupils from two schools, 28 were in the class experimental group and 25 were in the control group. For one week, the researcher employed the GeoGebra dynamic software programme. Data gathering tools included a questionnaire, a pre-test, and a post-test. For the data analysis, the researcher used the mean, variance, standard deviation, and t-value. According to the study's findings, experimental group students performed better than control group students.

"Effectiveness of GeoGebra towards Students' Active Learning, Performance and Interest to Learn Mathematics" – Nzaramyimana, 2021. This study explores the effectiveness of GeoGebra in enhancing students' active learning, academic performance, and interest in mathematics. The authors reference various previous works that demonstrate how dynamic mathematics software like GeoGebra supports the visualization of abstract concepts, especially in algebra and geometry. The literature cited in the paper emphasizes that traditional teaching methods often fail to engage students, while technological tools have the potential to make learning more interactive and student-centered. Past studies reviewed in the paper have shown that students taught with GeoGebra perform better in problem-solving tasks, demonstrate increased motivation, and actively participate in learning activities. The authors also highlight findings that suggest technology-aided instruction improves conceptual understanding and allows learners to explore mathematical ideas independently. Overall, the reviewed literature supports the claim that GeoGebra promotes active engagement and improves students' attitudes toward mathematics, which aligns with the focus and results of the current study.

Lamichhane (2017) published a thesis on the usefulness of GeoGebra in improving student geometry achievement. The study sought to investigate whether GeoGebra software increased 10th-grade pupils' competency in parallelogram and circle geometry. To solve the problem, the researcher used an experimental design. The researcher chooses two student groups: the experimental group and the control group. The researcher picked 75 students from both schools, 36 for the experimental group and 39 for the control group. The researcher examined and interpreted the data using means, variances, and standard deviations. After reviewing the data, it was discovered that the experimental group outperformed the control group.

The study "perception of students on the use of GeoGebra in geometry teaching" was conducted by Barai (2017). Finding out more about how secondary-level students viewed, engaged with, and were inspired by the use of GeoGebra in geometry education was the aim

of the study. The researcher selected 22 students from class 9 to take part in the study. The researcher used a mixed method for the research design. To gather the data, the researcher used questionnaires, such as Likert-type five-point measures. Mean and standard deviation were utilized to analyze quantitative data, while theme analysis was utilized to analyze qualitative data.

GeoGebra's application in geometric construction was examined by Bist (2017). The study's goals were to compare the academic achievement of students who were taught using GeoGebra versus the traditional method, as well as to look at how students felt about using GeoGebra for geometric building. The researcher selected two public schools to serve as the experimental and control groups. The t-test and standard deviation are used to analyze the collected data, and the researcher was brutally employed. Data was gathered using the questionnaire, pre-test, and post-test. The researcher found that pupils in experimental groups outperformed those in control groups after analyzing the data.

The article "Teacher intention to use GeoGebra in the teaching mathematics among Malaysian teachers" was published in the journal of educational technology by Belgheis and Kamalludeen (2018). A study was conducted to find out what teachers thought about using GeoGebra in math classes. Examined was the intention disparity between male and female educators. Examining instructors' plans to use GeoGebra in math classes based on their current competence levels was the aim of the study.

This study employed quantitative analysis from a cross-sectional survey. Math professors who had participated in a GeoGebra workshop at some point throughout their academic careers made up the 132 participants. An online poll was used to collect the data. A five-point Likart scale (Strongly Disagree, Disagree, Undecided, Agree, Strongly Agree) was used to collect responses. A total of 132 survey responses were counted. There were 76 women and 56 men in attendance. The researcher employed the mean and standard deviation to assess the data. Following that finding, there was no appreciable difference between the intentions of men and women to use GeoGebra in math classes.

In this case, the two most recent reviews showed how well GeoGebra works for teaching and studying math. The results of this study show that GeoGebra aids secondary pupils in understanding the relationship between geometry and different forms. Following an analysis of the data from both experiments, it was concluded that GeoGebra gave students better outcomes than the traditional method.

The effects of GeoGebra in teaching geometry to students in grade IX were studied by Chandramani Bobara in 2019. Finding out how well GeoGebra taught geometry in grade IX was the aim of this study. By comparing the academic achievement of the students who received instruction with and without the use of GeoGebra software, the effectiveness of teaching geometry using this software was evaluated. This study employs an experimental research design and is quantitative in nature. The researcher selected two government schools: one for the control group and one for the experimental groups. There were 27 students in the experimental group and 29 in the control group. Two distinct groups were given the same geometry lecture for a month.Tests before and after The researcher used an experimental design that was not equal. While the experimental group received teaching using the GeoGebra software, the control group received conventional instruction. To collect data for this study, a test of mathematical competency was taken by both groups. A set of questions based on the five-point Likart scale were given to the experimental group in order to determine their feelings on the GeoGebra software. The obtained data were analyzed by comparing the mean, S.D., and t-test using SPSS software.

Numerous researches of the literature show that the experimental group outperformed the control group and that GeoGebra is a helpful learning tool. Both teachers and students have found it to be an effective teaching and learning tool. It fosters an engaging environment for learning. The value of GeoGebra in secondary education has been extensively studied, while the idea of geometry has received less attention. Thus, the impact of GeoGebra on the concept of geometry in the sixth-grade geometry curriculum is the subject of this study.

Theoretical Framework:

Each research is based on a distinct theoretical concept. We have a conceptual basis for the research thanks to learning theories. Both the teacher and the student are involved in the teaching and learning process. There are a variety of learning styles and aptitudes in the classroom. Teaching tactics are based on a variety of learning theories. This work is based on the constructivist approach to learning. Constructivism is an educational philosophy that emphasizes active learning and how students construct their knowledge. It highlights the notion that students actively construct their own knowledge as part of the learning process.

It seems that constructivism distinguishes itself from traditionalism. According to a number of critics, many authors use the term "constructivist teaching" to describe any training

that is concentrated on inclusive inquiry and somewhat "child-centered" (Megraw and Baker, 2007). These findings show that learning is an individual activity that each student does on their own and that during the learning process, each student actively creates information.

