MS Research Thesis

EFFECTS OF GEOGEBRA SOFTWARE ON ACADEMIC ACHIEVEMENT IN MATHEMATICS AT PRIMARY-LEVEL STUDENTS

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EFFECTS OF GEOGEBRA SOFTWARE ON ACADEMIC ACHIEVEMENT IN MATHEMATICS AT PRIMARY- LEVEL STUDENTS

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AUTHOR'S DECLARATION

It is hereby declared that author of the study has completed the entire requirement for submitting this research work in partial fulfillment for the degree of Teacher Education. This thesis, in its present form, is the author's original work except those acknowledged in the text. The material included in the thesis has not been submitted wholly or partially for the award of any other academic certification than for which it is being presented.

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SUPERVISOR'S CERTIFICATE

The thesis titled "Effects of Geogebra Software on Academic Achievement in Mathematics at Primary-Level Students" submitted by Ms. Shaiqua Siddique Reg. No. 1- FOE/MSTE/F23 is partial fulfilment of the MS degree in Teacher Education has been completed under my/our guidance and supervision. I am satisfied with the quality of the student's research work and allow her to submit this for further processing as per IIUI rules and regulations.

Dr. Muhammad Munir Kayani

Dedication

This research is dedicated to the loving memory of my dear brother, Dr. Muhammad Junaid Siddique (Late), whose inspiration, affection, and guidance continue to light my path. I owe my deepest gratitude to my beloved parents. I am sincerely thankful to my respected supervisor, Dr. Muhammad Munir Kayani, for his valuable guidance, encouragement, and unwavering support throughout this research journey. I also extend my heartfelt appreciation to my teachers for their dedication and wisdom, and to my class fellows for their cooperation, motivation, and friendship that made this academic pursuit a truly memorable experience.

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Abstract

Mathematics at the primary level is essential for developing logical reasoning, problem-solving, and abstract thinking skills. Traditional teaching methods often fail to engage learners or foster deep conceptual understanding. This study investigated the effects of GeoGebra software on the academic achievement and knowledge retention of 5th-grade students at Government Girls Higher Secondary School, Kamra. Two null hypotheses were tested that there is no significant difference in academic achievement between students taught with GeoGebra and those taught with traditional methods, and that there is no significant difference in retention of mathematical knowledge between the two groups. A true experimental design was used with 64 students randomly assigned to experimental and control groups, where the experimental group received GeoGebra-integrated instruction while the control group was taught through conventional methods. Data were collected using a self-developed 50 MCQ-based pre-tests, post-test, and retention test. The results revealed that students taught with GeoGebra achieved significantly higher mean scores in both academic achievement and retention compared to those taught with traditional methods, and statistical analysis confirmed that these differences were highly significant. Consequently, both null hypotheses were rejected. Students in the experimental group demonstrated improved conceptual understanding, consistent performance, and sustained retention, whereas the control group showed minimal, statistically non-significant improvement. The study concludes that GeoGebra software is more effective than traditional methods in enhancing mathematics achievement and long-term retention at the primary level, and it highlights the significance of integrating technology-based instruction to make mathematics learning more interactive, engaging, and equitable. Future recommendations include incorporating GeoGebra into the national curriculum, providing systematic teacher training, ensuring adequate technological infrastructure, and extending research to other grades, subjects, and educational contexts.

Keywords: *Geogebra Software, Mathematics Education, Primary Students, Academic Achievement, Educational Technology*

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CHAPTER 1
INTRODUCTION

Teaching mathematics at the primary level plays a vital role in building students' core skills in logical reasoning. Problem-solving and abstract thinking. Traditionally, this subject has been taught using textbooks, rote memorization and the lecture method, which can sometimes limit student engagement and deep understanding. However, with the rise of educational technology, tools like Geogebra are opening new possibilities for making math more interactive and meaningful. Geogebra is a dynamic software that helps students explore mathematical concepts visually and algebraically, allowing for greater interaction and understanding. This study examines how combining Geogebra with traditional teaching methods affects primary school students' academic performance in mathematics. By comparing the outcomes of student taught through the conventional method with those who used Geogebra alongside their lesson, the research aims to assess the potential of digital tools to enhance math education and support better learning outcomes.

1.1 Background of the Study

Mathematics holds a vital position in the primary school curriculum, as it lays the foundation for critical thinking, logical reasoning, and problem-solving skills. However, many primary-level students struggle to grasp mathematical concepts when taught through traditional methods. These methods primarily based on lectures, textbook exercises, and rote memorization often do not actively engage learners or address their individual learning needs. The integration of educational technology has emerged as a promising approach to enhance teaching and learning outcomes. GeoGebra software is one such tool a free, dynamic, and interactive mathematics application that integrates geometry, algebra, graphing, spreadsheets, and calculus. It offers visual and interactive representations that help make abstract mathematical ideas more concrete and comprehensible, particularly for young learners. GeoGebra enables teachers to demonstrate mathematical concepts in real-time and allows students to explore, manipulate, and visualize mathematical relationships actively. These features can foster deeper conceptual understanding, promote independent learning, and enhance student motivation. Its implementation in mathematics instruction has been linked to increased student engagement and improved academic performance. Although

GeoGebra has been widely adopted in secondary and tertiary education, its use in primary-level classrooms especially in public schools of developing countries remains limited. Contributing factors include insufficient teacher training, lack of technological (Adedoyin & Bello, 2022).

1.2 Problem Statement

Many primary school students struggle with understanding mathematical concepts due to traditional teaching methods, leading to low academic achievement. Interactive digital tools like Geogebra offer a dynamic learning experience, yet their adoption in primary education remains limited. Teachers often rely on conventional methods, which may not effectively develop students' conceptual understanding and problem-solving skills. Students may struggle to grasp key mathematical concepts without integrating visual and interactive tools. This study aims to investigate how Geogebra influences academic achievement in primary-level mathematics.

1.3 Objectives of the Study

The objectives of the study were to:

1. Assess Geogebra software's effects on students' mathematics academic achievement.
2. Evaluate the effect of traditional teaching methods on academic achievement in mathematics at the primary level.
3. Compare the mathematical academic achievement of students using Geogebra software with those using traditional teaching methods.
4. Assess the retention of mathematical knowledge among students taught using Geogebra software compared to traditional methods.

1.4 Hypotheses of the Study

The hypotheses of the study were as follows:

H_{o1}: There is no significant difference in the academic achievement in mathematics between primary-level students taught using Geogebra software and those taught using traditional teaching methods.

H_{o2}: There is no significant difference in the retention of mathematical knowledge between students taught using Geogebra software and those taught through traditional teaching methods.

1.5 Significance of the Study

This study holds significant value for multiple stakeholders in the education sector. For teachers, it offers new teaching strategies and tools, such as the use of GeoGebra software, to make mathematics lessons more engaging, interactive, and effective. For parents and guardians, the anticipated improvement in students' academic performance can serve as motivation to become more actively involved in supporting digital learning at home. For the Ministry of Education, particularly the Punjab School Education Department (PSED), the study's findings can help guide decisions, policy formulation, and funding allocations for technology-based instructional programs. Moreover, the research will provide evidence-based strategies that can be utilized by classroom teachers, head teachers, subject coordinators, and school principals to enhance both teaching methods and student engagement. The results will also offer valuable guidance for School Monitoring Officers (SMOs), curriculum developers, textbook boards, and the National Curriculum Council (NCC) on how to integrate digital tools like GeoGebra into the national curriculum effectively. Ultimately, this research addresses the expectations of parents and the broader educational community who wish to see students achieve stronger results in mathematics through modern, technology-supported learning approaches.

1.6 Delimitations of the Study

Delimitations of the study were as follows:

1. The study was delimited to 5th-grade students of Government Girls Higher Secondary School Kamra**.**
2. It focused only on two chapters from the Punjab Textbook for Grade 5 Mathematics Whole Numbers and Operations and Fractions.

1.7 Operational Definitions

1.7.1 Geogebra Software

Geogebra Software refers to a dynamic mathematics application used in this study to teach selected 5th-grade mathematics topics. It includes features such as interactive geometry, algebra, graphing, and visualization tools that allow students to explore mathematical concepts through digital demonstrations and hands-on manipulation during the intervention sessions.

1.7.2 Traditional Teaching Method

Traditional Teaching Method in this study refers to conventional classroom instruction where the teacher uses chalk and blackboard, textbooks, verbal explanation, and routine exercises without the use of any digital tools software. The method emphasizes direct instruction, rote learning, and repetitive practice.

1.7.3 Primary School Student Academic Achievement

Primary School Student Academic Achievement in this research is defined as the level of 5th-grade students in mathematics, measured through a self-developed MCQ-based achievement test administered before and after the intervention. The scores reflect the students' understanding and mastery of the taught mathematical concepts.

1.8 Theoretical Framework

This study is anchored in well-established educational theories that provide a foundation for understanding how the integration of technology, particularly GeoGebra software, can enhance mathematics learning outcomes at the primary level. The framework draws upon three major theories Constructivist Learning Theory, the Cognitive Theory of Multimedia Learning, and Behaviorist Theory which collectively explain how and why the use of GeoGebra may positively influence students' academic achievement in mathematics.

1.8.1 Constructivist Learning Theory (Piaget, Vygotsky)

Constructivism posits that learners actively construct knowledge through interaction, exploration, and engagement with their environment. Piaget emphasized that children build understanding by manipulating and experimenting with objects, while Vygotsky highlighted the role of social interaction and scaffolding within the Zone of Proximal Development (ZPD). GeoGebra, as a dynamic mathematical tool, aligns with these principles by allowing learners to visualize abstract concepts, manipulate geometric and algebraic objects, and explore mathematical patterns. The software promotes active engagement, critical thinking, and independent discovery, enabling students to move beyond rote memorization toward meaningful learning. Furthermore, the teacher's role as a facilitator providing guidance and support while students explore mathematical relationships reflects Vygotsky's idea of scaffolding, where technology acts as a mediator to help students achieve higher levels of understanding.

1.8.1.1 Cognitive Theory of Multimedia Learning (Mayer)

Mayer's theory asserts that learning is more effective when information is presented through multiple channels verbal, visual, and symbolic because the human mind processes information through dual coding systems. GeoGebra incorporates this principle by offering simultaneous representations of mathematical concepts, such as combining equations (symbolic), graphs (visual), and numerical data (tabular). This multimodal presentation enables students to build stronger cognitive connections, thereby enhancing comprehension and retention. For example, when students manipulate a function graphically and simultaneously observe changes in its algebraic form, they develop deeper conceptual understanding. The integration of multiple representations also reduces cognitive overload by organizing information in ways that are easier to process, which is especially beneficial for primary-level learners who often struggle with abstract mathematical ideas (Mayer, 2021).

1.8.1.2 Behaviorist Theory (Skinner)

Behaviorism emphasizes the role of reinforcement, practice, and feedback in shaping learning outcomes. Geogebra provides immediate, interactive feedback as students manipulate mathematical objects and test hypotheses. Correct responses are reinforced through successful visualizations, while misconceptions are quickly identified and corrected. This immediate feedback loop fosters motivation, sustained engagement, and persistence in problem-solving. By transforming abstract exercises into interactive tasks, GeoGebra aligns with Skinner's principle that learning is strengthened through reinforcement, thus contributing to higher academic achievement (Skinner, 2020).

1.8.2 Application to this Study

Together, these theories provide a comprehensive foundation for this study. Constructivism justifies the focus on student-centered, exploratory learning; the Cognitive Theory of Multimedia Learning explains the role of multiple representations in deepening understanding; and Behaviorism highlights the importance of feedback in reinforcing correct responses and reducing errors. In this research, GeoGebra serves as the independent variable, while students' academic achievement in mathematics represents the dependent variable. The interplay of these theories explains the mechanisms through which technology-enhanced instruction can improve learning outcomes, providing a robust justification for investigating the effect of GeoGebra at the primary school level.By integrating these perspectives, the study not only establishes a strong theoretical foundation but also demonstrates how the use of GeoGebra can bridge the gap between traditional and modern teaching approaches. This framework thus supports the formulation of objectives, research questions, and hypotheses, while offering a clear rationale for adopting GeoGebra as an effective pedagogical tool in primary mathematics education.

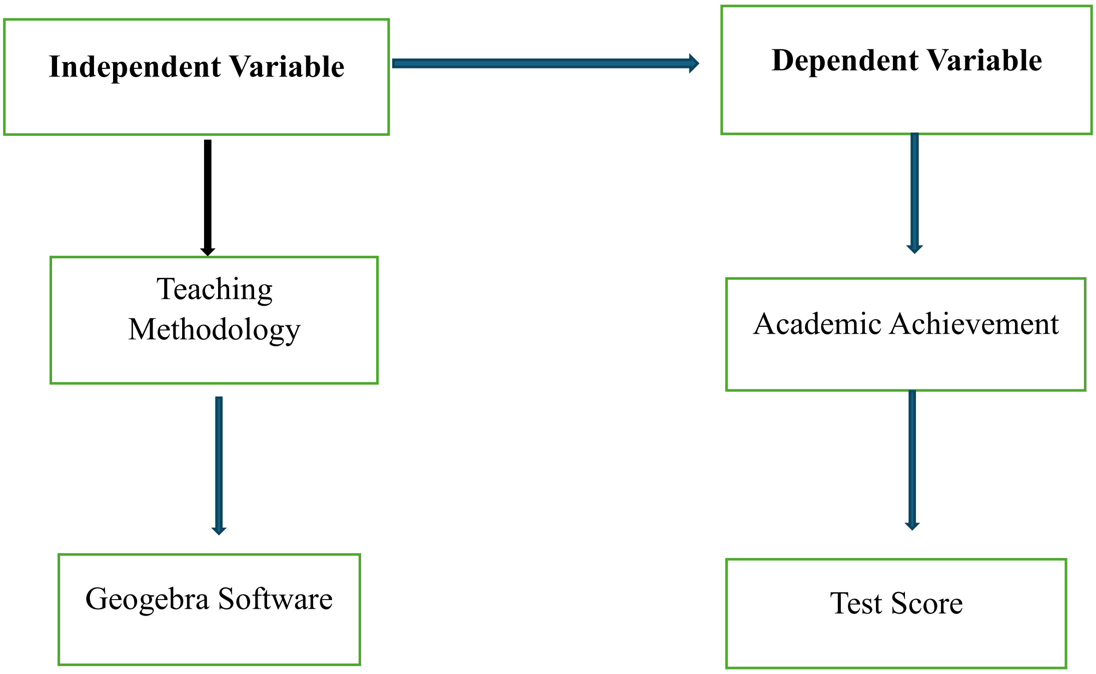
1.9 Conceptual Framework

This study is structured around the relationship between independent and dependent variables. The independent variables include GeoGebra software, methodology, and test scores, while the dependent variable is academic achievement in mathematics among primary-level students. GeoGebra software, as a dynamic mathematical tool, enables students to interact with abstract concepts through visualization and exploration (Hohenwarter & Lavicza, 2007; Kutluca, 2010), fostering deeper understanding in line with constructivist approaches (Piaget, 1972; Vygotsky, 1978).