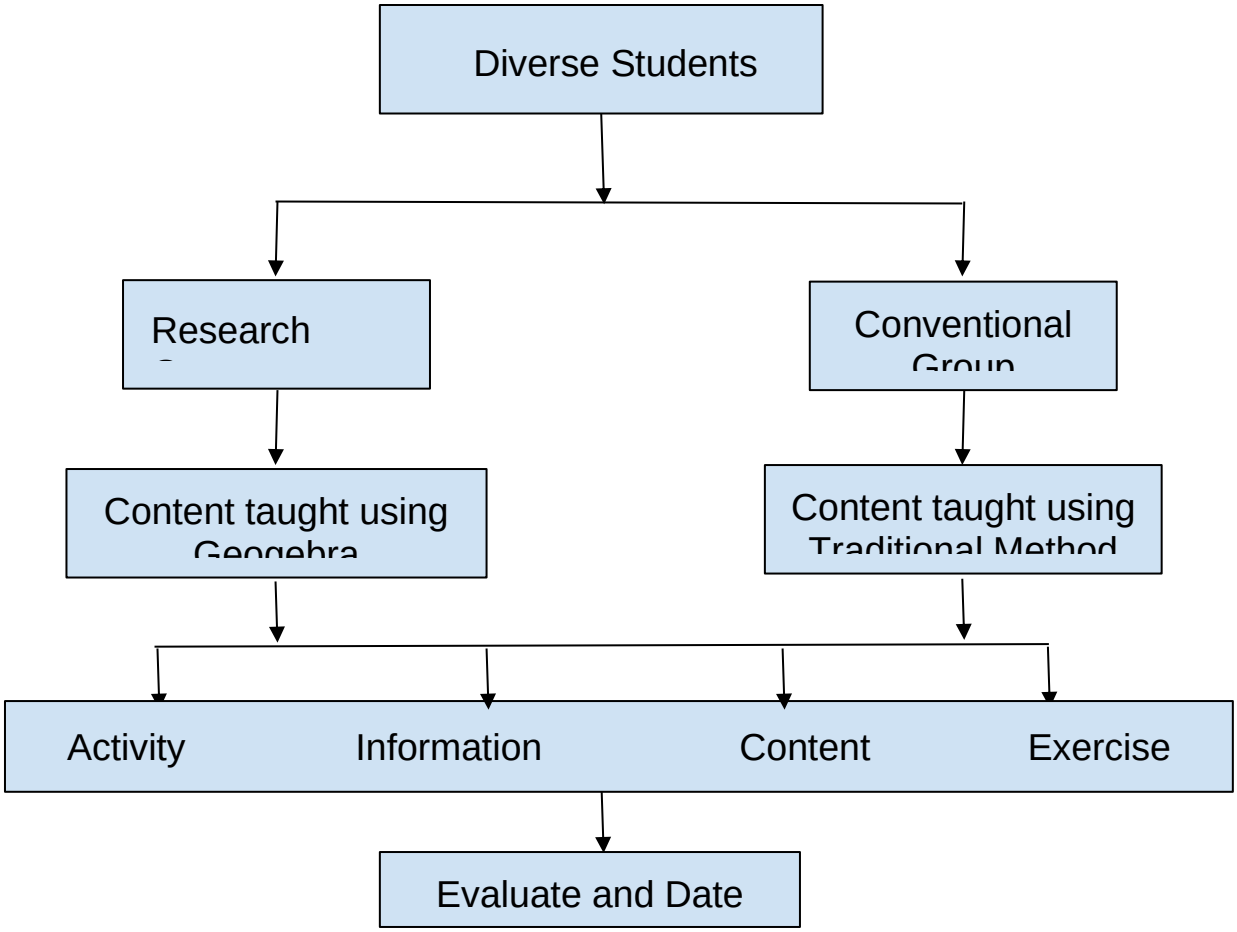
Teachers are motivated by constructivism. Constructivist teachers always push their students to assess how the activity is improving their learning. Students are urged to push themselves and their learning strategies in a constructivist classroom in order to become "expert learners." This has given them access to a greater variety of educational resources. In a well-designed learning environment, the students learn how to learn. It could look like a spiral. As students continue to reflect on their experiences, their thoughts become more complex and potent, and they also improve at incorporating new knowledge. Today, encouraging this process of learning and reflection is the teacher's main duty (Bhattacharjee, 2015).

This claim holds that professors play the function of instructors in the teaching and learning process and that students actively expand their knowledge. According to Glassford (1955), the constructivist approach to education is not widely embraced. As students acquire knowledge, learning never stops. Continuous exposure to the outside world is the foundation of the learning process. This illustrates how students adjust to the topic and the learning environment while actively creating their knowledge during the learning process.

Conceptual Framework:

With the help of a conceptual framework, the researcher can carry out tasks in the area of their selected research. Both the experimental and control groups were part of the researcher's research. The researcher's focus was on the experimental group of students who were instructed using GeoGebra software. The conceptual structure of the research is shown in the following diagram.

Flow chart of the framework



In the conventional group, the students were taught using the standard method; in the research group, they were taught using the software GeoGebra. The researcher presented activities based on a specific issue after examining exercise, content, information, and activity. The researcher was shown a number of visualizing forms related to the course topic in the experimental group. The student was encouraged and offered the opportunity to become a member of an experimental group. Lastly, by administering tests to students in both groups, the researcher investigated how the experimental group felt about using GeoGebra.

Students from two distinct schools were selected for this study, and both traditional and established research groups were formed. The research was taught and the numerous shapes linked to the subject matter were shown using GeoGebra. Instruction was given to the control group in a conventional manner without the use of any ICT instruments. The researcher selected mathematics at the secondary level as the topic, and the same resources were used by both groups.

Additional content was added with consent from the subject instructor and supervisor. The knowledge must be included in any content that helps researchers and subject teachers accomplish learning objectives. The seventh-grade research group assembled the topic-related content using GeoGebra. Based on a specific issue, the researcher concentrated on exercise, information, and action. Both groups took part in a lesson that covered the same material but used different teaching techniques. To evaluate their academic development, the students in both groups subsequently took an achievement test. A poll of teachers about Geogebra's inclusion in the math curriculum was then carried out.

CHAPTER II

CHAPTER II

METHODS AND PROCEDURES

Methodology is the process by which we get the information that directs our research. The methodology and processes used to carry out the research are given in this chapter. Additionally, this chapter includes the research design, sample, tools, data gathering process, and data analysis methodology.

Design of the research:

The three primary categories of research designs are mixed methods, quantitative, and qualitative. We are employing a mixed method research strategy in our study, which blends qualitative and quantitative techniques. This design is appropriate since we are gathering teacher opinions and feedback to learn about their experiences with GeoGebra in addition to comparing the efficacy of two distinct teaching approaches: the experimental group uses GeoGebra, while the conventional group uses the traditional blackboard method.

Two student groups from the same grade level were chosen. Fairness and generalizability are ensured by the wide range of pupils and their varied backgrounds. While the standard group receives instruction using conventional techniques, the experimental group uses GeoGebra software. We give both groups a pre-test before instruction starts to gauge their preliminary comprehension of the chosen subjects. To assess their learning outcomes, we administer a post-test following the instructional session. This makes up our study's quantitative component. The study's mathematical material, which focuses on the idea of the circle, is classified under the field of geometry. Among the subtopics are: Circle components, circles that are concentrated, Go around the points, characteristics of a circle's chords, angles that arcs and chords subtend, tangents, Sectors that are circular

We use Google Forms to gather qualitative information from math teachers in addition to student achievement. Open-ended questions about their degree of comfort with GeoGebra, challenges they encounter, outcomes they see, and recommendations for enhancement are all included in the form. This aids in our comprehension of the advantages and practical difficulties of utilizing GeoGebra from the viewpoint of the teachers.

We aim to determine the overall efficacy of GeoGebra in improving students' comprehension of geometric concepts related to circles and to assess whether it is advantageous

to incorporate GeoGebra into the standard mathematics curriculum by examining both the test results (quantitative data) and the teacher feedback (qualitative data).

Independent and Dependent variable:

In this study, the researchers taught Grade VII students about "Circle and its Properties" using the dynamic mathematics program GeoGebra as the independent variable. The academic performance of the students in the chosen geometry courses and the instructors' opinions about incorporating GeoGebra into the curriculum served as the dependent variables. The research also took into account unrelated factors including class fees, the availability of instructional resources, the school setting, and the involvement of teachers in class.

Sample and Population of the research:

Students in Grade VII with a wide range of math scores make up the group of pupils selected for this research. The researchers chose a small sample of pupils for the study since they were unable to include the entire population due to scheduling restrictions.

Twenty-one pupils from a Coimbatore district school, Pollachi were chosen as the experimental group, and GeoGebra software was used for teaching. 22 pupils from a Coimbatore district school, Pollachiwere chosen to serve as the conventional group, and they were instructed on the same material utilizing the conventional blackboard approach. The identical subject, which includes basic geometry topics, was presented to both groups, with an emphasis on "Circle and its Properties." A total of four math teachers participated in the teaching and data gathering procedure, working with the students in both groups.

Tools and Techniques:

Using a mixed method experimental design, this study collected data using both quantitative and qualitative methods. A questionnaire and an accomplishment exam in mathematics were among the tools.

Based on a quasi-experimental, pre-test–post-test non-equivalent group design, a pre-test and post-test were given to the experimental and conventional groups for the quantitative portion. These assessments were created to assess pupils' proficiency in geometry. The validity of the test items was confirmed by a pilot test, and the mathematics achievement test's reliability was established using the split-half approach.

For the qualitative portion, math teachers were given a questionnaire with open-ended questions to collect their opinions, difficulties, and recommendations about using GeoGebra in the classroom. Teachers' comfort levels and students' opinions of the GeoGebra software were also assessed using a five-point Likert scale.

The quantitative portion of the obtained data was analyzed using SPSS 29.0, while the qualitative replies were interpreted using thematic analysis. This combination made it easier to come to a thorough conclusion about the usefulness and efficacy of integrating GeoGebra into the standard mathematics curriculum.

Achievement Test:

The same question paper was used for the achievement tests of both the experimental and conventional groups. Pilot testing was conducted on both the pre-test and post-test question papers to ensure the quality and appropriateness of the items. The researcher carried out an analysis of the question paper with the assistance of a subject expert. Based on the feedback, necessary adjustments were made, especially to the simpler questions, to ensure suitability for both tests. The mode of instruction was carried out over a one-month period. The experimental group was taught using GeoGebra, while the conventional group was taught using the traditional method. The achievement test was designed to measure learning outcomes after the instructional period.

Validity and reliability:

The reliability of the pre-test and post-test question papers was calculated based on the pilot study. The reliability coefficient (r) was found to be 0.98, indicating a high level of consistency in the test items.

Validity is a crucial factor in determining the quality of the test. It ensures that the test measures what it is intended to measure. The validity of the test was established with the help of subject experts and experienced mathematics teachers, who reviewed the content and structure of the questions to ensure they were appropriate and aligned with the learning objectives.

To ensure the measurement tool's quality, validity is a crucial component. It assists in verifying that the device measures what it is supposed to. The research supervisor approved

the validity of the teacher perception measure in this research, and subject-matter experts also provided input.

The Cronbach's alpha test was performed to assess the questionnaire's reliability. With a reliability coefficient (r) of 0.776, the scale's internal consistency was deemed acceptable. Google Forms was used to disseminate the survey to the participants. SPSS software was used to analyze and interpret the gathered data.

Questionnaire:

Teachers' opinions regarding the inclusion of GeoGebra software in the math curriculum were examined using the questionnaire. Ten items on a five-point Likert scale were included in the study. Two primary themes were used to group the questionnaire's items:

- GeoGebra is a useful program for teaching mathematics, and
- The effect of GeoGebra in raising student achievement.

Before the questionnaire was used to assess instructors' opinions of the GeoGebra software, the study supervisor examined and verified its validity and reliability.

Control Mechanism:

The control mechanism increased the validity of the results by allowing the researcher to keep the research setting consistent and lessen the impact of unrelated variables. The researcher used a quasi-experimental design and mixed method experimental design in this study and made sure that the experimental and conventional groups received the same amount of time, attention, and educational materials.

To evaluate their learning outcomes, the identical pre-test and post-test question sheets were distributed to both groups. To ensure correctness and impartiality, the exam papers were reviewed twice. To prevent instructional bias, the same group of teachers taught each group individually throughout the same instructional hour.

Additionally, both the research group and the conventional group were selected from schools located at a similar distance, ensuring that environmental and infrastructural differences did not affect the research results.

Data Analysis and Interpretation Procedure:

The most important aspect of the research is the analysis and interpretation of data. The tools and techniques used for data collection form the foundation of the analysis process. This research followed a mixed method research design, combining both quantitative and qualitative approaches.

The teaching period lasted for one month for both the experimental and control groups, and the same topic (Geometry – Circles and its properties) was taught to both groups using different methods. A mathematics achievement test was conducted as a pre-test and post-test to assess students' understanding and learning outcomes.

A questionnaire based on a five-point Likert scale (Strongly Agree, Agree, Undecided, Disagree, Strongly Disagree) was used to collect quantitative data on teachers' perceptions regarding the use of GeoGebra in the classroom.

Additionally, open-ended questions were included in the survey to gather qualitative insights from teachers about their comfort level, challenges faced, and suggestions for the effective inclusion of GeoGebra in the curriculum.

To analyze the quantitative data, statistical tools such as mean, standard deviation, and t-test were used. Percentages and frequency counts were also applied to analyze the Likert-scale responses. For the qualitative responses, a thematic analysis was done to identify recurring ideas and opinions. All the data were processed and interpreted using Statistical Package for Social Science(SPSS) version 29.0.

Analysis of Data and Interpretation of Results:

This chapter is a crucial part of the research, focusing on the analysis and interpretation of the data collected. The data were obtained through a mathematics achievement test (pre-test and post-test) and a questionnaire containing both Likert scale items and open-ended questions. This research explores the effectiveness of GeoGebra in teaching Geometry at the Grade VII level.

The main objectives of this research were:

- To compare the academic achievement of students in the experimental group (taught using GeoGebra) and the conventional group (taught using traditional methods)
- To analyze teachers' perceptions regarding the inclusion of GeoGebra in the mathematics curriculum

Two schools were selected from the same district: Pollachi. A mixed method research design was adopted, and a quasi-experimental approach (pre-test/post-test non-equivalent group design) was used.

The researcher began data collection by conducting a pre-test for both groups. The experimental group was taught using GeoGebra software, while the conventional group followed traditional blackboard methods. After one month of instruction, a post-test was administered using the same test paper for both groups.

Additionally, a questionnaire was given to teachers to assess their perceptions, comfort level, difficulties, and suggestions regarding GeoGebra. The questionnaire consisted of Likert scale items and open-ended questions.

The data collected were analyzed and interpreted under the following headings:

- Mean and standard deviation for pre-test scores
- Mean and standard deviation for post-test scores
- Comparison of achievement scores in the pre-test
- Comparison of achievement scores in the post-test
- Teachers' perception toward the inclusion of GeoGebra in the curriculum

The statistical software SPSS version 29.0 was used for data analysis and interpretation. Tabulated data for both groups' pre-test and post-test results, along with interpretation, are presented below.

Conventional Group:

In the achievement test, there were nine items based on the topic "Circles and its properties" taught at the Grade VII level. The test was administered to both the experimental group and the conventional group. The conventional group received instruction through

traditional blackboard methods. The individual scores of students were recorded before and after the intervention. The mean and standard deviation of the pre-test and post-test scores for the conventional group are shown in Table 2.1.

Table 2.1: Mean and Standard Deviation of the Conventional Group

TEST	MEAN	STANDARD DEVIATION
Pre-test	5.19	1.64
Post-test	10.64	1.70

Interpretation of Table 2.1:

The above table shows that the mean score of the conventional group improved from 5.91 in the pre-test to 10.64 in the post-test. The standard deviation values are 1.64 and 1.70 for the pre-test and post-test respectively, indicating a relatively consistent spread in scores. This improvement suggests that even under traditional teaching methods, students showed a moderate increase in understanding of the topic after the instructional period. The sample size for the conventional group is 22 students.

Research Group:

The achievement test, consisting of 10 items totaling 20 marks, was administered to both groups on the topic “Circle and its properties” in Class VII. The same test paper was used for the pre-test and post-test. The research group received instruction using the GeoGebra software as the teaching aid. Individual scores of students in both the pre-test and post-test were recorded. The mean and standard deviation of the pre-test and post-test scores for the research group are shown in Table 2.2.

Table 2.2: Mean and Standard Deviation of the Research Group

TEST	MEAN	STANDARD DEVIATION

Pre-test	5.57	1.84
Post-test	15.00	1.46

Interpretation of Table 2.2:

As shown in the table, the mean score of the research group improved significantly from 5.57 in the pre-test to 15.00 in the post-test. The standard deviation decreased from 1.84 to 1.46, indicating not only a higher performance but also less variability in scores after the use of GeoGebra. This suggests that the GeoGebra-based intervention greatly enhanced students' understanding of geometric concepts related to circles and improved their overall achievement in mathematics. The sample size for the research group is 21 students.

Comparison of Pre-test:

It is the process of comparing the pre-test score of both the groups. Finding the interpretation of pre-test scores of both of the groups. By using hypothesis testing, conclusions about the capabilities of students in pre-test is obtained.

Table 2.3: Pre-Test Comparison of Research and Conventional Groups

Group	Mean Score	Standard Deviation	Sample Size	t-value	p-value
Research Group	5.52	1.03	21	0.080	0.936
Conventional Group	5.50	0.91	22		

Interpretation of Table 2.3:

The values were calculated using SPSS version 29.0. From the hypothesis testing, we can interpret the comparison between the pre-test scores of the research and conventional groups. The mean difference is minimal, and the t-value is 0.080, with a p-value of 0.936, which is greater than 0.05.