Teaching methodology is another crucial factor, as the effectiveness of Geogebra depends on how it is integrated traditional methods often limit engagement, whereas innovative approaches promote participation, critical thinking, and conceptual clarity (Dikovic, 2009; Arslan & Ubuz, 2014). Test scores serve as performance indicators, with pretests establishing baseline knowledge and post-tests reflecting the impact of Geogebra and the teaching methodologies on student achievement (Zakaria & Lee, 2012). Together, these independent variables Geogebra software, teaching methodology, and test scores directly influence the dependent variable, academic achievement. Academic achievement, in this context, is defined as the improvement in students' mathematical knowledge, skills, and problem-solving abilities as measured through standardized assessments (Singh et al., 2010; Köller et al., 2001). The framework assumes that the integration of Geogebra software, when effectively applied through an appropriate teaching methodology, leads to improved test scores and, consequently, higher academic achievement. This conceptual framework highlights the interconnectedness of variables: GeoGebra provides the tool, teaching methodology provides the approach, test scores serve as the performance measure, and academic achievement reflects the overall learning outcome.

Figure 1

Conceptual Framework



CHAPTER 2
LITERATURE REVIEW

Teaching mathematics at the primary level is crucial for developing students' logical reasoning, problem-solving, and abstract thinking skills. Traditionally, mathematics has been taught through textbooks, rote memorization, and lecture-based methods, which often limit student engagement and result in only a surface-level understanding of concepts. Many young learners struggle to grasp mathematical ideas when taught this way, as it becomes difficult for them to connect lessons with real-life applications. With the rise of educational technology, dynamic tools such as GeoGebra are transforming math instruction by making it more interactive and meaningful. GeoGebra integrates visual, graphical, and symbolic elements into a user-friendly platform, allowing students to explore mathematical concepts visually and algebraically while receiving immediate feedback. This interactive approach not only deepens understanding but also enhances student motivation and engagement. By combining GeoGebra with traditional teaching practices, this study aims to examine its impact on primary students' academic performance in mathematics, offering insights into how digital tools can enrich classroom instruction, foster deeper conceptual understanding, and improve overall learning outcomes.

2.1 Review of Related Literature

Integrating technology into classroom instruction has become essential for enhancing students' academic performance, particularly in mathematics. Among the various educational technologies, GeoGebra, a dynamic mathematics software, has gained prominence due to its interactive and visual capabilities that support conceptual understanding. This section reviews recent empirical studies from 2023 and 2024 that explore the effect of Geogebra on student academic achievement, specifically at the primary level. Geogebra is widely recognized for combining geometry, algebra, spreadsheets, graphing, statistics, and calculus in a single platform. It allows students to visualize mathematical concepts dynamically, fostering engagement and deeper understanding. According to Ahmad and Khan (2023), incorporating GeoGebra into Grade 5 mathematics classrooms in Pakistan improved performance in fractions and geometry. Their quasi- experimental study found a significant increase in post-test scores of the experimental group compared to the control group taught using traditional methods. The authors attributed this improvement to the interactive features of GeoGebra, which allowed learners to manipulate shapes and observe mathematical relationships in real-time.

Similarly, in a study conducted in Nigeria, Okoro and Okechukwu (2024) reported that primary school students exposed to GeoGebra-based instruction showed enhanced problem-solving skills and better conceptual clarity. The researchers noted that animations and real-time graphical feedback helped bridge the gap between abstract mathematical ideas and practical understanding. In the years of 2024 suggests a positive correlation between using GeoGebra and academic achievement in mathematics. In their experimental study, Li and Zhao (2023) examined the performance of Grade 4 and Grade 5 students in China before and after the integration of GeoGebra. Their findings showed a significant improvement in test scores and increased student motivation and classroom participation. They emphasized that early exposure to mathematical technology tools lays a strong foundation for abstract thinking and analytical reasoning. Another study by Malik and Rahman (2024) in a public-sector school in Punjab, Pakistan, explored how GeoGebra influences students' achievement in number operations. The study revealed that students using GeoGebra outperformed those in the control group on the immediate post-test and a delayed retention test administered two weeks later. These results indicate that GeoGebra effectively promotes short-term academic gains and supports long-term knowledge retention.

One of the main advantages of GeoGebra in primary education is its ability to transform static textbook problems into dynamic visual explorations. This approach caters to various learning styles, especially for younger learners who benefit from multisensory input. According to a mixed-methods study by Singh and Kaur (2023), students reported higher levels of enjoyment and confidence in mathematics after regularly using GeoGebra in class. Teachers also observed improved participation and reduced math anxiety among students. Furthermore, the same study indicated that students developed better spatial visualization and critical thinking abilities. These skills are foundational for mathematical success and align well with 21st-century education goals, such as problem-solving and digital literacy. Additionally, the availability of GeoGebra in multiple languages and its compatibility with low-cost devices make it an accessible option for resource-constrained schools. A qualitative study by Hussain and Fatima (2024) pointed out that while many teachers recognized the potential of GeoGebra, they lacked the technical skills and pedagogical knowledge to implement it successfully. The study recommended regular professional development sessions and curriculum-aligned lesson planning using Geogebra as essential steps for successful integration. Moreover, there is a need for localized content and culturally relevant examples when using digital tools in diverse classrooms. Ensuring equity in access to technology remains a significant concern in developing countries. Nevertheless, the positive outcomes documented in various studies suggest that with adequate support, GeoGebra can be a valuable addition to the mathematics teaching toolkit at the primary level.

2.2 Dynamic Mathematics Software

Geogebra, an innovative Dynamic Mathematics Software (DMS), has gained global recognition as a transformative digital tool that integrates geometry, algebra, statistics, calculus, and other mathematical domains into a single, interactive platform, significantly enhancing the teaching and learning of mathematics. As a DMS, Geogebra offers dynamic visualizations that allow users to manipulate mathematical objects in real time, thereby promoting exploratory learning, conceptual understanding, and the development of higher-order thinking skills. Over the past decade, particularly from 2016 to 2024, numerous studies have documented its educational impact, demonstrating how Geogebra fosters learner engagement, reduces math anxiety, and improves academic achievement. Geogebra-based instruction significantly enhanced students' geometric understanding compared to traditional teaching methods, owing to its capacity to visualize and dynamically manipulate shapes and figures. This finding is echoed by Cagayan and Yildiz (2020), who found that the software contributed to deeper mathematical reasoning and more meaningful learning experiences. Teachers also benefit from Geogebra' s versatility, as it supports diverse instructional strategies such as inquiry-based learning, collaborative tasks, and differentiated instruction, allowing educators to design content that caters to varied learning styles and abilities. The software's open-source nature and cross-platform accessibility further enhance its utility in diverse educational contexts, particularly in under-resourced settings where cost-effective solutions are essential (Bakar et al., 2022). Moreover, studies during the COVID-19 pandemic highlighted Geogebra's potential in facilitating remote and hybrid learning; for instance, it was reported that students using Geogebra in online classes maintained higher levels of interest and performance in mathematics than those relying solely on static resources (Ozdinc,2021).Furthermore, the software supports interactive assessments, enabling teachers to monitor students' understanding in real-time and adjust their instruction accordingly (Khalil & Awad, 2023). Research has also explored the role in enhancing pre-serviceand in-service teacher training. Integrating Geogebra into teacher education programs positively influenced teachers' confidence in using educational technology and their ability to design engaging mathematical tasks. Similarly, Aydin and Delialioglu (2020) argued that Geogebra empowers teachers to create mathematically rich learning environments that align with 21st-century pedagogical standards. As technology continues to evolve, recent works, such as that by Singh and Al-Sharafi (2024), emphasise the need for ongoing professional development and institutional support to maximise the pedagogical potential of DMS tools like Geogebra in school curricula. Despite its benefits, the effective implementation of GeoGebra also faces challenges, including limited digital infrastructure in some regions, insufficient training for educators, and resistance to change from traditional teaching approaches (Mustafa & Wulandari, 2022).

However, these barriers can be addressed through strategic interventions such as curriculum alignment, school-level policy support, and teacher capacity-building programs. With continued innovation and support, Geogebra remains a leading DMS that enhances students' mathematical understanding and fosters a learner-centred environment that promotes curiosity, creativity, and problem-solving. As educational systems increasingly prioritise technology integration, Geogebra is a valuable tool that bridges theory and practice, making mathematics more accessible, engaging, and meaningful for learners across all educational levels (Santos et al., 2020).

2.2.1 Geogebra Software

GeoGebra is a dynamic, interactive software created by Markus Hohenwarter in 2001 that supports teaching and learning in various mathematical topics. It combines geometry, algebra, spreadsheets, graphing, statistics, and calculus into one easy-to-use platform. The name reflects its dual focus: "Geo" for geometry and "Gebra" for algebra. Freely available worldwide, it helps educators and students visualize and explore concepts through dynamic constructions. Its interactive environment encourages learning by doing and develops deeper conceptual understanding.

2.2.2 Components of GeoGebra Software

GeoGebra integrates multiple mathematical tools into a single platform, providing an interactive environment for teaching and learning mathematics. Its main features include the Graphics View for constructing and manipulating figures, the Algebra View for equations and functions, and the Spreadsheet View for data analysis. The CAS View supports symbolic computation, while the 3D Graphics View allows exploration of three-dimensional objects. Additionally, the Probability Calculator facilitates statistical analysis, and the Input Bar enables direct command entry, ensuring precise control of mathematical objects (Hohenwarter & Lavicza, 2020).

2.2.3 Features of Geogebra Software

GeoGebra is a dynamic mathematics software that integrates geometry, algebra, calculus, and statistics into a single digital learning environment. This integration allows learners to visualize and manipulate mathematical concepts interactively, promoting conceptual understanding rather than rote memorization. The software's dynamic feature enables users to modify parameters and instantly observe the effects on graphs, equations, and geometric figures, thus strengthening students' comprehension of relationships among mathematical representations. According to Juandi et al. (2021), GeoGebra-based learning has a strong positive effect on students' mathematics achievement, as the software's visual and interactive environment supports deep learning and active engagement. The study highlights that students who used GeoGebra outperformed their peers who were taught through traditional methods, confirming its effectiveness as a digital learning tool.GeoGebra's structure combines the capabilities of a computer algebra system (CAS) and dynamic geometry software (DGS), allowing users to explore algebraic and geometric relationships simultaneously. Acikgül and Onuk Keskin (2025) explained that GeoGebra interconnects multiple representations of mathematical knowledge when a change is made in one form, it is automatically reflected in others, thereby helping learners understand the consistency across different mathematical views. This interconnectedness promotes meaningful learning by linking visual, numerical, and symbolic reasoning. Additionally, GeoGebra is freely available, compatible with various platforms, and supported by a large international user community, which enhances its accessibility and pedagogical value across different educational levels. These features make GeoGebra a powerful tool for improving students' understanding of mathematical concepts, particularly at the primary level where visualization and hands-on interaction are crucial for learning abstract ideas

2.2.4 Role of Technology and Geogebra Software in Education

The integration of technology into education has significantly transformed the teaching and learning process, especially in mathematics, where abstract concepts often create barriers to student understanding and achievement. Technology serves as an essential medium for making learning more interactive, accessible, and student-centered by offering tools that support visualization, exploration, and problem-solving in ways that traditional methods cannot achieve (Rahman et al., 2020). In this context, GeoGebra has emerged as a dynamic, open-source mathematical software that combines algebra, geometry, calculus, graphing, and statistics into a single interactive platform, enabling students to visualize mathematical relationships, test hypotheses, and manipulate objects in real time to construct their own understanding of concepts (Shadaan & Eu, 2020). Unlike conventional teaching methods that rely heavily on memorization and static illustrations, GeoGebra transforms mathematics lessons into engaging and dynamic experiences that align with constructivist learning theories, allowing learners to actively participate, experiment, and collaborate in knowledge construction. It not only enhances conceptual understanding but also fosters higher-order thinking skills such as critical reasoning, analysis, and creativity, while simultaneously boosting motivation and reducing mathematics anxiety, which often hinders student achievement (Nisar & Shabbir, 2020). Moreover, GeoGebra benefits teachers by providing a versatile tool for lesson planning, interactive demonstrations, and formative assessment, allowing them to adapt instruction to diverse learner needs and promote inclusive classroom practices. Research findings in recent years have consistently shown that students taught with the integration of GeoGebra outperform those in traditional classrooms, demonstrating stronger problem-solving abilities, better academic performance, and improved confidence in mathematics learning (Shadaan & Eu, 2020; Rahman et al., 2020). Therefore, the role of technology, particularly GeoGebra, in education is indispensable, as it not only improves mathematical achievement but also prepares learners with the critical and analytical skills required to succeed in 21st-century education. Therefore, the integration of technology and GeoGebra software in education promotes interactive learning, enhances students' conceptual understanding, and supports the development of critical thinking and problem-solving skills essential for 21st-century education.