Therefore, the null hypothesis (H_0) is accepted at the 0.05 level of significance, indicating that there is no statistically significant difference between the pre-test means of the

two groups. This confirms that both groups had similar levels of understanding before the intervention, making the comparison fair and valid.

Comparison of post-test:

It is the process of comparing the post-test scores of the Research group and conventional group. Through this hypothesis testing is made, to identify the impact of Geogebra on students.

Table 2.4: Post-Test Comparison of Research and Conventional Groups

Group	Mean Score	Standard Deviation	Sample Size	t-value	p-value
Research Group	15.00	1.14	21	12.57	0.0000000000000119
Conventional Group	10.64	1.14	22		

Interpretation of Table 2.4:

The values were analyzed using SPSS version 29.0. This table shows the comparison of post-test scores between the research group (taught using GeoGebra) and the conventional group (taught using traditional methods). The mean score of the research group is 15.00, while the conventional group's mean is 10.64. The t-value is 12.57, and the p-value is 0.00000000000000119, which is extremely less than 0.05.

Therefore, the null hypothesis (H_0) is rejected at the 0.05 level of significance. This indicates that there is a statistically significant difference between the post-test means of the two groups. Hence, the group taught using GeoGebra software performed significantly better than the group taught using the traditional method. This indicates that GeoGebra-based instruction was more effective than traditional methods in improving student performance.

Teacher's Perception Towards Inclusion of GeoGebra in the Regular Curriculum:

To assess teachers' perceptions regarding the integration of GeoGebra software into the regular mathematics curriculum at the Class VII level, a mixed-method approach was employed. A structured questionnaire based on a five-point Likert scale was designed and distributed to mathematics teachers. The questionnaire contained 30 items, covering various aspects of using GeoGebra in teaching, including its effectiveness, usability, student engagement, and impact on learning outcomes.

The questionnaire was administered to 15 mathematics teachers through Google Forms. Teachers were asked to select the most appropriate response for each statement, ranging from Strongly Agree to Strongly Disagree.The items were designed to reflect both positive and negative aspects of using GeoGebra. Teachers were asked to respond to each statement based on their own experience or perspective. A majority of the items were categorized under "Teaching through GeoGebra is effective," and focused on key aspects such as:

1. Enhancing students' conceptual understanding
2. Improving performance in achievement tests
3. Visualizing and conceptualizing geometry content clearly
4. Creating an interactive and engaging learning environment
5. Increasing student participation and interest in mathematics

Additionally, an open-ended section was provided at the end of the questionnaire, allowing teachers to freely express their opinions, suggestions, or concerns regarding the inclusion of GeoGebra in the regular curriculum.

The responses were collected and analyzed using SPSS Version 29.0. Descriptive statistics such as frequency, percentage, and mean score were used for closed-ended responses. For reliability testing, Cronbach's Alpha was calculated and found to be 0.82, indicating acceptable internal consistency of the questionnaire.

The qualitative data obtained from the open-ended responses were analyzed thematically and incorporated to strengthen the interpretation of teachers' perceptions. The overall findings indicated that a majority of teachers had a favorable attitude towards the integration of GeoGebra, recognizing it as an effective tool for enhancing conceptual understanding and student interest in geometry.

Table 2.5: Questionnaire that shows Geogebra is effective for students learning

Questions	Response for the question				
	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
GeoGebra helps students visualize mathematical concepts effectively	5	6	2	2	-
Teaching with GeoGebra improves students' problem-solving skills	6	6	3	-	-
GeoGebra enhances the understanding of geometric transformations.	8	7	1	-	-
Using GeoGebra makes learning algebra and geometry more engaging.	6	7	2	-	1
GeoGebra is useful for demonstrating real-world applications of mathematics	4	8	1	1	2
GeoGebra should be included in the regular mathematics curriculum.	3	7	1	2	-
GeoGebra helps below-average students improve their mathematical performance	7	8	-	-	-
The interactive nature of GeoGebra encourages active participation in class.	6	8	1	-	-
GeoGebra helps students retain mathematical concepts for a longer time.	6	6	2	1	-
Using GeoGebra in assessments and exams can enhance student performance	6	4	3	2	

Interpretation of table 2.5:

The five questions presented in Table 4.5 reflect the effects of GeoGebra on students' learning from the perspective of teachers. Each item indicates varying levels of agreement and disagreement. The majority of teachers agree that GeoGebra is effective for enhancing student learning. However, there is some hesitation regarding the formal inclusion of GeoGebra in the regular curriculum.

Given below shows that the interpretation of the table through pie chart

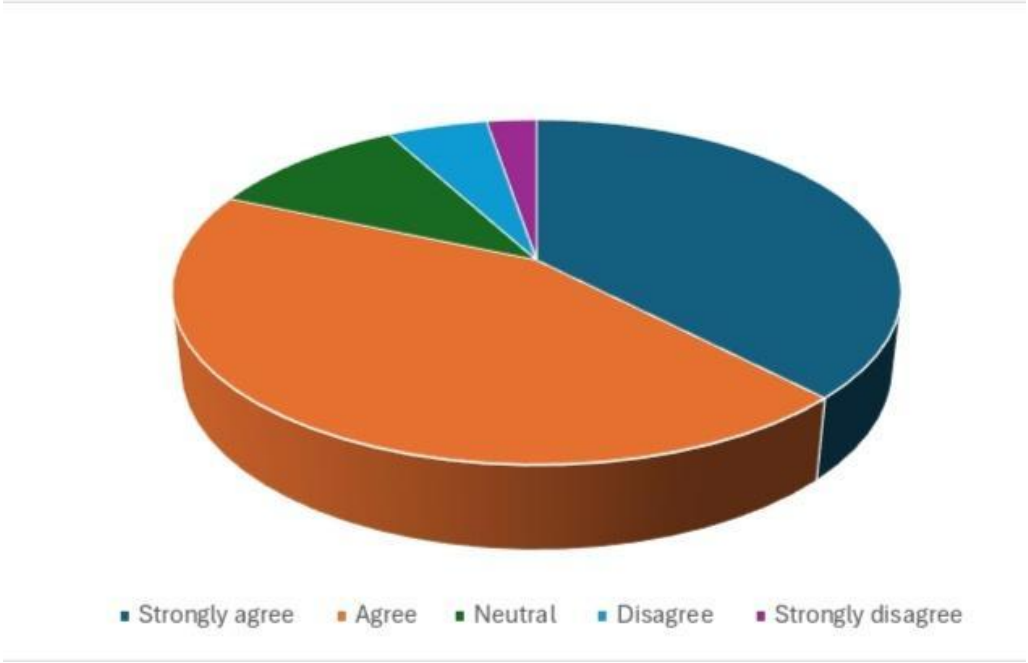


Fig 2.1 Response for Geogebra is effective in students learning

Extended Interpretation of Table 2.5 with Open-ended Responses:

The five-point Likert scale responses suggest that most teachers recognize the positive impact of GeoGebra on student learning—such as improved understanding, better achievement, and increased classroom participation. However, their responses to open-ended questions provided deeper insights.

Some teachers expressed concern about the practical challenges of including GeoGebra in the curriculum, such as:

- Lack of digital infrastructure in rural schools
- Insufficient training for teachers

- Time constraints within the existing syllabus

Others highlighted that while GeoGebra is effective, its use should be gradual and supplementary before making it a mandatory part of the curriculum. These qualitative responses emphasize the need for professional development, technical support, and curriculum restructuring to support digital integration.

Benefits of Teachers While Teaching Geometry Using GeoGebra:

The integration of technology in mathematics education has proven to be an effective approach in enhancing both teaching and learning experiences. As part of this research project, a questionnaire based on a five-point Likert scale was administered to 15 mathematics teachers to assess their perspectives on the use of GeoGebra software while teaching the topic "Circle and its Properties" in Class VII. Along with the Likert scale items, the form included open-ended questions to gather qualitative insights into the teachers' individual experiences and perceived benefits.

Based on the responses collected, several key benefits were identified from the teachers' point of view when using GeoGebra in the classroom:

1. **Ease of Use**:
   Most teachers agreed that GeoGebra is easy to handle and requires minimal technical expertise. The intuitive interface and ready-to-use tools made it convenient for teachers to incorporate the software into their lessons without extensive prior training.