2.3 Case Studies Demonstrating Benefits in Mathematics Classrooms

Between 2021 and 2025, several case studies across different educational contexts have demonstrated the benefits of innovative approaches in mathematics classrooms. For instance, in Pakistan, a quasi-experimental study conducted in Dera Ghazi Khan revealed that a blended teaching approach combining digital tools with traditional instruction led to significantly higher mathematics achievement among Grade 3 students compared to conventional methods, reporting a very high effect size (≈ 1.60), thus evidencing the effectiveness of integrating technology into early mathematics learning (Khan, 2022). Similarly, a curriculum analysis study in Pakistan emphasized that embedding critical thinking skills including logical reasoning, real-world problem solving, and pattern recognition into the national mathematics curriculum (Grades I–XII) shifts the focus from rote memorization to conceptual understanding, thereby improving learners' ability to apply mathematics in practical situations (Ali, 2023). At the international level, a longitudinal U.S. case study involving elementary teachers examined the use of video-based professional development centered on worked examples, multiple representations, and deep questioning. Results showed that teachers who engaged in "noticing" and reflecting on these pedagogical features enhanced their ability to connect concrete and abstract representations when teaching inverse relations, although fostering deep questioning required additional support (Ding, Mochaourab, & Spiro, 2023). Likewise, in Australia, a case study of the "Building Thinking Classrooms" framework demonstrated how evidence-based practices such as encouraging student inquiry, collaborative problem-solving, and visible random groupings resulted in greater student engagement and improved mathematical thinking, while also promoting professional growth for teachers adapting to this instructional model (Bishop & McPhail, 2025). Collectively, these studies conducted between 2021 and 2025 highlight that integrating technology, fostering critical thinking, adopting inquiry-based and reflective practices, and re-designing teacher professional development all contribute to enhanced mathematics achievement and deeper learning experiences for students. Mathematics serves as the foundation for numerous disciplines, including science, technology, engineering, and economics, equipping learners with essential skills for academic achievement and future professional success.

2.3.1 Challenges in Implementing GeoGebra in Primary Education

One of the main barriers to implementing GeoGebra in primary education is limited access to technology. Many schools, particularly in rural or under-resourced regions, lack adequate infrastructure, computing devices, and reliable internet connectivity. Even where computers are available, they are often too few for whole-class use, limiting hands-on experience. Internet instability further affects software updates and access to online resources, while financial constraints make it difficult for schools to purchase new hardware or maintain existing systems. Consequently, traditional teaching methods remain dominant.Another significant challenge is inadequate teacher training. Although GeoGebra is user-friendly, teachers often lack the necessary skills and confidence to integrate it effectively. Many educators have little exposure to digital tools during their training and face limited opportunities for structured in-service professional development. This creates reluctance to adopt technology, especially when teachers are uncertain about aligning GeoGebra with curricular objectives or managing classroom time. The absence of mentorship and collaborative networks further isolates teachers, reducing motivation and innovation.

Curricular alignment also poses difficulties. Teachers may not know how to link GeoGebra activities with learning outcomes or select topics where it is most effective, such as geometry or number representation. Without clear guidance, instructional manuals, or sample lesson plans, the integration process can appear disruptive rather than supportive of learning. Classroom management is another concern; as digital tools can sometimes distract students. Teachers need strategies to keep learners engaged, set clear routines, and design age-appropriate, purposeful activities (Adedoyin & Bello, 2022).

2.3.2 Overcoming Challenges in GeoGebra Integration

Addressing these barriers requires investment in educational infrastructure. Governments, schools, and development partners should prioritize funding for digital devices, internet connectivity, and maintenance. Affordable technologies like tablets or low-cost laptops can ensure broader access, while offline use of GeoGebra and local networks can minimize reliance on internet availability. Shared resources, mobile labs, and partnerships with NGOs or private sector donors can also help schools secure equipment. Equally important is teacher training. Professional development programs should begin with introductory workshops and progress toward advanced applications, enabling teachers to practice lesson design with GeoGebra in real classroom contexts. Continuous support, refresher courses, and advanced workshops are essential for sustaining teacher competence. Establishing communities of practice, online forums, and mentorship programs can further build teacher confidence and innovation. Including technology integration in teacher education curricula can ensure future educators are well-prepared. Curricular support is also critical. Developing guides, sample lesson plans, and activity sheets can help teachers map GeoGebra to specific outcomes. Finally, successful implementation depends on effective classroom management and student engagement strategies. Teachers must establish routines, assign meaningful tasks, and incorporate collaborative activities that foster problem-solving and teamwork. Gamification, interactive quizzes, and rewards can make lessons enjoyable while reinforcing concepts. Parent workshops and access to online resources can extend learning beyond the classroom, strengthening the home school connection.

2.3.3 Theoretical Foundations in Mathematics Education

Constructivism is a theory of learning that emphasizes the role of learners in constructing their own understanding and knowledge based on their experiences. In the context of mathematics education, constructivist learning theory is highly relevant, asit encourages students to actively participate in their learning process, build on prior knowledge, and engage in problem-solving activities. Jean Piaget and Lev Vygotsky, whose work has had significant influence on how mathematics is taught and learned. Jean Piaget's theory of cognitive development posits that children move through distinct stages of cognitive development, each characterized by a different way of thinking and understanding the world. Piaget identified four stages of cognitive development:

1. Sensorimotor Stage (Birth to 2 years)
2. Preoperational Stage (2 to 7 years)
3. Concrete Operational Stage (7 to 11 years)
4. Formal Operational Stage (11 years and older)

Piaget's theory is particularly influential in mathematics education as it emphasizes the importance of children's interaction with their environment in shaping their cognitive abilities. He argued that learning is a process of active construction rather than passive absorption. According to Piaget, mathematical concepts such as numbers, operations, and spatial relations are not simply learned from teachers but are actively constructed by the child through exploration and problem-solving activities. Vygotsky's theory of social constructivism emphasizes the role of social interaction and cultural context in learning. Unlike Piaget, who focused primarily on the individual child's development, Vygotsky believed that cognitive development is fundamentally shaped by the child's interactions with others, especially more knowledgeable peers or adults. This approach places significant importance on collaborative learning and the social aspects of education. Vygotsky introduced several key concepts that have profound implications for mathematics education (Schunk, 2020).

2.3.4 Connecting Piaget and Vygotsky's Theories in Mathematics

Both Piaget and Vygotsky's theories contribute valuable insights into the design of mathematics curricula. While Piaget emphasizes individual cognitive development and the importance of hands-on, experiential learning, Vygotsky highlights the role of social interaction and the importance of cultural and contextual factors in learning. Integrating these two perspectives can provide a more holistic approach to mathematics education, where students have opportunities to explore concepts individually collaboratively. In practical terms, Piaget's ideas encourage teachers to design lessons that are developmentally appropriate and focus on discovery-based learning, while Vygotsky's ideas encourage the use of collaborative strategies and scaffolding to support students' learning within their ZPD. Together, these theories suggest that effective mathematics education requires both individual exploration and social interaction.

2.3.5 Philosophical Foundation of Technology Base Learning

The use of Geogebra software in mathematics education is grounded in a range of philosophical perspectives that inform how learners construct, engage with, and understand mathematical knowledge. Constructivism, primarily associated with Jean Piaget and Lev Vygotsky, provides a central foundation for technology-based learning through Geogebra. According to this theory, learners actively build their understanding by interacting with their environment. Geogebra facilitates this process by allowing students to manipulate mathematical objects, test hypotheses, and visualize outcomes dynamically. It supports exploratory learning, where students construct meaning through engagement and experimentation. Vygotsky's idea of the Zone of Proximal Development (ZPD) is also evident when learners use Geogebra collaboratively, receiving scaffolding from teachers or peers as they tackle tasks just beyond their current ability. From the lens of pragmatism, as advocated by John Dewey, learning is most effective when it is rooted in experience and practical application. Geogebra enables learners to engage with mathematics in a hands-on, meaningful way, connecting abstract concepts to real-world contexts. By modeling geometric figures, algebraic expressions, or statistical data, students can experiment and solve problems in a dynamic environment.

This reflects the pragmatist belief that knowledge should be functional and adaptable, developed through doing rather than passive listening. (Hohenwarter & Lavicza, 2020). Realism also plays a role in the philosophical foundation of Geogebra-based learning. Realism holds that knowledge reflects objective truths about the external world, and mathematics is seen as a tool to describe and understand those truths. Geogebra allows students to model real-world phenomena such as projectile motion or data patterns helping them perceive mathematical principles as accurate representations of reality. This enhances the learner's ability to connect theoretical knowledge with observable outcomes. Meanwhile, idealism, which emphasizes mental activity and the pursuit of universal truths, is echoed in Geogebra ability to support abstract reasoning. By engaging with mathematical structures and relationships, learners use the software as a tool for internal reflection, pattern recognition, and the intellectual appreciation of mathematical beauty. Although behaviorism is less dominant in technology-integrated learning, elements of it are present in how Geogebra provides immediate feedback to learners. As students interact with the software, they receive visual and numerical responses to their input, which can serve as reinforcement for correct understanding or motivation to revise errors. This form of feedback helps shape learning behaviors and supports iterative improvement. In summary Geogebra is a philosophically rich educational tool that aligns with constructivist, pragmatic, realist, idealist, and behaviorist principles, making it highly effective for enhancing mathematical learning across different educational philosophies and learner needs.The philosophical foundation of technology-based learning highlights the integration of digital tools to foster critical thinking, creativity, and lifelong learning aligned with contemporary educational objectives.

2.4 Traditional Teaching Method

The traditional teaching method refers to a teacher-centered approach where educators serve as the primary source of knowledge, typically using direct instruction methods such as lectures, textbook-based lessons, rote memorization, and classroom reading. This method has long been the dominant form of instruction, emphasizing structured learning, teacher authority, and standardized content delivery (Gill & Kusum, 2022). In this approach, students are often passive recipients of information, expected to listen, take notes, and reproduce learned material in exams, rather than actively constructing their understanding. Despite shifts toward constructivist and student-centered models in recent decades, the traditional method remains relevant due to its clarity, simplicity, and consistency, particularly in contexts where curriculum standardization, time efficiency, and classroom control are critical (Ahmad et al., 2020). One of the key advantages of traditional teaching is its ability to manage large classrooms effectively, offering uniform instruction and maintaining academic discipline. It is particularly valuable in situations that require transmitting core knowledge, foundational skills, or exam preparation. Moreover, in under-resourced settings or developing countries, where access to educational technologies may be limited, the traditional method remains a practical and often necessary pedagogical strategy (Bibi, 2021). Traditional teaching is not a single method but includes various types, each suited for specific learning objectives. The lecture method remains the most prevalent form, allowing teachers to efficiently convey information to many students. Rote memorization, while often critiqued, is essential for learning foundational facts such as multiplication tables, vocabulary, and formulas.

The demonstration method is standard in science and vocational subjects, enabling teachers to model procedures or experiments while students observe. Textbook-based instruction, another hallmark of traditional pedagogy, ensures that students follow a prescribed curriculum, especially in examination-oriented systems (Malik & Murtaza, 2023). In addition, chalk-and-talk continues to be widely practiced in classrooms where digital resources are unavailable. Although traditional teaching methods may not foster creativity or higher-order thinking as effectively as modern, interactive approaches, they provide essential benefits in structured learning environments and remain a cornerstone of education systems worldwide. Thus, while pedagogy innovation is critical, traditional methods' enduring significance lies in their ability to provide academic rigor, curriculum fidelity, and clear educational expectations (Rehman et al., 2020).

2.4.1 Nature and Characteristics of Traditional Teaching Method

Traditional teaching methods are rooted in long-established practices that emphasize teacher-centered learning. In this approach, the teacher is the central authority, responsible for planning lessons, delivering knowledge, and assessing students, while learners usually remain passive recipients of information. Knowledge is considered fixed, and the teacher’s role is to transmit it, leaving students to absorb and memorize rather than actively engage in the learning process. The curriculum followed in traditional classrooms is highly structured and often rigid, shaped by textbooks, standards, or examinations. Lessons progress linearly with little flexibility for individual needs, and textbooks are the primary instructional resource. Although this ensures uniformity, it can restrict creativity and adaptation to diverse learners. A common characteristic of such teaching is rote memorization, where students are expected to recall facts, formulas, and definitions. While this may be useful for accuracy in subjects like mathematics and science, it does little to foster deep conceptual understanding or problem-solving skills.

Traditional classrooms are further marked by limited interaction, where learning flows mainly from teacher to student. Opportunities for collaboration, discussion, and peer learning are minimal, restricting students’ ability to think critically and engage deeply with the material. Assessment practices are typically exam-driven, relying on quizzes, tests, and written assignments that emphasize recall of information. This system often creates pressure on students to perform well, encouraging surface-level learning rather than meaningful understanding. Discipline and order also play a central role, as teachers maintain authority through structured seating, rules, and strict classroom management. While this helps create a focused learning environment and ensures mastery of essential content, it may also suppress creativity and self-expression. In essence, traditional teaching methods are characterized by teacher authority, rigid curricula, rote learning, minimal interaction, exam-based assessment, and strict discipline. They aim to ensure mastery of core content and uniformity in learning, but their "one-size-fits-all" approach often fails to address the varied needs, learning styles, and interests of students.

2.4.2 Historical background and Evolution of Traditional Methods

The roots of traditional teaching methods can be traced back to the earliest forms of organized education, where the transmission of knowledge was largely teacher-centered and authoritarian in nature. In ancient civilizations such as Egypt, Greece, China, and India, education focused on memorization, repetition, and recitation of sacred or classical texts under the guidance of scholars and philosophers. The teacher was viewed as the ultimate authority, responsible for delivering knowledge, maintaining discipline, and evaluating students' performance. Learners were expected to listen attentively, absorb information, and reproduce it accurately. This method, which emphasized discipline and obedience, became the cornerstone of early formal education systems and reflected the cultural belief that knowledge was best transmitted through direct instruction (Kumari et al., 2023). During the Medieval and Renaissance periods, traditional instruction gained even greater prominence as education became institutionalized in monastic and cathedral schools. Learning was based on religious doctrine and classical literature, and students were trained to memorize texts verbatim. The role of the teacher remained dominant, as they lectured and dictated lessons while students passively copied or recited. This period solidified the lecture as the central instructional technique a practice that continues to characterize traditional classrooms even in modern times. The structure of these schools emphasized hierarchy, authority, and rigid discipline, which were considered essential for moral and intellectual formation. These early systems laid the groundwork for the teacher-centered classrooms that emerged during the Industrial Revolution (Kumari et al., 2023).

The nineteenth century marked a significant transformation in the evolution of traditional methods as formal schooling became a state responsibility. The Industrial Revolution's demand for literate and obedient workers encouraged the creation of standardized education systems. Schools adopted structured curricula, uniform textbooks, and fixed schedules designed to promote efficiency and conformity. The teacher served as the central figure, delivering lessons to large groups of students in an orderly manner. Examinations and written tests became the primary means of assessing student learning. This system viewed students as passive recipients of information rather than active participants in knowledge construction. As a result, education during this period prioritized content mastery and rote memorization over creativity and problem-solving. By the mid-twentieth century, educational thinkers began to question the limitations of such teacher-centered models. Although traditional methods remained widespread, critics argued that they did not fully address the individual needs of learners or foster critical thinking skills. Educational philosophers such as John Dewey promoted the idea of experiential learning and advocated for a shift from passive learning to active engagement. In contemporary education, the evolution of traditional methods has continued alongside rapid technological advancements. While modern educators increasingly adopt digital tools and student-centered approaches, traditional teaching practices remain deeply embedded in many educational systems. Teachers still rely on lectures, guided practice, and repetition particularly when teaching foundational concepts in subjects like mathematics and language.

According to Kumari et al. (2023), these methods are still effective for developing discipline, factual recall, and procedural understanding. However, educators now recognize the importance of integrating traditional methods with interactive technologies and learner-centered strategies to create balanced instructional environments. Overall, the historical evolution of traditional teaching methods reflects an enduring commitment to structure, authority, and discipline in the learning process. From ancient societies to the modern classroom, the teacher has remained a central figure in knowledge transmission. The evolution of pedagogy in the twenty-first century has encouraged educators to blend conventional instruction with innovative, participatory techniques that foster deeper understanding and active engagement. Rather than viewing traditional and modern methods as opposing systems, contemporary education increasingly values their integration. Traditional approaches continue to play a vital role in providing the foundation for learning, while modern pedagogies enhance motivation, creativity, and critical thinking. Understanding this historical progression allows educators to appreciate the lasting influence of traditional teaching while adapting it to meet the demands of modern learners.

2.4.3 Role of the Teacher in Traditional Instruction

In traditional instruction, the teacher serves as the central authority, transmitting knowledge through lectures, demonstrations, and structured lessons while students remain passive recipients expected to memorize information with limited opportunities for exploration or critical thinking. Lessons are highly teacher-centered, relying on textbooks, blackboard teaching, and note-taking, with evaluations focused on recall and retention. The classroom is structured, emphasizing order, discipline, and obedience over creativity or autonomy, with students typically seated in rows and activities planned with little flexibility. While this approach often results in passive learning and low engagement, it remains prevalent in primary mathematics due to its effectiveness in reinforcing foundational arithmetic operations such as addition, subtraction, multiplication, and division through direct instruction, repetition, and guided practice. Rote learning helps students memorize essential math facts, improving fluency and accuracy, while immediate feedback minimizes misconceptions.

The predictable and organized environment benefits young learners who thrive on consistency, and regular drills, quizzes, and tests provide accountability and reinforce procedural fluency. Repetition through board work, worksheets, and homework aids long-term retention and supports automaticity in basic skills like number recognition and place value. However, research highlights notable limitations of traditional methods: Salim and Osman (2020) found that textbook-driven instruction in Malaysia led to disengagement and an overreliance on memorization, while Khan and Ayub (2023) showed that GeoGebra-assisted teaching fostered collaboration, motivation, and deeper comprehension, despite challenges of insufficient training and infrastructure in rural schools. Similarly, Diamine and Mthembu (2021) reported moderate performance gains when traditional teaching was supplemented with formative assessments and feedback. Thus, while traditional methods remain valuable for building arithmetic fluency and providing structured learning environments, their effectiveness is limited unless complemented with interactive and student-centered approaches.

2.4.4 Traditional Teaching Methods and Students' Academic Achievement in Primary Mathematics

Traditional teaching methods in primary mathematics refer to practices that are predominantly teacher-centered, focusing on the transmission of knowledge through lectures, demonstrations, textbook exercises, and repetitive practice. In this approach, the teacher assumes the central role in explaining concepts and procedures, while students are viewed as passive recipients of information who memorize rules and algorithms for application in problem-solving (Gill & Kusum, 2022). These methods have historically dominated classroom instruction because they are easy to organize, allow for coverage of syllabus content, and emphasize discipline and order. In primary mathematics, traditional teaching methods often involve drill-and-practice techniques to reinforce arithmetic operations, number recognition, and procedural fluency, which are considered essential foundational skills. Such strategies may lead to short-term academic achievement, particularly in standardized testing situations where procedural knowledge is rewarded (Adedoyin & Bello, 2022). However, despite their effectiveness in enhancing immediate recall and computational accuracy, these methods tend to limit students' opportunities for exploration, reasoning, and creative problem-solving, which are vital for long-term understanding and higher-order mathematical thinking (Arslan & Ubuz, 2014).Empirical evidence from international studies suggests that when mathematics is taught through direct instruction without student participation, learners may achieve proficiency in performing operations but struggle to apply concepts in novel or real-life contexts (Freeman et al., 2014).

This limitation arises because traditional teaching methods often neglect the development of conceptual understanding, emphasizing "how" to perform procedures rather than "why" they work. As a result, students may become dependent on memorized steps and find it difficult to transfer their learning to new problems. Furthermore, research indicates that sustained reliance on teacher-centered instruction can reduce motivation and engagement, especially among young learners who benefit more from hands-on and inquiry-based learning experiences (Begum, 2020). In the context of primary education, this challenge becomes particularly significant, as children at this stage are naturally curious and learn best through interactive exploration and visual aids that connect abstract concepts to concrete experiences (Hassan, 2020).

Studies conducted in Pakistan reveal that many primary mathematics teachers continue to rely heavily on traditional pedagogical approaches due to a lack of training in modern teaching techniques, limited access to technological tools, and rigid curriculum requirements (Gill & Kusum, 2022). While such methods can efficiently transmit factual knowledge, they often fail to foster higher-order thinking skills such as analysis, reasoning, and problem-solving (Adedoyin & Bello, 2022). For example, when students are taught multiplication or division using rote learning, they may remember the steps but lack a conceptual understanding of quantities and relationships. Consequently, when confronted with complex problems or unfamiliar question formats, their academic performance tends to decline (Arslan & Ubuz, 2014). In contrast, student-centered and technology-integrated teaching approaches such as activity-based learning, collaborative tasks, and the use of digital tools like GeoGebra have been found to significantly improve students' comprehension, engagement, and long-term retention in mathematics (Freeman et al., 2014).Despite this, traditional methods still hold relevance in contexts where resources are limited or when introducing basic arithmetic skills that require procedural mastery before conceptual generalization (Begum, 2020). Effective teachers often combine traditional explanations with interactive questioning and practical examples to balance conceptual and procedural learning. The key factor determining success appears to be not the method itself but the teacher's competence, adaptability, and ability to connect instruction with students' cognitive levels and experiences (Hassan, 2020). Hence, while traditional teaching methods continue to play a role in foundational mathematics education, integrating them with modern, student-centered pedagogies can significantly enhance students' academic achievement and ensure a more holistic mathematical understanding at the primary level.

Research findings on traditional methods are mixed. Some studies suggest that they enhance short-term gains and performance in knowledge-based assessments, while others argue they fall short in promoting long-term retention, conceptual understanding, and higher-order thinking. The effectiveness of these methods is context-dependent, influenced by teacher quality, classroom management, and societal expectations. In some regions, they align well with educational goals, while in others, they are seen as outdated for preparing students for modern challenges. Recent reforms advocate blending traditional and modern approaches to balance foundational knowledge with interactive, inquiry-based learning. In primary mathematics, conventional teaching emphasizes direct instruction, memorization, and repetitive practice, often relying on textbooks and summative assessments. This teacher-centered approach builds procedural fluency and accuracy in basic operations like addition, subtraction, and multiplication, enabling students to perform well in standardized tests. However, it often fails to foster conceptual understanding, reasoning, and problem-solving.

Students may memorize procedures without grasping the underlying principles, limiting their ability to apply knowledge in unfamiliar contexts. Moreover, passive environments can reduce motivation and engagement, particularly when interactive and hands-on elements are absent. The one-size-fits-all nature of traditional pedagogy does not address diverse learning styles, leading to disinterest among advanced learners and difficulties for struggling students. Consequently, learning disparities and achievement gaps may widen. While structured practice supports skill acquisition, growing evidence highlights the need for balanced, constructivist approaches that integrate exploration, collaboration, and student agency without neglecting core skills (Abdullah & Zakaria, 2021).

2.4.5 Limitations of the Traditional Teaching Method

The traditional teaching method, while traditional and widely used, presents several limitations that can affect the learning process in modern educational environments. One of the major drawbacks is limited student participation. This method primarily centers on the teacher delivering content, often leaving little room for students to actively engage in the learning process. As a result, opportunities for students to participate in discussions, ask questions, or explore concepts independently are restricted, which can hinder the development of essential skills such as critical thinking and problem-solving (Johnson & Wang, 2021). Another issue with the traditional teaching method is the risk of passivity. When the teacher dominates the classroom with extended verbal explanations and limited interactive elements, students may become disengaged. Without active involvement in the lesson, students may struggle to maintain focus, leading to a lack of interest and reduced attention span. This passivity can affect the overall learning experience, as students may fail to absorb or retain the information being presented (Harris & Patel, 2023). Furthermore, the one-size-fits-all approach of the Traditional teaching method fails to address the diverse learning needs of students. Not all students learn in the same way; some may require more interactive, hands-on, or visual learning experiences to fully understand and retain information. The uniformity of the Traditional teaching method, with its emphasis on direct instruction and limited use of alternative teaching methods, does not cater to these varying needs. This lack of differentiation can particularly disadvantage students who struggle with auditory or traditional text-based learning methods, hindering their academic progress (Khan et al., 2022).

2.4.6 Strategies for Effective Use of Traditional Teaching Method in Primary Mathematics Instruction

Although the Chalk-and-Talk method has its inherent limitations, it can still be an effective tool for primary mathematics instruction when used strategically. By employing certain best practices, teachers can maximize the potential of this traditional approach to enhance student engagement and learning outcomes. One key strategy is incorporating active learning. While the teacher provides direct instruction, it is essential to create opportunities for students to engage with the content actively. This can be achieved by allowing students to practice concepts, solve problems independently, or collaborate with peers. Such activities help students internalize and apply mathematical principles, fostering a deeper understanding of the material (Harris & Patel, 2023). Another effective strategy is interactive questioning. Teachers can use questioning techniques to encourage students to think critically about the content. Rather than simply reciting facts or following instructions, students can be prompted to reflect on their understanding, analyze concepts, and discuss their reasoning. This form of engagement promotes higher-order thinking skills and helps reinforce the lessons being taught (Gonzalez & Lopez, 2022).

In addition, the use of visual aids can significantly enhance the learning experience. Teachers should integrate diagrams, charts, and other visual tools alongside their presentations to cater to diverse learning styles. Visual aids help students who are more visually oriented to grasp abstract mathematical concepts, making the lesson more accessible and engaging for a wider range of learners (Smith & Jones, 2023). Lastly, frequent feedback plays a crucial role in ensuring that students remain on track. Immediate feedback on students' responses allows teachers to correct misunderstandings and reinforce correct problem-solving strategies. This ongoing feedback loop helps students consolidate their learning and stay motivated by demonstrating progress and areas for improvement (Johnson & Wang, 2021). By combining these strategies with the traditional teaching method, teachers can create a more dynamic and inclusive learning environment in primary mathematics classrooms. The Traditional teaching method, though often seen as a traditional and less interactive approach, continues to play a significant role in enhancing mathematical understanding among primary school students. Research indicates that, when used effectively, it can contribute to improved mathematics achievement by providing clear, structured explanations and visual aids. However, to avoid the limitations of this method, teachers should incorporate interactive elements and encourage active participation. Ultimately, the effectiveness of the traditional teaching method depends on its implementation, with strategic adaptations enhancing its potential to support students in mastering foundational mathematical concepts.

2.4.7 Traditional Methods in the Context of Developing Countries

In developing countries, traditional teaching methods remain the cornerstone of instructional practice, primarily due to cultural traditions, limited financial resources, inadequate teacher training, and the scarcity of technological infrastructure. These methods typically rely on teacher-centered instruction, where the teacher serves as the principal source of knowledge and authority in the classroom, and students are expected to listen, memorize, and reproduce information rather than engage in critical thinking or problem-solving activities. This approach, often referred to as the “chalk-and-talk” method, emphasizes rote learning, textbook-based instruction, and the completion of standardized exercises designed to prepare students for examinations rather than to develop their conceptual understanding (Chen, 2025). In many developing countries across Asia and Africa, this form of teaching persists because it aligns with social and cultural expectations that value discipline, obedience, and respect for authority within the classroom environment. Teachers often adopt these methods not only because they are familiar and culturally accepted, but also because they are practical in contexts where class sizes are large, instructional materials are scarce, and there is little access to digital resources or modern teaching aids. For example, in rural and low-income schools, a single teacher may be responsible for managing over fifty students at a time, making interactive or student-centered learning difficult to implement effectively.

Despite their limitations, traditional methods offer several practical advantages in developing contexts. They are cost-effective, easy to implement, and require minimal resources or technical skills. These approaches also allow teachers to cover the prescribed curriculum efficiently, which is especially important in education systems that prioritize exam performance and standardized testing over creativity and innovation. However, numerous studies have shown that such methods often fail to promote deeper understanding, critical thinking, and problem-solving skills among learners. When students are treated as passive recipients of information, they may achieve short-term memorization but struggle to apply knowledge in real-world contexts or retain it over time (Magwa et al., 2025). The rigidity of traditional instruction also limits opportunities for collaboration, inquiry-based learning, and formative assessment all of which are crucial for fostering engagement and developing higher-order cognitive skills. Moreover, the COVID-19 pandemic exposed significant weaknesses in traditional systems across developing countries, as schools that depended entirely on face-to-face teaching found it nearly impossible to transition to remote or blended learning modes due to a lack of digital infrastructure and teacher readiness. This highlighted the urgent need for pedagogical flexibility and the gradual introduction of low-cost, context-appropriate technological tools that can complement existing teaching methods.To address these challenges, experts suggest that educational reform in developing countries should focus not on the complete abandonment of traditional teaching, but on its evolution into more blended and interactive models that respect cultural realities while promoting active learning. Teachers should be provided with continuous professional development to learn how to integrate participatory techniques such as group discussions, project-based learning, and problem-solving tasks within the framework of traditional instruction. Furthermore, policymakers should ensure that schools are equipped with at least basic digital tools and learning resources, enabling gradual exposure to technology-enhanced teaching. The goal should be to maintain the structure and discipline associated with traditional methods while enriching them with approaches that enhance student engagement, motivation, and understanding. As Chen (2025) notes, the transformation of education in developing countries must be context-sensitive, taking into account local socio-economic and cultural conditions rather than merely replicating models from developed nations. In this way, traditional teaching methods can evolve into a hybrid form that balances the strengths of teacher authority with the benefits of student-centered learning, thereby preparing learners for the cognitive and technological demands of the 21st century (Magwa et al., 2025).