2. **Time Efficiency in Concept Explanation**:
   Teachers reported that using GeoGebra significantly reduced the time required to explain geometrical concepts. The dynamic visualizations allowed students to grasp complex ideas quickly, especially topics involving circles, chords, tangents, and angles.

3. **Increased Confidence in Teaching**:
   The ability to demonstrate geometric constructions and properties interactively boosted teachers' confidence in delivering lessons. Many expressed that GeoGebra helped them clarify abstract concepts more effectively, leading to improved classroom interaction.

4. **Higher Student Engagement and Response Rate**: According to the responses, GeoGebra encouraged greater participation among students. Teachers noted that students were more attentive, curious, and willing to engage with the content when visual and interactive elements were incorporated into the lesson.

These perceived benefits reflect the positive role of GeoGebra as an instructional aid in geometry classes. Teachers viewed it not just as a supportive digital tool but as a transformative element that enhanced both the teaching process and student learning outcomes.

However, despite these advantages, some concerns were raised in the open-ended responses regarding the feasibility of integrating GeoGebra into the regular curriculum. A few teachers mentioned limitations such as lack of training, infrastructure issues in rural schools, and time constraints during syllabus coverage. These insights are important in understanding both the strengths and practical challenges of adopting GeoGebra widely across schools.

In the subsequent table (Table 2.6), the summarized teacher responses are presented in percentage format, based on the Likert scale choices.

Table 2.6: Questionnaire on the Effectiveness of GeoGebra from a Teacher's Perspective

Questions	Response for the question				
	Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
GeoGebra is an effective tool for teaching mathematical concepts.	**7**	**6**	**-**	**1**	**1**
Using GeoGebra in teaching improves student engagement.	**9**	**6**	**1**	**-**	**-**
GeoGebra helps teachers explain abstract concepts more clearly.	**6**	**8**	**1**	**-**	**-**
Inclusion of GeoGebra in the	**5**	**6**	**4**	**-**	**-**

curriculum enhances digital learning.					
GeoGebra is a useful tool for conducting online mathematics education.	**5**	**7**	**3**	**-**	**-**
More students respond positively to GeoGebra-based lessons than traditional teaching.	**6**	**6**	**1**	**1**	**1**
GeoGebra supports differentiated instruction for students with varying abilities.	**5**	**7**	**2**	**-**	**-**
Teaching with GeoGebra is more effective than traditional chalk-and-board methods.	**7**	**5**	**2**	**-**	**-**
As a teacher, I prefer using GeoGebra in my mathematics classes.	**5**	**7**	**1**	**1**	**-**
The use of GeoGebra should be expanded in teacher training programs.	**8**	**5**	**1**	**1**	**-**

Interpretation of Table 2.6:

This summarizes the responses of 15 mathematics teachers regarding the effectiveness of using GeoGebra in teaching geometry, particularly the topic *" Circle and its Properties."* The feedback, collected through a five-point Likert scale, reflects an overall positive perception among teachers.

A majority of teachers agreed or strongly agreed that GeoGebra is an effective tool for teaching mathematical concepts. They found it especially helpful in clarifying abstract ideas and improving student engagement through interactive visualizations.

Teachers also noted that concepts were easier to explain, and GeoGebra helped save instructional time. Many expressed a preference for using GeoGebra over traditional methods

and supported its integration into the curriculum as well as inclusion in teacher training programs.

Although the responses were largely positive, a few teachers raised concerns regarding the lack of training, infrastructure limitations, and the practicality of regular implementation in some school settings. Teachers acknowledged GeoGebra as a valuable instructional aid that enhances both teaching and learning in geometry—provided adequate resources and support are made available.

Given below shows that interpretation of Geogebra through pie chart

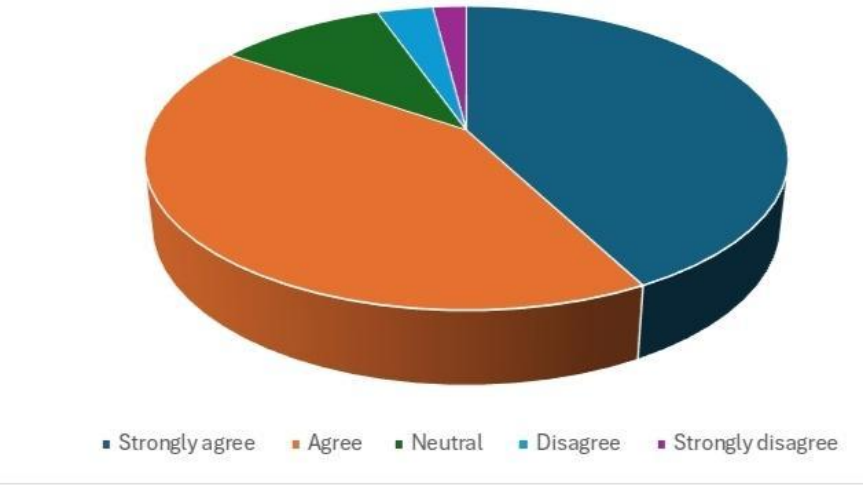


Fig 2.2 Response for Geogebra is effective in teachers perception

Insights from Open-Ended Responses:

In addition to the structured items, teachers provided valuable insights through open-ended questions, offering a richer understanding of their personal experiences, practical challenges, and suggestions. Below is a summary of the common themes that emerged from the qualitative data:

1. **GeoGebra as a Visual Aid**:

   Teachers repeatedly mentioned that GeoGebra enabled them to show rather than tell, making abstract ideas visible. One teacher wrote, " Students who usually struggle with the diagrams were able to understand the properties of a circle instantly

when I animated the construction on Geogebra".

2. **Need for Infrastructure and Support**:
   Several teachers pointed out the lack of resources in government or rural schools. While they appreciated the software, they emphasized the need for projectors, computers, and training sessions to use it effectively.

3. **Positive Change in Student Attitude**:
   Some teachers reported a noticeable shift in student enthusiasm, especially among weaker students. A teacher commented, "One of my emerging students asked to try the construction himself on the smartboard. That never happened before."

4. **Curriculum Integration Concerns**:
   Although many agreed GeoGebra is effective, a few expressed concerns about its formal inclusion in the syllabus, citing time constraints and lack of alignment with existing textbooks.

5. **Professional Growth**:
   A few teachers mentioned that using GeoGebra contributed to their professional development. It allowed them to explore new teaching methods and collaborate with peers during workshops or online forums.

Table 2.7: Summary of Open-Ended Teacher Responses on Using GeoGebra

Question	Common Themes from Responses
1. How comfortable are you with using GeoGebra for teaching geometry?	Most teachers felt comfortable after brief practice; some required initial guidance or tutorials.

2. What are the benefits you observed when using GeoGebra in your classroom?	Quick concept demonstration, better student attention, easy construction of figures, increased clarity of abstract concepts.
3. What challenges or difficulties did you face while using GeoGebra for teaching?	Lack of training, internet dependency, shortage of devices in classrooms, limited time to explore the software fully.
4. How did your students respond to lessons taught using GeoGebra compared to traditional methods?	Students showed more interest and excitement, asked more questions, and understood geometry concepts more easily.
5. Do you think GeoGebra helps improve students' understanding of geometric concepts? Why or why not?	Yes—because it provides visual and interactive tools that help students understand spatial and theoretical ideas better.
6. What suggestions do you have for improving the use of GeoGebra in classroom teaching?	Provide regular training sessions for teachers, install required infrastructure, integrate GeoGebra in syllabus planning.
7. Do you feel GeoGebra should be included in the regular mathematics curriculum? Please justify your answer.	Most teachers supported its inclusion, citing long-term benefits in digital literacy and geometry understanding.
8. What support or training do you think teachers need to effectively use GeoGebra?	Workshops, user manuals, on-call tech support, and regular refresher courses.