Traditional instruction heavily relies on repetition and drill-based exercises, which are vital in assisting primary students in internalizing mathematical concepts and procedures. Repetitive practice through worksheets, board exercises, and homework reinforces memory and builds automaticity in solving mathematical problems. Regular exposure to similar problems strengthens neural pathways associated with mathematical thinking. Repetition aids in the long-term retention of mathematical knowledge. By revisiting concepts multiple times in different contexts, students are more likely to remember and apply them correctly in assessments and real-life applications. Through continuous practice, primary students can automate basic skills such as number recognition, place value understanding, and procedural fluency. This automation frees up cognitive space for higher-level problem-solving in later grades. In many public schools where class sizes are large and resources limited, repetitive practice is an efficient strategy for ensuring that all students receive uniform instruction and opportunities for skill reinforcement (Gupta & Tiwari, 2020).In developing countries, traditional teaching methods continue to dominate educational systems despite widespread global advocacy for innovative and student-centred learning. These methods are mainly teacher-centred, relying on rote memorization and direct instruction, where students play a largely passive role. According to Cannon (2021), even when educational reforms promote modern, participatory teaching, most classroom practices remain rooted in traditional pedagogies due to systemic constraints and limited teacher training opportunities. This persistence underscores the difficulty of transforming established instructional norms within resource-limited educational environments.

The prevalence of traditional teaching in developing nations is often linked to structural and contextual challenges such as inadequate infrastructure, large class sizes, and insufficient professional development programs for teachers. In many countries, including Pakistan, educators rely heavily on lecture-based teaching because of rigid curricula, lack of access to technology, and limited exposure to innovative pedagogical approaches (Kashif et al., 2024). Tafamidze and Chimbu (2025) also observed that teachers in low-income educational settings tend to prioritize content delivery over student engagement, as they are under pressure to complete prescribed syllabi. Consequently, the absence of supportive institutional mechanisms perpetuates a reliance on conventional methods, even when educators recognize the benefits of student-centred practices.Cultural beliefs and societal expectations further reinforce the dominance of traditional instruction. In many developing contexts, education is closely associated with authority, discipline, and respect for teachers, making teacher-centred instruction socially acceptable and culturally desirable. Mohd Noor, Mahamod, and

Nasri (2025) noted that these cultural perceptions influence how teachers and learners respond to pedagogical innovation, with many equating authoritative instruction with effective teaching. Similarly, Falasi (2024) emphasized that assessment systems in developing countries tend to reward memorization and factual recall rather than critical thinking or creativity, which discourages teachers from adopting interactive and inquiry-based learning approaches. Therefore, even when modern tools and technologies are available, educators often adhere to traditional techniques to align with exam-oriented expectations and societal norms. In the context of primary mathematics education, such as in Pakistan and other developing countries, traditional teaching methods typically involve teachers explaining mathematical concepts while students passively take notes or solve repetitive exercises.

This approach limits opportunities for exploration, reasoning, and conceptual understanding. However, integrating technological tools like GeoGebra can provide a transformative pathway toward more interactive learning experiences. GeoGebra enables visual representation and hands-on engagement with mathematical concepts, promoting deeper comprehension among students. Nevertheless, successful integration requires contextual adaptation, teacher empowerment, and alignment with the curriculum to ensure sustainable pedagogical change (Tafamidze & Chimbu, 2025). Traditional teaching methods remain deeply rooted in the educational systems of developing countries due to structural barriers, cultural expectations, and examination-driven curricula. While these methods ensure classroom discipline and efficient content delivery, they often restrict creativity, engagement, and higher-order thinking. Understanding this context is essential for implementing educational innovations such as GeoGebra effectively. By building upon existing teaching traditions and addressing contextual challenges, educators can bridge the gap between conventional and innovative pedagogies, fostering gradual but sustainable improvement in classroom practices (Kashif et al., 2024; Mohd Noor et al., 2025).

2.4.8 Philosophical Foundation of Traditional Teaching Methods

The traditional teaching method, characterized by teacher-centered instruction, structured content delivery, and emphasis on memorization and discipline, is deeply rooted in various philosophical schools of thought that have shaped educational theory and practice for centuries. These philosophical foundations continue to inform the way many classrooms operate today, particularly in formal, institutional settings where academic standards, discipline, and uniformity are prioritized. By examining traditional teaching through the lenses of idealism, realism, behaviorism, and perennials, we can better understand the theoretical principles that underlie its persistent use and enduring relevance. One of the most influential philosophical foundations of traditional education is idealism, a perspective that emphasizes the primacy of the mind, ideas, and eternal truths. Idealism is closely associated with thinkers such as Plato and Immanuel Kant, who believed that education should cultivate the intellect and moral character of individuals by guiding them toward absolute truths and values. In this view, the teacher is seen as an intellectual and moral authority who imparts wisdom and timeless knowledge to students. Traditional teaching methods align well with idealism because they focus on transmitting established truths, often found in classical texts and foundational disciplines such as literature, philosophy, and mathematics (Hussain et al., 2020). The teacher- centered nature of traditional instruction reflects the idealist belief in a hierarchical relationship between teacher and learner, where the teacher plays a central role in leading students to higher levels of thought and understanding. The structured nature of lessons, emphasis on intellectual rigor, and reliance on canonical knowledge all echo the idealist conviction that education is about uncovering universal truths and developing rational minds.

Closely related to idealism is realism, another foundational philosophy that significantly influences traditional teaching. Realism, championed by philosophers like Aristotle and later John Locke, asserts that reality exists independent of human perception and that knowledge is gained through the systematic observation and understanding of the external world. In education, realism promotes factual knowledge, objective truth, and practical experience. The traditional classroom's reliance on textbooks, factual content, and observable phenomena directly reflects the realist approach. Teachers are viewed as experts who convey knowledge that corresponds to the real world, and students are expected to acquire this knowledge through structured study and repetition. Realism supports the notion of a standardized curriculum that covers core subjects essential to understanding the natural and social order. The orderly classroom environment, the use of exams to measure objective knowledge, and the emphasis on accuracy and clarity are all manifestations of the realist philosophy in traditional teaching. Another philosophical underpinning of traditional teaching comes from behaviorism, a psychological theory and educational philosophy that emerged in the early 20th century through the works of Skinner, John Watson, and Edward Thorndike. Behaviorism focuses on observable behavior and posits that learning occurs through conditioning and reinforcement. Traditional teaching methods, such as repetition, drills, rewards and punishments, reflect behaviorist principles. In this framework, the teacher is seen as the controller of the learning environment, guiding students' behavior through external stimuli and reinforcement mechanisms. For example, praise, grades, or discipline reinforce desirable behaviors and discourage undesired ones. The behaviorist education model mirrors the emphasis on correct responses, structured practice, and mastery of specific learning objectives in traditional classrooms. This approach assumes that all students can be trained to learn given the proper environmental conditions, and it values efficiency, discipline, and measurable outcomes, hallmarks of traditional pedagogy (Adedoyin & Bello, 2022).

2.4.9 Criticism

Traditional teaching methods, often characterized by teacher-centered instruction, rote memorization, and limited student participation, have faced increasing criticism in recent years for their inability to meet the evolving needs of learners. Critics argue that these approaches restrict creativity, discourage critical thinking, and fail to prepare students for problem-solving in real-life contexts (Kumar, 2019). In traditional classrooms, students are typically passive recipients of knowledge rather than active participants in constructing understanding, which undermines learner autonomy and engagement (Bakhsh, 2020). Moreover, the heavy reliance on lectures and examinations in traditional methods has been criticized for promoting surface learning rather than deep comprehension, as students often memorize information for assessments without fully understanding concepts (Hussain & Ahmad, 2019). With the rapid growth of digital technologies and innovative pedagogies, traditional methods are also seen as outdated, as they do not adequately incorporate interactive, learner-centered strategies that align with 21st-century skills such as collaboration, communication, and digital literacy (Memon, 2020). Thus, while traditional methods have historically played an important role in education, scholars in 2019–2020 emphasized their limitations in fostering higher-order thinking and lifelong learning. Traditional teaching methods have been widely criticized in contemporary educational research for their teacher-centered nature and limited engagement with students' diverse learning styles. Critics argue that such methods often rely heavily on rote memorization and lecture-based instruction, which tend to suppress creativity, discourage inquiry, and hinder the development of higher-order thinking skills. Moreover, traditional approaches frequently neglect the integration of technology and fail to accommodate the individual learning needs of students in a rapidly changing educational landscape. As a result, learners may become passive recipients of information rather than active participants in the learning process. Modern educators emphasize that meaningful learning occurs when students are encouraged to explore, collaborate, and construct their own understanding through interactive and student-centered methods (Rahman, 2025).

2.4.10 Merits and Demerits

The merits of traditional teaching methods include their structured, systematic approach, which can provide clear learning goals and assessments, ensuring that students build foundational knowledge in a step-by-step manner (Brophy, 2000). These methods also maintain consistency and are often easier to implement in environments with limited access to technology. However, the primary demerit is the lack of student engagement and the one-size-fits-all nature of instruction, which may not cater to diverse learning styles (Gage, 1994). In contrast, the merits of GeoGebra include its ability to make abstract mathematical concepts more concrete by providing interactive, visual representations that promote deeper understanding (Maaß, 2010). GeoGebra's real-time feedback and adaptability to individual learning paces make it an invaluable tool for differentiation in the classroom (Hennessy, 2000). The demerits, however, include the reliance on technology, which can be problematic in schools with inadequate resources or for students who are not familiar with digital tools (NCTM, 2000). Additionally, overuse of Geogebra may discourage students from mastering manual problem-solving skills.

Traditional teaching methods are grounded in a rich philosophical heritage, including idealism, realism, behaviorism, and perennials. Each of these philosophical schools contributes to different aspects of traditional instruction from the emphasis on moral and intellectual development, to the focus on objective knowledge and factual learning, to the use of reinforcement and conditioning in classroom management. Despite the growing popularity of progressive, student-centered approaches, traditional methods remain widely used and respected, particularly in educational contexts that demand structure, discipline, and content mastery. Understanding the philosophical foundations of traditional teaching not only helps educators appreciate its theoretical depth but also provides insight into how and why it continues to influence modern educational practices. Tool for differentiation in the classroom (Hennessy, 2000). The demerits, however, include the reliance on technology, which can be problematic in schools with inadequate resources or for students who are not familiar with digital tools (NCTM, 2000). Additionally, overuse of GeoGebra may discourage students from mastering manual problem-solving skills. Delivery, and Socratic dialogue are all rooted in perennial philosophy. Learning, to the use of reinforcement and conditioning in classroom management. Despite the growing popularity of progressive, student-centered approaches, traditional methods remain widely used and respected, particularly in educational contexts that demand structure, discipline, and content mastery. Understanding the philosophical foundations of traditional teaching not only helps educators appreciate its theoretical depth but also provides insight into how and why it continues to influence modern educational practices.

2.5 Comparative Analysis of Traditional Teaching Methods and Geogebra Software

Traditional teaching methods and modern digital tools such as Geogebra represent two distinct pedagogical approaches in mathematics education. Traditional methods are teacher-centered, emphasizing structured lessons, rote memorization, and procedural fluency. They often rely on textbooks, chalk-and-board demonstrations, and summative assessments to evaluate students' mastery of content. These approaches provide discipline, uniformity, and clarity, making them effective for developing foundational skills such as arithmetic operations and factual knowledge. However, they may neglect creativity, conceptual understanding, and individual learning needs, which can reduce motivation and hinder problem-solving abilities. In contrast, GeoGebra is a dynamic software that integrates geometry, algebra, calculus, and data analysis into an interactive environment. Unlike the one-way transmission of knowledge in traditional teaching, GeoGebra promotes student-centered learning by allowing learners to manipulate objects, visualize relationships, and receive immediate feedback. This interactive and exploratory approach supports conceptual understanding, critical thinking, and engagement. It also accommodates diverse learning styles, as students can experiment, observe, and connect multiple mathematical representations. When comparing both approaches, traditional methods excel in providing structure and efficiency in delivering procedural knowledge, whereas GeoGebra enhances conceptual comprehension and active learning. Empirical studies indicate that students using GeoGebra demonstrate improved problem-solving skills, higher engagement, and better long-term retention compared to those relying solely on traditional instruction. However, traditional methods remain valuable for ensuring accuracy and building core mathematical fluency.

A combined approach that integrates the structured discipline of traditional teaching with the interactive, exploratory features of GeoGebra may therefore provide the most effective outcomes in mathematics education. Traditional teaching methods in mathematics are predominantly teacher-centered, emphasizing direct instruction, memorization, and repetitive practice. In this approach, teachers act as the primary source of knowledge, while students play a passive role in receiving and reproducing information. Such methods, though effective for content delivery and discipline, often limit students' opportunities for exploration, problem-solving, and deeper conceptual understanding. According to Muslim, Zakaria, and Fang (2023), traditional approaches tend to prioritize procedural fluency and examination performance over creativity and critical thinking, which can hinder learners' ability to apply mathematical concepts in real-life contexts. In contrast, GeoGebra a dynamic and interactive mathematical software—supports constructivist learning by engaging students in hands-on exploration, visualization, and discovery. By allowing learners to manipulate geometric figures, algebraic equations, and numerical data dynamically, GeoGebra fosters an active learning environment that enhances conceptual understanding and motivation (Muslim et al., 2023).

2.6 Theoretical Review

Technology integration in education, grounded in constructivist learning theory, emphasizes learner-centered environments where students actively construct knowledge. Vygotsky's theory of social constructivism supports the use of tools like GeoGebra to foster meaningful learning experiences through interaction and scaffolding (Bozkurt & Ruthven, 2020). The software's visual and manipulative affordances enable abstract mathematical concepts to be internalized more effectively than through lecture-based methods. The Technological Pedagogical Content Knowledge (TPACK) framework has also been instrumental in understanding how teachers integrate GeoGebra into their pedagogical practices (Koehler et al., 2020). Teachers need not only content knowledge but also the skills to use technology effectively to support student learning. GeoGebra, with its intuitive interface and capacity for real-time manipulation, aligns with the principles of the TPACK model, which fosters adaptive teaching strategies.Traditional teaching methods, characterized by rote memorization, lecture delivery, and paper-pencil tasks, rely heavily on teacher-centered practices. While these methods have long been the norm, they often fail to accommodate diverse learning needs or stimulate critical thinking and creativity (Abdullah & Zakaria, 2021). Theoretical models advocating for active learning and inquiry-based instruction challenge these limitations, suggesting the need for a pedagogical shift towards interactive, student-centered strategies.

2.7 Empirical Review

Recent studies have extensively examined the efficacy of GeoGebra in improving mathematics achievement and engagement. A quasi-experimental study by Hohenwarter and Lavicza (2021) involving secondary students revealed significant gains in geometry understanding when lessons were taught using GeoGebra compared to traditional methods. Students in the experimental group demonstrated enhanced spatial reasoning, problem-solving skills, and conceptual clarity.Similarly, a randomized control trial conducted in Indonesia by Putra et al. (2022) evaluated the impact of GeoGebra-based instruction on eighth-grade students' algebraic thinking. The findings indicated that students exposed to GeoGebra scored higher on post-tests and expressed increased motivation and confidence in mathematics. The study highlighted that the visual and dynamic features of the software encouraged exploration and deeper comprehension. A comparative study by Khan and Ayub (2023) investigated the long-term effects of technology-integrated instruction in primary schools across South Asia. The research found that GeoGebra-assisted teaching fostered collaborative learning and sustained academic achievement, especially in topics like fractions and measurement. However, the study also reported challenges such as insufficient teacher training and lack of infrastructure in rural schools, hindering the widespread implementation of such tools. Contrastingly, studies examining traditional teaching methods continue to underscore their limitations. For instance, Salim and Osman (2020) conducted qualitative analysis of primary teachers' instructional practices in Malaysia and found that the predominance of textbook-driven teaching led to student disengagement and procedural learning. Students often failed to grasp underlying mathematical concepts, relying instead on memorization. Nonetheless, empirical findings suggest that traditional methods may still be effective under certain conditions. A study by Dlamini and Mthembu (2021) found that when traditional teaching was supplemented with formative assessments and feedback loops, student performance improved moderately. This indicates that while traditional approaches are often less effective on their own, thoughtful integration of interactive elements can enhance their impact.

2.8 Critical Summary

The teaching of mathematics has long been grounded in traditional pedagogical approaches that emphasize teacher-led instruction, repetitive exercises, and fixed procedures. These methods, though time-tested and structured, are increasingly being critiqued in light of contemporary educational needs that call for interactive, learner-centered, and technology-integrated instruction. In recent years, the emergence of digital tools like Geogebra software has challenged the dominance of traditional teaching methods, proposing a dynamic alternative that caters to diverse learner styles and enhances conceptual understanding. A critical comparison of these two instructional paradigms traditional methods and Geogebra-based teaching reveals significant contrasts in philosophy, pedagogy, effectiveness, and adaptability within modern classrooms. Traditional mathematics instruction has historically relied on lecture-based delivery, textbook-driven exercises, and emphasis on procedural fluency. Teachers using this approach often function as the sole source of knowledge, transmitting information to students who are expected to absorb and reproduce it. This model, while ensuring curriculum coverage and promoting discipline, often limits opportunities for critical thinking and creativity. Students in traditional classrooms are typically passive recipients of knowledge, with limited engagement in exploratory or collaborative learning activities. Moreover, the heavy reliance on static representations such as diagrams on the board or printed visuals in textbooks may hinder students' ability to grasp abstract mathematical relationships. Though this approach has been effective for certain learning outcomes, especially those related to basic skills and algorithmic procedures, it often falls short in promoting deep understanding, problem-solving, and the development of higher-order thinking skills.

In contrast, GeoGebra, an interactive mathematics software, transforms the learning environment by introducing dynamic visualization, real-time manipulation, and exploratory learning into mathematics instruction. Designed to integrate geometry algebra, calculus, and statistics into a unified platform, GeoGebra empowers both teachers and students to interact with mathematical concepts in a visual and hands-on manner. Unlike traditional static instruction, GeoGebra allows for immediate feedback, enabling learners to test hypotheses, observe the effects of changes in parameters, and engage with mathematics as an evolving, logical system rather than a set of fixed rules. This active engagement fosters a constructivist learning environment where students build their own understanding through experimentation and discovery, guided by teacher facilitation rather than direct transmission. The critical differences between GeoGebra and traditional teaching methods extend beyond pedagogy to their impact on student motivation and learning outcomes. Research has shown that students taught using GeoGebra tend to display increased interest in mathematics, improved conceptual understanding, and greater confidence in their problem-solving abilities. The software's capacity to accommodate visual, auditory, and kinesthetic learners supports differentiated instruction, which is difficult to achieve using traditional methods alone (Adedoyin & Bello, 2022). Moreover, GeoGebra enables students to see the connections between multiple representations of mathematical concepts such as graphs, equations, and numerical data hus deepening their understanding and retention. In traditional classrooms, such integrative learning experiences are often absent or limited by the constraints of chalk-and-talk teaching and paper-based materials. Despite the advantages of GeoGebra, it is important to recognize that its effectiveness is not guaranteed in all educational contexts. One of the major criticisms of technology-based instruction is the digital divide that exists in many schools, especially in developing countries or rural areas. Access to hardware, reliable internet, and electricity is still a barrier in many primary and secondary schools, limiting the implementation of software like GeoGebra. Furthermore, the successful use of GeoGebra requires teachers to be not only technologically proficient but also pedagogically innovative. Many educators trained under traditional systems lack the confidence or professional development opportunities to effectively integrate digital tools into their teaching. Resistance to change, time constraints, and rigid curricula further complicate the transition from traditional to technology-enhanced instruction. Therefore, while GeoGebra offers transformative potential, its implementation must be accompanied by adequate infrastructure, training, and policy support.

Another critical aspect to consider is the suitability of each approach for different learning goals. Traditional methods, despite their limitations, continue to serve important functions in mathematics education. For foundational arithmetic skills, procedural drills, and standardized test preparation, traditional teaching strategies may be more straightforward and time-efficient. Not all concepts require dynamic visualization, and in some cases, over-reliance on software tools may result in superficial learning if not properly guided. GeoGebra, while excellent for exploring geometric properties or understanding function behavior, may not always be necessary or practical for topics that require manual computation or symbolic reasoning. Thus, rather than viewing GeoGebra and traditional methods as mutually exclusive, a blended or hybrid approach may offer the most effective solution. Teachers can use GeoGebra to introduce or deepen understanding of complex topics, while still employing traditional methods to reinforce basic skills and ensure structured progression (Adedoyin & Bello, 2022

CHAPTER 3
RESEARCH METHODOLOGY

The research methodology explains how the stud was carried out, including how data was collected, analyzed, and how the experimental pat of the study was designed. This section covers the research design target population, sample and sampling technique, tools used for data collection, methods of analysis and ethical considerations.

3.1 Research Design

This quantitative, true experimental study measured the effect of Geogebra software on 5th-grade students' mathematics. Sixty-four Government Girls Higher Secondary School Kamra (GGHS)students were randomly assigned to control and experimental groups. The control group received traditional instruction, while the experimental group was taught using Geogebra software.

3.2 Population

The population of this study consisted of Grade V students enrolled in six public school branches in Attock, with a total of **N = 297**. Data regarding the schools and their enrollment was collected from the official Government of Punjab School Education Department website (https://schools.punjab.gov.pk/).

Table 3.1

Branches of GGHSS Attock Population

Branches of GGHSS Attock	**Population**
GGHSS people colony	49
GGHSS AMF Kamra	52
GGHSS ARF Kamra	48
GGHSS Dhok Fatah	64
GHSS No.2 Attock	34
GGHSS City No.1 Attock	49
Total	297

3.3 Sample and Sampling Technique

A purposive random sampling technique was employed to select participants for the study. The sample consisted of 64 Grade V students (n = 64) enrolled at Government Girls Higher Secondary School, Kamra. The students were divided into two equal groups: an experimental group (n = 32) and a control group (n = 32). Both groups were comparable in terms of age, grade level, and prior mathematical achievement to ensure equivalence. The purposive selection ensured that all participants had consistent exposure to the same curriculum and learning environment, while random assignment helped minimize selection bias between the groups.

3.4 Instruments

An achievement test was developed and administered as a pre-test and post-test to the experimental and control groups. Additionally, Geogebra software models assessed students' conceptual understanding, problem-solving abilities, and logical reasoning skills, including visualization tools, interactive exercises, and mathematical modelling.

3.4.1 Construction of the Test

Subject achievement tests were used for the pre-test and post-test, consisting of 50 multiple-choice questions.

3.4.2 Content Selection

Test items were derived from the curriculum objectives of Grade V mathematics to ensure alignment with the learning outcomes.

3.4.3 Question Types

The tests comprised multiple-choice questions (MCQs) to assess conceptual understanding, problem-solving skills, and computational accuracy.

3.4.4 Difficulty Level

Questions were formulated at varying levels of difficulty easy, moderate, and challenging to differentiate between students with different levels of understanding.

3.4.5 Test Format

Both tests included the same structure and number of items to allow for a reliable comparison of performance before and after the intervention.

3.5 Scoring procedure of the Test Item

A rubric tailored to the nature of the test items was developed to assess academic achievement. This rubric included a stepwise scoring system for each test item.

3.6 Selection of Test

The following factors were considered when selecting the text for the experimental study in the chosen school:

1. Consultation with 5th-grade teachers

2. The course syllabus prescribed by the Punjab Textbook Board

3. School examination constraints

4. The duration of the experiment is six weeks.

Based on these considerations, selected two chapters from the 5th-grademathematics textbook that the Punjab Textbook Board published. The chosen topics and their respective subtopics are as follows:

Chapter 1: Whole Numbers and Operations

1.1: Numbers up to one million

1.2: Multiplication and Division

1.3: Number Patterns

Chapter 2: Fractions

2.2: Addition and Subtraction of Fractions

2.3: Multiplication of Fractions

2.4. Division of Fractions

2.5. Procedure (Validity, Pilot Testing, Reliability)

3.7 Validity

The instrument was validated to ensure it accurately measured the intended outcomes. Content validity was confirmed by soliciting feedback from Mathematics subject matter experts, ensuring alignment with the study objectives. Based on this input, necessary revisions were made to enhance the instruments and improve their accuracy.

3.8 Reliability

The reliability of the instruments was assessed using the split half method to ensure consistence in measurement. Result from pre-test and Post-Test were compared to confirm the stability of the instrument over time. Achieving high reliability indicated that the instrument produced dependable and repeatable outcomes.

Table 3.2

Reliability of Achievement Test

Reliability Measure	Value
Spearman-Brown Coefficient	0.759

3.9 Pilot Testing

A pilot test was conducted on the students of grade V from Government Girls Higher Secondary School before the actual data collection phase to evaluate the instruments. This process helped to identify potential flaws and ensured that the instruments functioned as intended. The insights gained from pilot testing guided adjustments to enhance their overall effectiveness for the study.

3.9.1 Item Analysis

Based on pilot results, items were analyzed for difficulty index, discrimination index, and reliability coefficient. Items that were ambiguous or failed to discriminate effectively between high and low performers were revised or removed.

3.9.2 Finalization

After adjustments, the pre- and post-tests were finalized and administered under standardized conditions to the experimental and control groups.

3.9.3 Threats and Steps to Control These Threats

A threat is any internal or external factor that can harm safety, assets, or the achievement of objectives. In research, a threat is any condition or variable that can bias results and reduce the study's validity and reliability.

Table 3.3

Internal Threats

Threats	Steps To Control Threats
History	External events occurring during the study period (e.g., holidays, school events) could influence students' academic achievement. Control: Both groups were taught the same content and tested under 24 similar conditions, helping to mitigate external influences.
Selection Bias	Occurs when participants in different groups are not equivalent at the start. For example, one group might have more high-achieving students, which could influence outcomes independently of the treatment. Control: Use random assignment to ensure groups are comparable, or use matching to pair participants with similar characteristics across groups. Students dropping out from either group could skew results, especially if those who drop out have particular characteristics.
Testing	The pre-test may influence students' responses on the post-test, as they may remember the questions. Control: To reduce this threat, you could vary the sequence or format of post-test questions, while keeping content consistent.
Interaction of History and Treatment	Unique events occurring during the study period at this particular school might limit generalizability to other times or contexts.

Table 3.4

External Threats

Threats	Steps To Control Threats
Interaction of Selection and Treatment	The findings may not generalize to students outside the sampled school or Grade V level, as the sample may not represent the wider population. Control: Random sampling helps improve generalizability. Additionally, providing detailed descriptions of the sample and setting aided future researchers in assessing applicability to other contexts.
Interaction of Setting and Treatment	Results may be specific to the environment of the Government school Kamra may not generalize to other school settings. Control: Use consistent classroom settings and the same instructor for both groups to ensure the treatment's effects are measured without being overly influenced by specific environmental factors.
Interaction of History and Treatment	Unique events occurring during the study period at this particular school might limit generalizability to other times or settings. Control: The study period is relatively short (two months), which minimizes the likelihood of major external events affecting results. Documenting any significant external events can also assist in interpreting the findings
Interaction of Setting and Treatment	The results may be specific to the environment of Government Girls Higher Secondary School Kamra and may not generalize to other school settings.

3.10 Implementation Plan

The implementation of the experimental study was carried out using two different teaching approaches, GeoGebra software-based teaching and traditional teaching methods. The experiment focused on two Chapter of the 5th-grade mathematics curriculum.

3.10.1 Geogebra Software-Based Teaching

Geogebra, a dynamic mathematics software, was utilized to create an interactive learning environment where students could visualize and manipulate mathematical concepts. The implementation involved the following components: The software facilitates constructivist learning, allowing students to actively engage with mathematical concepts through manipulation and experimentation rather than passive reception of information (Almeida & Costa, 2025).