Interpretation of Table 2.7:

The responses to the open-ended questions offered deeper insights into the actual classroom experiences of mathematics teachers. Many teachers found GeoGebra to be user-friendly and highly effective, especially for visualizing difficult concepts like circles, chord, tangents, and circle properties. Teachers consistently noted a positive shift in student behavior, including better focus and improved understanding.

However, concerns were raised around lack of training, insufficient digital infrastructure, and the need for structured support for effective classroom implementation. Most teachers supported the inclusion of GeoGebra in the school curriculum, provided that sufficient training and resources were made available.

This qualitative data supports the quantitative findings and strengthens the argument for wider adoption of GeoGebra in teaching geometry.

Given below shows that Open-ended Teachers response of using Geogebra through pie chart

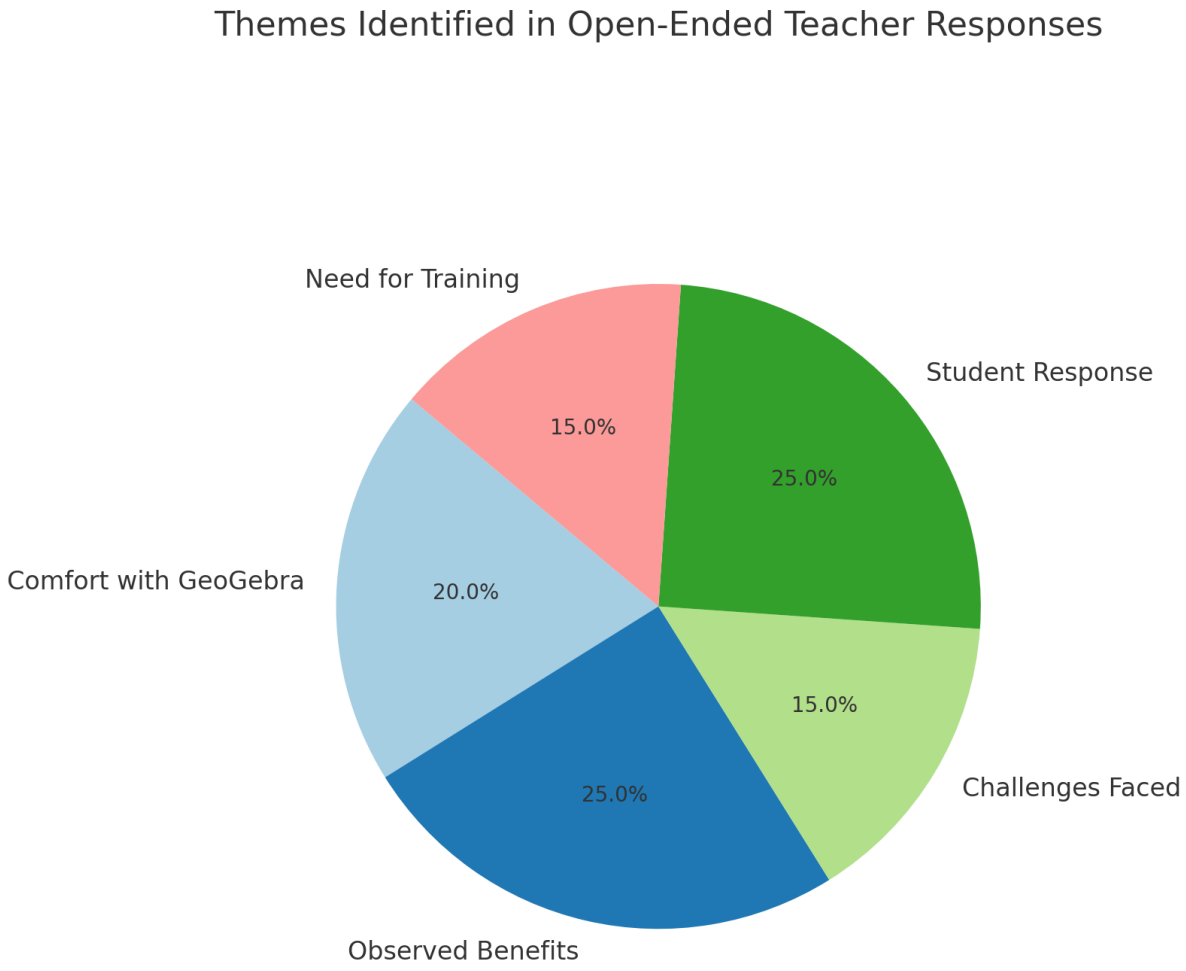


Fig 2.3 Teacher responses to open-ended questions about using GeoGebra

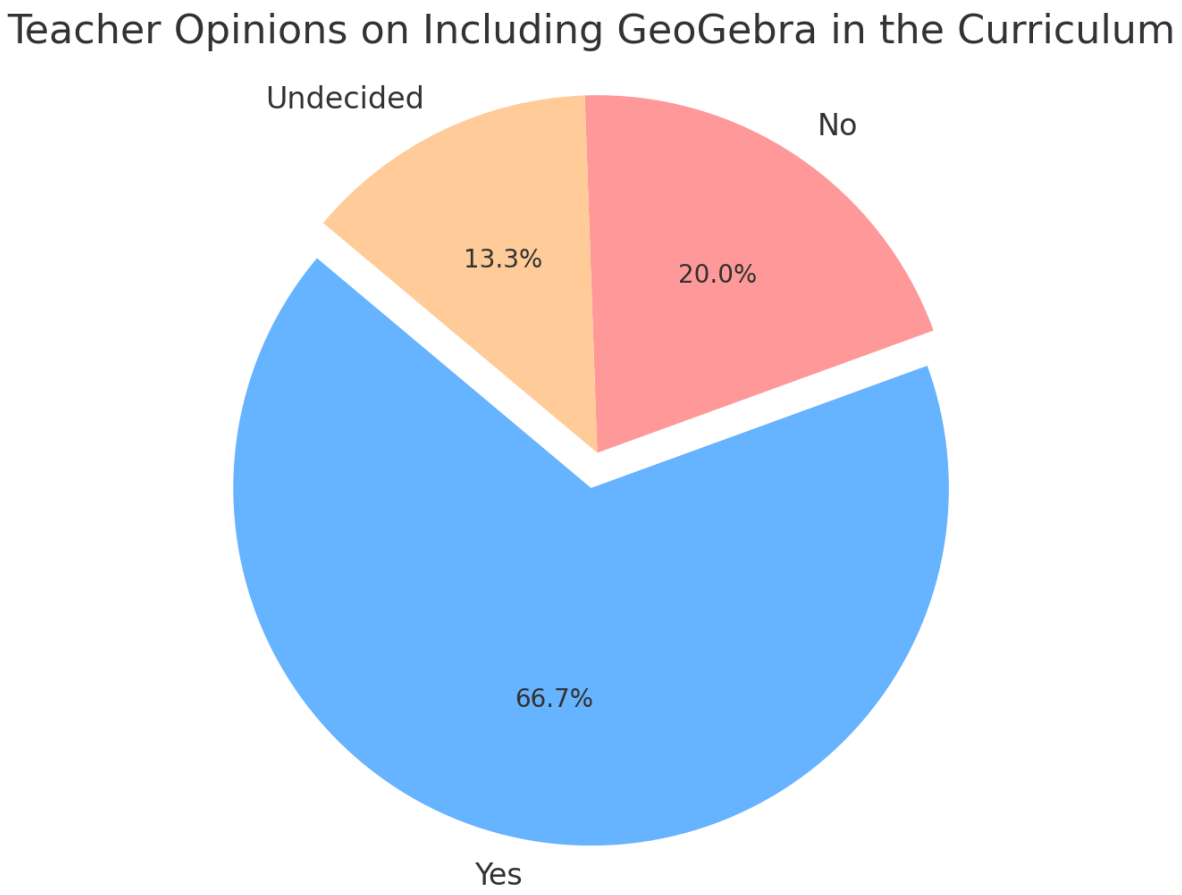


Fig 2.4 Teacher's opinion on including Geogebra in the curriculum

Teacher Opinions on Including GeoGebra in the Curriculum:

The chart above illustrates the distribution of teacher opinions on whether GeoGebra should be included in the regular mathematics curriculum:

- **Yes:** 67%
- **No:** 20%
- **Undecided:** 13%

This visual representation reinforces that a majority of teachers support the inclusion of GeoGebra in the curriculum, while a smaller portion remains undecided or opposed, highlighting the need for further awareness, support, and training.