- Visualization of Fractions: Using Geogebra tools, fractions were represented as parts of shapes (e.g., circles, rectangles) to help students understand numerator and denominator concepts.
- Addition and Subtraction of Fractions: Interactive fraction bars and number lines were created in Geogebra to demonstrate addition and subtraction of fractions. Students could drag pieces to combine or remove fractions dynamically, promoting conceptual understanding.
- Multiplication of Fractions: Geogebra area model tool was used to illustrate fraction multiplication, showing students how to calculate the product of fractions by shading overlapping regions.
- Division of Fractions: Using the software, division of fractions was visualized by partitioning shapes and exploring reciprocal relationships, allowing students to interactively discover the rules.
- Classroom Procedure: Each lesson began with a brief introduction to the concept, followed by demonstrations using Geogebra. Students were then encouraged to practice on computers/tablets, solving interactive exercises. Immediate feedback was provided by the software and the teacher.

3.10.2 Traditional Teaching Method

The traditional teaching method involved traditional classroom instruction using chalk, board, textbooks, and printed worksheets. The implementation included:

- Lecture and Explanation: The teacher explained the concepts of fractions step by step, using verbal and visual cues on the blackboard.
- Demonstration of Operations: Examples of addition, subtraction, multiplication, and division of fractions were solved on the board while students observed and took notes.
- Practice Exercises: Students completed worksheets containing similar problems to reinforce learning. Peer discussion was encouraged to clarify doubts.
- Recap and Reinforcement: At the end of each lesson, the teacher summarized key points and solved additional examples to consolidate learning.

3.10.3 Integration and Comparison

The experimental study divided 64 students into two groups of 32 each:

- Experimental Group: Taught using GeoGebra software.
- Control Group: Taught using the traditional teaching method.

Both groups were taught the same topics 40–45 minute lessons. Pre-tests and post-tests consisting of MCQs and problem-solving tasks were conducted to measure academic achievement. Observations were recorded regarding student engagement, participation, and understanding. The implementation ensured that each teaching approach was delivered systematically, with attention to content coverage, instructional clarity, and active student involvement, allowing a fair comparison of the effectiveness of GeoGebra versus traditional teaching methods**.**

3.11 Data Collection

Academic achievement was assessed through pre-tests administered to the experimental and control groups before the intervention period. These tests focused on key concepts related to the curriculum. Academic achievement was then measured using post-tests administered to both groups immediately after the intervention. The pre-test was conducted to establish a baseline before the intervention. Geogebra Software learning techniques were implemented for the experimental group, while post-tests were used to evaluate immediate learning outcomes. Additionally, a retention test was administered two weeks after the post-test to assess long-term knowledge retention.

3.12 Data Analysis

Data were collected, analyzed, and interpreted. Quantitative data analysis techniques were used, including descriptive statistics (mean, and standard deviation), and inferential statistics were employed to test the hypothesis. An independent samples T-test was conducted to determine whether there was a significant difference in the post-test mathematics scores between students taught using Geogebra software and those taught using the traditional teaching method.

3.13 Ethical Considerations

Ethical considerations were strictly followed throughout the study. Informed consent was obtained from all participants before data collection. Participants were assured of confidentiality and their right to withdraw at any stage. The data collected were used solely for research purposes.

CHAPTER 4

DATA ANALYSIS AND INTERPRETATIONS

This chapter presents a comprehensive analysis of the collected data to examine the effect of Geogebra software on the academic achievement of primary school students in Math. The study utilized an experimental group, which experienced Geogebra software, and a control group, which received traditional instruction. Each group comprised 32 students. The evaluation was conducted through pretest and post-test scores. The analysis involves detailed descriptive and inferential statistics, graphical representations, and an in-depth discussion of the results. The main objective of this analysis is to determine whether Geogebra base learning strategies significantly enhance academic performance compared to traditional teaching methods. This chapter is organized into several sections, including descriptive and inferential statistics.

4.1 Descriptive Statistics

Descriptive statistics in experimental research summaries and organize data from control and experimental groups. They include measures like mean, median, standard deviation, and frequency. These statistics help assess group characteristics and track changes before and after an intervention. They provide a foundation for further inferential analysis.

Table 4.1

Mean scores and standard deviations of pretest and post-test of experimental group

Test	**N**	**Mean**	**Std. Deviation**
Pretest	32	24.6875	7.98562
Posttest	32	41.5625	7.03419

Table 4.1 shows the analysis of the pretest and post-test scores for 32 participants, revealing a significant improvement in academic performance following the intervention. The mean score on the pretest was 24.69 with a standard deviation of 7.99, indicating relatively low initial performance with moderate variability among students. After the intervention, the mean score increased to 41.56, with a standard deviation

instructional method or educational tool applied between the pretest and Post-test positively impacted learners' academic achievement. The decrease in standard deviation from pretest to Post-test also suggests a slight reduction in score variability, indicating that students’ performance became more consistent after the intervention. The results showed that the intervention effectively enhanced students’ academic performance. To confirm the statistical significance of this observed improvement, a paired samples t-test would be recommended.

Table 4.2

Mean scores and standard deviations of pretest and post-test of control group

Test	Mean	N	Std. Deviation
Pretest	24.6875	32	7.98562
Post-Test	28.8750	32	9.38341

Table 4.2 presents the descriptive statistics for the pretest and post-test scores of 32 students who participated in an educational intervention to improve academic performance. The mean pretest score was 24.69 with a standard deviati7.99, indicating moderate variation in students' initial performance levels. After the intervention, the mean post-test score increased to 28.88, reflecting an improvement of approximately 4.19 points, which suggests a positive effect of the intervention on academic achievement. However, the post-test standard deviation also increased to 9.38, indicating greater variability in students’ performance, possibly due to differences in how individuals responded to the intervention. The results imply that at the educational strategy or tool used was generally effective, although its impact varied among students. The consistency in the number of participants (N = 32) across both tests enhances the reliability of this comparison.

4.2 Inferential Statistics

Inferential statistics were employed to determine whether the differences observed between the groups were statistically significant. An independent samples t-test was conducted to compare the pretest and post-test scores of the experimental and control groups, providing insights into the effectiveness of GeoGebra-based instruction compared to traditional teaching methods.

Table 4.3

Mean Scores and Standard Deviations of Pretest and Post-test of Control Group

Comparison	Groups	t-value	p-value	Result
Pretest vs. Post-test (41.56)	Experimental Group	8.97	< 0.001	Statistically sigficant difference was found, indicating a notable improvement in academic achievement after the intervention.
Pretest vs. Post-test (28.88)	Control Group	1.92	0.059	No significant difference was observed, suggesting minimal change in academic performance without the intervention.

Table 4.3 presents the results of a statistical comparison between pretest and post-test scores for both experimental and control groups to evaluate the effectiveness of an educational intervention. The mean post-test score (41.56) in the experimental group was significantly higher than the pretest score, with a t-value of 8.97 and a p-value less than 0.001. This indicates a statistically significant improvement in academic achievement following the intervention, suggesting that the applied teaching method or tool had a positive and measurable effect on students' performance. In contrast, the control group, which did not receive the intervention, showed a more minor increase in mean post-test score (28.88) compared to the pretest, with a t-value of 1.92 and a p-value of 0.059. Since this p-value is greater than the conventional threshold of 0.05, the difference is not statistically significant, implying that the observed improvement in the control group may have occurred by chance and not due to any specific instructional strategy.

4.3 Retention Test

The retention test serves as a crucial component for evaluating the long-term impact of the instructional method. While the pretest and Post-test measure immediate learning gains, the retention test assesses how well students have retained the learned concepts over time after the instructional period has ended. The primary purpose of conducting a retention test is to determine whether students can maintain the mathematical knowledge and skills acquired using Geogebra software over an extended period without immediate reinforcement. This provides deeper insights into the effectiveness and sustainability of the teaching method used. This study administers the retention test to the same group of students (experimental and control) after a fixed time interval (e.g., 2–4 weeks after the post-test). The test items are similar in structure and content to the pretest and post-test but administered without prior revision. This setup ensures that the results reflect proper retention rather than short-term memory.

Table 4.4

Mean scores and standard deviations of retention test with Post-test of control group

Test	Mean	N	Std. Deviation
Retention test	28.3125	32	8.49074
post-test	28.8750	32	9.38341

The paired samples statistics table compares the Post-test and retention test scores for a sample of 32 students. The mean score of the Post-test is 28.88 with a standard deviation of 9.38, while the mean score of the retention test is slightly lower at 28.31 with a standard deviation of 8.49. The standard error of the mean is 1.66 for the Post- test and 1.50 for the retention test. This slight decrease in the mean score from the Post- test to the retention test suggests a slight decline in students' academic performance over time, which is expected as some forgetting may occur after the instructional period. However, the difference between the two means is minimal, indicating that students retained most of the knowledge gained during the learning process. To determine whether this decrease is statistically significant, a paired samples t-test would be required.

Table 4.5

Mean scores and standard deviations of retention test with post-test of experimental group

Test	Mean	N	Std.Deviation
Post-test	41.5625	32	1.24348
Retention test	41.8750	32	1.21794

The paired samples Statistics table presents the mean post-test and retention test scores for a sample of 32 students. The mean score of the post-test is 41.56 with a standard deviation of 7.03, while the retention test has a slightly higher mean of 41.88 with a standard deviation of 6.89. The standard error of the mean for the post-test is 1.24, and for the retention test, it is 1.22. These results indicate that students retained the mathematical concepts well over time, as the retention test scores are very close to, and slightly higher than, the post-test scores. The slight difference suggests no significant decline in performance, implying that the instructional method (e.g., Geogebra or traditional teaching) sustained student learning. Further analysis (like a Paired Samples t-test) would confirm if this difference is statistically significant.

CHAPTER 5

SUMMARY, FINDINGS, DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents a comprehensive overview and interpretation of the research findings. It begins with a summary of the entire research process, including the objectives, methodology, and results covered in the preceding chapters. It then outlines the major findings in relation to the research questions and provides a detailed discussion by comparing the results with existing literature. The chapter also includes numbered conclusions drawn directly from the findings and offers practical recommendations for teachers, school leaders, and curriculum developers.

5.1 Summary

Learning mathematics is key to developing students' critical thinking and problem-solving skills needed for advanced studies. At the primary level, a strong math education builds a foundation for future success. Traditional teaching, mainly lectures and memorization, often fails to promote deep understanding, causing disengagement, especially with abstract topics like fractions. Recently, technology has offered new solutions. GeoGebra, a dynamic math software combining algebra, geometry, and more, allows interactive, hands-on learning. It supports active knowledge building and is aligned with constructivist theory. However, its use in primary schools is still limited due to low awareness, training gaps, and a lack of resources. This quantitative, actual experimental study was conducted to measure the effect of GeoGebra software on the academic achievement of 5th-grade students in mathematics. The population comprised 297 Grade V students from various Government Girls Higher Secondary School branches in Attock. The ARF Kamra branch was selected as the sample site due to its larger student enrollment and better availability of technological resources such as mobile phones, computers, and tablets. The control group received instruction through traditional teaching methods, and the experimental group was taught using GeoGebra software. Academic achievement was assessed through both pre-tests and post-tests, with a retention test conducted two weeks later to evaluate long-term knowledge retention. The sample was divided equally, with 32 students in the control and experimental groups. A self-developed multiple. choice achievement test was used before and after the intervention to assess students' learning outcomes.

The selected math content covered two chapters from the Punjab Textbook Board's 5th-grade mathematics syllabus: Whole Numbers and Fractions. Lessons included subtopics such as numbers up to one million, multiplication and division, number patterns, and operations on fractions. A scoring rubric was developed for test evaluation, and the instruments were validated by subject experts for content accuracy. Reliability was confirmed using the split-half method, ensuring consistent results. Data were collected and analyzed using both descriptive and inferential statistics. The intervention spanned six weeks, with the first week dedicated to the pre-test, weeks two to six to the instructional phase, and the final week to the post-test. A retention test was conducted in the eighth week. A comparative analysis between the two instructional approaches clearly demonstrates that GeoGebra-based teaching is more effective than traditional teaching methods. The experimental group's consistent improvement reflects the power of technology-integrated learning to transform abstract mathematical ideas into concrete and visual forms. Through GeoGebra, students were able to explore mathematical concepts dynamically, visualize relationships, and manipulate figures in real time, leading to better comprehension and long-term retention. In addition to improving achievement scores, the use of GeoGebra also appeared to sustain students' motivation and engagement throughout the learning process. The interactive nature of the software encouraged active participation, enabling learners to construct their own understanding rather than passively receiving information from the teacher.

5.2 Findings

The findings of the research were:

1. The mean score of the experimental group increased from 24.69 (SD = 7.99) in the pretest to 41.56 (SD = 7.03) in the posttest. This 16.87-point gain highlights a substantial improvement in academic performance after using GeoGebra software.

2. The decrease in standard deviation from 7.99 to 7.03 indicates that not only did students' scores improve, but their performance also became more consistent and uniform across the group after the intervention.

3. A paired samples t-test conducted on the experimental group yielded a t-value of 8.97 with a p-value < 0.001, confirming that the improvement was statistically significant and unlikely due to chance.

4. The control group, which was taught through traditional methods, showed only a minor increase in mean scores from 24.69 (SD = 7.99) to 28.88 (SD = 9.38), marking a gain of just 4.19 points.

5. The rise in standard deviation from 7.99 to 9.38 suggests that the traditional teaching method led to more uneven learning outcomes, with some students benefiting while others did not.

6. The t-value of 1.92 and p-value of 0.059 for the control group's pretest and posttest comparison indicate that the improvement was not statistically significant, meaning the gains could be due to random variation.

7. The experimental group's significant improvement demonstrates that GeoGebra is an effective instructional tool in teaching primary mathematics, resulting in higher achievement and reduced score dispersion.

8. The minimal and non-significant improvement in the control group suggests that traditional teaching methods may not be sufficient to address the diverse learning needs of students, leading to greater inconsistency in achievement.

9. The data strongly supports integrating dynamic and interactive tools like GeoGebra in classroom instruction to enhance learning outcomes and promote educational equity.

10. These findings indicate that innovative pedagogical approaches, such as using GeoGebra, can significantly outperform conventional methods in improving academic achievement, advocating for their wider adoption in mathematics education at the primary level.

11. The retention test results indicate significant differences in long-term knowledge retention between the control and experimental groups.