Teaching using Geogebra is unnecessary for the regular curriculum:

Everything has two sides, like a coin with a useful and useless side, or a positive and negative side. Likewise, Geogebra software has both sides. Formerly, we saw the positive perspective of Geogebra. Now, we will examine the negative side of Geogebra.

The demerits of using Geogebra in regular classes include:

- ➢ Time-consuming preparation for teaching
- ➢ Difficulty completing the syllabus on time
- ➢ Inappropriateness for application in all schools
- ➢ Inability to teach all concepts
- ➢ Lack of proper evaluation
- ➢ More technical issues

These are some of the demerits of using Geogebra. Among these, we can visually see the effects through the results obtained via Geogebra teaching. The table below shows the responses obtained from teachers. Each question has five possible responses: strongly agree, agree, neutral, disagree, and strongly disagree. Each response was recorded and is given below.

Table 2.8: Questionnaire on the Challenges of Using GeoGebra in Teaching

Questions	Response for the question				
	Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
Teaching using GeoGebra is time-consuming.	**3**	**9**	**1**	**2**	**-**
It is difficult to cover the syllabus using GeoGebra	**5**	**4**	**3**	**2**	**-**
GeoGebra is not appropriate for the assessment process	**5**	**6**	**1**	**2**	**1**
It is inappropriate for all schools to use GeoGebra in regular class sessions.	**5**	**10**	**5**	**-**	**-**

GeoGebra is only useful for specific concepts, not all mathematical topics.	**6**	**4**	**3**	**2**	**-**
It is difficult to integrate such software into the school curriculum.	**5**	**7**	**3**	**-**	**-**
As a teacher, I find GeoGebra unsuitable for student evaluation.	**6**	**4**	**2**	**2**	**1**
Students can visualize concepts with GeoGebra but struggle to apply them in notebooks.	**3**	**4**	**6**	**1**	**1**
Not all teachers are comfortable using GeoGebra for daily teaching.	**5**	**7**	**1**	**-**	**2**
Students find it difficult to remember the tool's name and functions.	**4**	**5**	**6**	**-**	**-**

Interpretation of table 2.8:

This shows the negative impact of Geogebra on its inclusion in the regular curriculum. Hence, we can conclude that inclusion of geogebra in regular classes is impossible but the impact of geogebra teaching in students' learning is desirable, so we can use the geogebra as a practical basis for children's conceptual knowledge. Like in the science curriculum we can make the geogebra for student's maths practical.

Given below shows that interpretation of GeoGebra through pie chart

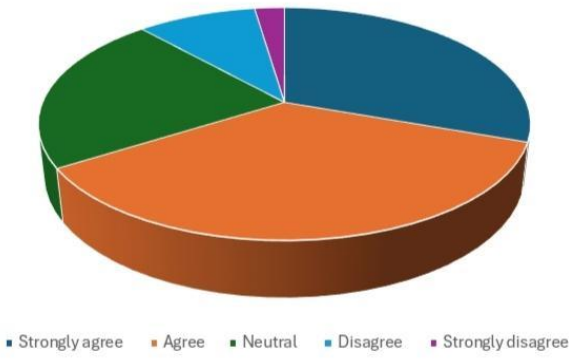


Fig 2.5 Response about negative effects of Geogebra

This chart depicts the negative effects of GeoGebra. All the teachers who responded for the questionnaire can accept the demerits of GeoGebra inclusion in regular math teaching. It can be figured from the chart.

CHAPTER III

CHAPTER III
FINDINGS, CONCLUSION AND IMPLICATION

3.1 Conclusion

This research aimed to investigate the effectiveness of GeoGebra software as an instructional tool in teaching the topic ″Circle and its Properties″ to Class VII students. A quasi-experimental design was employed as part of a mixed methods approach, combining both quantitative and qualitative data to provide a comprehensive understanding of the impact of GeoGebra on teaching and learning geometry.

For the quantitative component, two groups were studied: a research group taught using GeoGebra and a conventional group taught through traditional blackboard methods. An achievement test comprising 10 questions (20 marks) was administered to both groups as a pre-test and post-test using the same question paper. The analysis of test scores revealed that the research group demonstrated significantly higher gains in performance compared to the conventional group.

- The research group's mean score increased from 5.57 to 15.00, with a decrease in standard deviation from 1.84 to 1.46, indicating improved understanding and consistency in performance.

- The conventional group's mean score rose from 5.91 to 10.64, with a slight increase in standard deviation, indicating moderate improvement.

These findings strongly suggest that using GeoGebra positively impacts students' comprehension of geometric concepts, particularly those involving abstract reasoning such as circles, chords, tangents, and angles. GeoGebra enabled students to visualize and manipulate figures dynamically, which enhanced their conceptual clarity and engagement.

The qualitative component involved data collection through teacher questionnaires, including both Likert scale-based items and open-ended questions. A total of 15 mathematics teachers responded to the survey. Their insights provided valuable perspectives on the practical benefits and challenges of using GeoGebra in classroom teaching.

Teachers widely reported the following advantages:

- **Ease of use** due to GeoGebra's intuitive interface.
- **Reduced instructional time** when explaining complex concepts.
- **Increased confidence** in teaching geometry.
- **Higher student engagement**, with students showing greater curiosity and willingness to participate.

Teachers viewed GeoGebra not just as a technological tool but as a transformative pedagogical tool that supports interactive, student-centered learning. However, challenges were also highlighted. These included:

- **Lack of proper training** in using educational software.
- **Limited infrastructure** in rural and under-resourced schools.
- **Time constraints** in completing the prescribed syllabus.

The research concludes that GeoGebra is an effective, innovative, and engaging tool for teaching geometry at the middle school level. When incorporated thoughtfully, it enhances both teaching practices and student learning outcomes. The mixed methods approach helped in capturing both the statistical evidence of learning gains and the personal experiences of teachers, providing a well-rounded understanding of GeoGebra's impact.

3.2 Suggestions

In light of the findings and feedback obtained from both students and teachers, the following suggestions and recommendations are put forward for educators, curriculum planners, and policymakers:

1. **Integration of GeoGebra in the Curriculum**
   GeoGebra should be incorporated into the **school mathematics curriculum**, particularly in units involving geometry and algebra. Topics like circles, angles, transformations, and constructions can be taught more effectively with the use of this dynamic tool.

2. **Teacher Training and Professional Development**
   Adequate training should be provided to teachers through **workshops, online tutorials, and in-service programs**. Training modules should focus not only on how to operate the software but also on pedagogical strategies to integrate it effectively in classroom teaching.

3. **Provision of Digital Infrastructure**
   Schools must be equipped with basic digital infrastructure, including **computers, projectors, smart boards, and reliable internet access** to ensure seamless integration of technology into teaching. Budget allocations and government schemes can support this initiative, especially in under-resourced schools.

4. **Creation of Teaching Resources**
   Interactive **lesson plans, activity sheets, and demo videos** using GeoGebra should be developed and made available for teachers at all levels. Educational boards and mathematics forums can collaborate to build repositories of such resources.

5. **Inclusion in Pre-Service Teacher Education**
   Training in GeoGebra and other educational software should be made a mandatory part of **B.Ed. and teacher education programs**, so that future teachers enter the profession with the necessary technological skills.

6. **Regular Monitoring and Feedback Mechanisms**
   Schools should implement a **feedback system** to assess the effectiveness of GeoGebra in actual classroom settings and gather suggestions from both teachers and students for continuous improvement.

7. **Further Research**
   Future studies can explore the **long-term impact** of GeoGebra-based instruction on learning outcomes, and its **applicability to other mathematical topics** such as trigonometry, algebra, and calculus. Research can also be expanded to **different educational levels**, including primary and secondary education.

3.3 FINDINGS, CONCLUSION AND IMPLICATIONS

This chapter presents the key findings derived from the quantitative (achievement test) and qualitative (teacher survey and open-ended responses) data collected through the mixed methods research design. It also outlines the conclusions drawn from the research, discusses the educational implications, and offers suggestions for further research.

Findings of the Achievement Test:

The core objective of this research was to examine the effectiveness of GeoGebra-based teaching on student achievement in the topic "Circle and its Properties" among Class VII students, mathematical performance. The quasi-experimental design included two schools—one designated as the research group (taught using GeoGebra) and the other as the conventional group (taught using traditional methods).

- The pre-test results showed that the mean achievement score of the research group was 5.14, and that of the conventional group was 5.04, indicating no significant difference in students' prior knowledge between the two groups.

- During the intervention, students in the research group were observed to be more active and participative, as documented through class observation notes and attendance records. The dynamic and visual features of GeoGebra seemed to enhance student interest and involvement.

- The post-test results revealed a clear improvement in the performance of students taught using GeoGebra. The mean score of the research group increased to 7.00, while the conventional group reached only 6.00. This suggests that GeoGebra-based teaching had a positive impact on students' learning outcomes compared to traditional methods.

Findings of the Teacher Survey:

In addition to the achievement test, a Google Form-based survey was conducted among 15 mathematics teachers. It included both Likert-scale and open-ended questions to explore teachers' perspectives on the use of GeoGebra in classroom teaching.

Key findings from the Likert-scale questions:

- A majority of teachers agreed that GeoGebra is an effective and useful tool for teaching geometry and mathematical concepts.

- Teachers reported that GeoGebra improves student engagement, helps in explaining abstract concepts, and should be included in teacher training programs.

- However, when asked about the inclusion of GeoGebra in the regular curriculum, opinions were divided. Some expressed concern about practical limitations, such as a lack of infrastructure, limited access to devices, and insufficient training.

Key findings from the open-ended responses:

- Teachers found GeoGebra easy to handle, time-saving, and effective in boosting student understanding.

- Some challenges mentioned included technical difficulties, internet issues, and the need for dedicated training sessions to use the software more efficiently.

- Several teachers suggested that while GeoGebra is highly beneficial for practical and activity-based learning, it may not be feasible for use on a daily basis in all school environments due to limited resources.

Conclusion:

This mixed methods research concludes that GeoGebra software is an effective ICT tool in enhancing the teaching and learning of geometry at the secondary school level.

From the quantitative analysis (achievement test), it is evident that students taught using GeoGebra showed better performance than those taught using traditional methods. The post-test score of the research group outperformed the conventional group, indicating a positive impact on academic achievement.

From the qualitative analysis (teacher survey), most teachers recognized GeoGebra's ability to visually demonstrate concepts, engage students, and increase teaching efficiency. Despite concerns over infrastructure and curriculum integration, the general consensus favored the use of GeoGebra as a supplementary and practical teaching tool.

Thus, GeoGebra not only enhances students' conceptual understanding but also supports teachers' instructional practices, especially for below-average and average learners who benefit from visual and interactive methods.

Educational Implications:

Based on the study's findings, the following educational implications are proposed:

- GeoGebra should be integrated into teacher training programs, enabling mathematics teachers to effectively incorporate technology in their lessons.
- Curriculum developers should consider including GeoGebra-based activities for topics in geometry to foster visual learning.
- Educational institutions, especially in rural areas, should be equipped with necessary infrastructure (e.g., computers, projectors, internet) to support ICT-based teaching.
- Workshops and continuous professional development opportunities should be provided to help teachers become proficient in using GeoGebra.
- GeoGebra can be a valuable resource in remedial teaching for students struggling with abstract mathematical concepts.

Recommendations for Further Research:

- Future studies could explore the impact of GeoGebra on higher education students or across other mathematical topics such as algebra, calculus, or mensuration.
- A comparative study can be conducted to evaluate the long-term retention of concepts taught through GeoGebra versus traditional methods.

- Researchers can investigate students' perceptions of learning through GeoGebra and how it affects their attitudes toward mathematics.

- Studies can be undertaken to examine teachers' attitudes and readiness toward integrating GeoGebra into daily instruction.

- Further research could focus on developing GeoGebra-based modules for specific curriculum standards to assess their scalability and effectiveness across schools.

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APPENDIX

Appendix -1

Pre-test Question Paper

Part A **4x1=4**

1. Define radius and diameter of a circle.
2. What is a chord of a circle?
3. What are concentric circles?
4. What is the center of a circle?

Part B **3x2=6**

5. Draw a circle and mark the following: center, radius, and a chord.
6. Explain how many diameters can be drawn in a circle.
7. What is the difference between an arc and a chord?

Part C **2x5=10**

8. Explain the properties of a circle with the help of a diagram (parts, radius, diameter, arc, chord, segment).
9. Draw two concentric circles. Take a chord in the bigger circle and show the perpendicular from the center. What can you observe?

Appendix -2

Post-test Question Paper

Part A **4x1=4**

1. Define radius and diameter of a circle.
2. What is a chord of a circle?
3. What are concentric circles?
4. What is the center of a circle?

Part B **3x2=6**

5. Draw a circle and mark the following: center, radius, and a chord.
6. Explain how many diameters can be drawn in a circle.
7. What is the difference between an arc and a chord?

Part C **2x5=10**

8. Explain the properties of a circle with the help of a diagram (parts, radius, diameter, arc, chord, segment).
9. Draw two concentric circles. Take a chord in the bigger circle and show the perpendicular from the center. What can you observe?

Appendix - 3

Reliability of the achievement

Reliability

Scale: All Variables

Case Processing Summary

Cases	N	%
Valid	5	100.0
Excluded	0	0.0
Total	5	100.0

listwise deletion based on all variables in the procedure.

Reliability Statistics:

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.984	.985	2

Item Statistics

	Mean	Std. Deviation	N
TEST	12.80	2.774	5
RETEST	13.20	2.588	5

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
26.00	28.700	5.355	2

Intraclass Correlation Coefficient

	Intraclass Correlation [b]	95% Confidence Interval	F Test with True Value 0
		Lower Bound	Upper Bound
Single Measures	.973[a]	.753	.997
Average Measures	.986[c]	.860	.999

Appendix - 4

Questionnaire

Questions	Response for the question				
	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
GeoGebra helps students visualize mathematical concepts effectively.					
Teaching with GeoGebra improves students' problem-solving skills					
GeoGebra enhances the understanding of geometric transformations.					
Using GeoGebra makes learning algebra and geometry more engaging.					
GeoGebra is useful for demonstrating real-world applications of mathematics.					
GeoGebra should be included in the regular mathematics curriculum.					
GeoGebra helps below-average students improve their mathematical performance.					
The interactive nature of GeoGebra encourages active participation in class.					
GeoGebra helps students retain					

mathematical concepts for a longer time.					
Using GeoGebra in assessments and exams can enhance student performance					
GeoGebra is an effective tool for teaching mathematical concepts.					
Using GeoGebra in teaching improves student engagement.					
GeoGebra helps teachers explain abstract concepts more clearly.					
Inclusion of GeoGebra in the curriculum enhances digital learning.					
GeoGebra is a useful tool for conducting online mathematics education.					
More students respond positively to GeoGebra-based lessons than traditional teaching.					
GeoGebra supports differentiated instruction for students with varying abilities.					
Teaching with GeoGebra is more effective than traditional chalk-and-board methods.					
As a teacher, I prefer using GeoGebra in my mathematics classes.					
The use of GeoGebra should be expanded in teacher training programs.					
Teaching using GeoGebra is time-consuming.					
It is difficult to cover the syllabus					

using GeoGebra					
GeoGebra is not appropriate for the assessment process.					
It is inappropriate for all schools to use GeoGebra in regular class sessions.					
GeoGebra is only useful for specific concepts, not all mathematical topics					
It is difficult to integrate such software into the school curriculum					
As a teacher, I find GeoGebra unsuitable for student evaluation					
Students can visualize concepts with GeoGebra but struggle to apply them in notebooks.					
Not all teachers are comfortable using GeoGebra for daily teaching.					
Students find it difficult to remember the tool's name and functions.					