12. In the control group, students' mean score slightly decreased from 28.88 (post-test) to 28.31 (retention test), reflecting a minor decline in performance, a natural outcome due to the absence of reinforcement after instruction. This suggests that traditional teaching methods may not fully support long-term retention

13. The experimental group taught using GeoGebra software showed a slight increase in mean score from 41.56 (post-test) to 41.88 (retention test). This slight improvement highlights the sustained effect of GeoGebra-based

instruction, suggesting that students not only retained the learned concepts but may have continued to internalise them even after the instructional period.

14. The experimental group's mean score significantly increased from 24.69 to 41.56 ($p < 0.001$), indicating a strong improvement due to GeoGebra- based instruction. In contrast, the control group showed a minor, non- significant gain from 24.69 to 28.88 ($p = 0.059$). This suggests that the observed improvement in the experimental group was not by chance. Therefore, H_{01} is rejected, confirming a significant difference in academic achievement between the two groups.

5.3 Discussion

The findings related indicate a significant difference in the retention of mathematical knowledge between the two groups. The control group's mean score decreased from 28.88 to 28.31, showing a slight decline in retained knowledge. In contrast, the experimental group's mean score increased from 41.56 to 41.88, reflecting stable or slightly improved retention. Therefore, H_{02} is rejected, as the data suggest that students taught using GeoGebra software retained mathematical. Discussion the results of this study provide compelling evidence supporting the use of GeoGebra software to improve academic achievement in primary-level mathematics. The significant improvement in the experimental group's performance from a pretest mean of 24.69 to a posttest mean of 41.56 demonstrates the software's ability to enhance students' mathematical understanding and learning outcomes. GeoGebra's dynamic features, which integrate geometry, algebra, and numerical operations, allow students to explore mathematical concepts through direct interaction and visualization. This interactive experience promotes deeper cognitive engagement, which is often lacking in traditional teaching approaches.

The comparative analysis between the experimental and control groups further strengthens the case for integrating technology into primary mathematics instruction. While the control group showed only a minor and statistically insignificant improvement, the experimental group exhibited a large and statistically significant gain. This suggests that traditional instruction alone may no longer meet the learning needs of today's students, especially when digital tools are readily available and proven effective. A similar conclusion was drawn by Hussein et al. (2020), who reported that students exposed to technology-enriched learning environments outperformed their peers in traditional settings. Another notable outcome of the study was the reduction in the standard deviation of scores within the experimental group, indicating improved consistency in performance. This points to the inclusive nature of GeoGebra, which appears to support diverse learners more equitably than conventional methods. Learners with different abilities could likely engage with mathematical ideas at their own pace and level of understanding through GeoGebra's intuitive and manipulable visual interface. This finding aligns with the work of Lim and Fatimah (2023), who found that digital mathematical tools help minimize performance gaps in mixed-ability classrooms by promoting individualized exploration. The increase in the mean score from the post-test (M = 41.56, SD = 7.03) to the retention test (M = 41.88, SD = 6.89) indicates that students retained the learned mathematical concepts effectively over time. This slight improvement suggests that the instructional approach used was successful in reinforcing students' understanding and promoting long-term learning. The minimal difference between the two mean scores demonstrates that there was no decline in performance, implying that the knowledge gained during the instructional phase remained stable. These results highlight the effectiveness of the teaching strategy in supporting continuous learning and ensuring that students maintained their academic achievement even after the completion of the instructional period.

Another important observation concerns long-term knowledge retention. Students who learned mathematics through GeoGebra not only retained the concepts for a longer period but also showed evidence of continued internalization of knowledge after the instructional period. This sustained retention may be attributed to the hands-on, exploratory experiences that GeoGebra provides, helping students construct durable mental representations of mathematical relationships. Conversely, students who were taught using traditional methods experienced a decline in retention, likely due to the lack of interactive reinforcement and practical application of concepts.

The findings of this research are consistent with previous studies that emphasize the benefits of technology integration in mathematics education. Prior research has shown that the use of GeoGebra enhances students' motivation, confidence, and problem-solving abilities, making learning more meaningful. Technology-supported instruction promotes deeper conceptual understanding and encourages collaborative learning environments that engage all students. These studies, along with the present findings, strongly suggest that technology-based instructional methods should be adopted more widely in primary education to enhance teaching effectiveness and learning outcomes. This discussion highlights that GeoGebra-based instruction provides a more effective and inclusive learning experience than traditional teaching methods. It transforms mathematics from a static, abstract subject into a dynamic and engaging one. By promoting active learning, visualization, and long-term retention, GeoGebra helps students develop a genuine interest in mathematics and builds a strong foundation for future academic success. The study underscores the importance of integrating digital tools into classroom instruction to meet the needs of 21st-century learners and to bridge the gap between traditional pedagogy and modern technological advancements.

5.4 Conclusions

This study demonstrates that GeoGebra software significantly enhances primary students' mathematics achievement compared to traditional methods, validating the research hypotheses and highlighting the potential of technology-based instruction to make learning more engaging, interactive, and effective. Based on the findings, the following conclusions were drawn.

1. The use of GeoGebra software helped students improve their mathematics performance, as shown by the large increase in their mean scores.
2. The decrease in standard deviation shows that students' learning became more consistent, meaning most students benefited equally from the software.
3. Traditional teaching helped students improve only a little in mathematics. The difference in scores also shows that some students learned more, while others did not learn much.
4. The results indicate that the control group taught through traditional methods showed only a small improvement, which was not statistically significant. This means that the slight increase in scores may have happened by chance and did not reflect strong academic progress.
5. The findings indicate that students who were taught with GeoGebra software retained their mathematical knowledge better than those taught with traditional methods. The slight increase in the experimental group's scores shows that GeoGebra helped students keep and strengthen their learning even after the teaching period.

6. Regarding H_{01}, which stated that no significant difference exists in the academic achievement in mathematics between primary-level students taught using GeoGebra software and those taught through traditional methods, the analysis revealed a substantial and statistically significant improvement in the experimental group's mean scores compared to the minimal, non-significant gain in the control group. These results provide strong evidence that GeoGebra-based instruction significantly enhances students' academic performance in mathematics. Thus, H_{01} is rejected.
7. Concerning H_{02}, which asserted that no significant difference exists in the retention of mathematical knowledge between students taught using GeoGebra software and those taught through traditional methods, the findings indicated that the experimental group not only maintained but slightly improved their scores in the retention test, whereas the control group experienced a decline. This demonstrates that GeoGebra-based instruction supports superior long-term retention of mathematical concepts. Therefore, H_{02} is also rejected.
8. GeoGebra-based instruction proved far more effective than traditional methods in enhancing achievement, sustaining engagement, and improving long-term retention in 5th-grade mathematics, validating the value of technology-integrated teaching for lasting and meaningful learning.

5.5 Recommendations of Study

This study explored how using Geogebra software may help primary students learn and remember mathematics better than traditional teaching methods Based on the conclusions, the following recommendations are proposed.

1. Based on conclusion 1, which showed that the use of GeoGebra software significantly improved students' mathematics performance, it is recommended that primary schools may integrate GeoGebra into regular mathematics instruction. Teachers may design lessons that utilize GeoGebra's interactive features to strengthen students' conceptual understanding.

2. Based on conclusion 2, which showed that the decrease in standard deviation reflects consistent learning across students, it is recommended that educators may employ GeoGebra to promote equitable learning outcomes. The software may be used to provide visual explanations, guided exploration, and collaborative learning experiences that support all learners equally.

3. Based on conclusion 3, which showed that the traditional teaching methods led to only minor improvement and inconsistent learning results, it is recommended that teachers may reduce reliance on lecture-based instruction. Instead, they incorporate technology-enhanced and student-centered strategies, such as GeoGebra-based activities, to engage all learners and improve overall performance.

4. Based on conclusion 4, which showed that the control group's small improvement was statistically insignificant, educational institutions may reassess the effectiveness of traditional pedagogies. It is recommended that teacher training programs emphasize the integration of innovative tools like GeoGebra and provide continuous professional development to build teachers' confidence and skills in digital pedagogy.

5. Based on conclusion 5, which showed that the students taught with GeoGebra demonstrated better long-term retention of mathematical knowledge, it is recommended that GeoGebra may be adopted as a regular reinforcement tool after formal lessons. Teachers can assign GeoGebra-based practice tasks or visual simulations to strengthen students' retention and conceptual mastery over time

5.6 Recommendations for Future Studies

Based on the study's findings, the following future recommendations may help enhance mathematics teaching and learning outcomes light of the study's findings, the following future recommendations are suggested:

1. Further studies may be carried out on larger groups and in different subjects to check the wider effect of GeoGebra on students' learning.

2. Further studies may compare traditional teaching with modern methods on larger groups of students to better understand how different approaches influence equal learning outcomes.

3. Future studies may be carried out with larger groups of students and longer teaching periods to see if the results of traditional methods become more effective over time.
4. Future studies may explore the use of GeoGebra with other subjects and grade levels to find out if similar positive effects on long-term retention can be achieved.

5. Future research may explore GeoGebra's effect on other mathematical topics beyond whole numbers and fractions.
6. Studies may be carried out in rural or under-resourced schools to see how GeoGebra works in different learning environment.

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APPENDICES

APPENDIX A: Lesson Plans for Geogebra Software (Experimental Group)

Lesson Plan:1

Topic: Whole Numbers and Operations

Grade: 5

Subject: Math

Chapter: Whole Numbers and Operations

Duration: 40 minutes

Introduction (5 minutes):

Greet students and introduce the topic using a few real-life examples involving large numbers (e.g., population, money).

Ask guiding questions:

What are whole numbers?

Where do we see large numbers in real life?

Development/Presentation (25 minutes):

Demonstration using Geogebra:

Open GeoGebra software and share screen or use projector.

Step 1: Use the "Input Bar" to show number line up to 1,000,000.

Step 2: Plot numbers like 10,000; 100,000; 1,000,000 and compare their placement.

Step 3: Demonstrate basic operations:

- Addition: Use sliders to create two numbers and add them.
- Subtraction: Show subtraction of smaller numbers from larger ones using the number line.
- Multiplication & Division: Use dynamic input boxes to enter numbers and show results with bar models or number lines.

Step 4: Explore number patterns (e.g., skip counting, sequences) using the sequence tool in GeoGebra.

Student Activity:

- Students will use computers/tablets with GeoGebra to:
- Perform two operations each (addition, subtraction, multiplication, division) using GeoGebra.
- Identify number patterns.

Conclusion (5 minutes):

Recap key points: What are whole numbers? How can we use GeoGebra to understand operations?

Ask students to reflect on how the software helped them understand math better.

Assign a small activity: "Create a number pattern using GeoGebra at home and bring a screenshot tomorrow.

Lesson Plan:2

Subject: Math
Grade: 5

Chapter: Whole Numbers and Operations
Topic: Numbers up to One Million
Duration: 40 minutes

Method: GeoGebra-Based Instruction

Objectives:

By the end of this lesson, students will be able to:

- Identify and read numbers up to one million.
- Place numbers correctly on a number line using GeoGebra.
- Compare and order large numbers visually.
- Understand place value up to the millions.

Lesson Structure:

Introduction (5 minutes):

- Begin with a brief discussion: “What is the largest number you’ve ever seen?”
- Introduce the topic: Numbers up to One Million.
- Briefly demonstrate the GeoGebra interface and explain its use for number visualization.

Step 1: Demonstration on GeoGebra (10 minutes)

- Open GeoGebra.
- Create a number line from 0 to 1,000,000.
- Mark 100,000; 500,000; and 1,000,000 on the line.
- Explain how numbers grow in place value (ones → tens → hundreds → thousands → lakhs → millions).

Step 2: Place Value Exploration (10 minutes)

- Use GeoGebra's input bar to break down numbers (e.g., 456,789 = 400,000 + 50,000 + 6,000 + 700 + 80 + 9).
- Display this with colored point markers.

Step 3: Class Activity (10 minutes)

- Ask students to use GeoGebra (on tablets/computers) to plot given numbers on a shared number line.
- Encourage them to explore comparing numbers by distance on the number line.

Conclusion (5 minutes):

- Recap key learning: What are the place values up to a million?
- Ask 2–3 students to summarize what they did in GeoGebra.
- Assign a homework task using GeoGebra to explore their own 6-digit number.

Lesson No:3

Grade: 5
Subject: Mathematics

Topic: Whole Numbers and Operations
Sub-topic: Numbers up to One Million
Duration: 40 minutes

Objectives:

By the end of the lesson, students will be able to:

- Use GeoGebra to explore place value in numbers up to one million.
- Visually manipulate and build large numbers using digital sliders and charts.
- Enhance number sense using interactive number lines.

Lesson Structure

Introduction (5 minutes):

- Launch GeoGebra and share the interface on projector/screen.
- Explain: "Today we will use GeoGebra to learn how to work with large numbers."

Development (30 minutes):

Step 1: Place Value Using Sliders (10 minutes)

- Open GeoGebra and create 6 sliders labeled: Hundred Thousands, Ten Thousands, Thousands, Hundreds, Tens, Units.
- Let students drag sliders to form different numbers.
- Ask: What number have you made? What is its expanded form?

Step 2: Interactive Number Line (10 minutes)

- Use the number line tool in GeoGebra.
- Mark numbers like 100,000 – 1,000,000.
- Students locate numbers like 456,000 and 789,999 on the number line.

Step 3: Place Value Blocks Simulation (10 minutes)

- Use images/tools of blocks representing place values.
- Build numbers by combining digital manipulatives.
- Students take turns creating numbers using the virtual blocks.

Conclusion (5 minutes):

- Ask: How did GeoGebra help us today?
- Recap how sliders and the number line made it easier to understand place values.
- Quick assessment: Students form a number using sliders and explain its value.

Lesson No :4

Grade: 5

Subject: Mathematics

Topic: Fractions

Sub-topic: Addition and Subtraction of Fractions

Duration: 40 Minutes

Teaching Method: Technology-Integrated (GeoGebra)

Objectives

By the end of this lesson, students will be able to:

- Understand how to add and subtract like and unlike fractions.
- Visualize fractions using dynamic fraction models in GeoGebra.
- Use GeoGebra tools to explore equivalent fractions.

Lesson Structure

Introduction (5 minutes)

- Greet students and introduce the topic.
- Ask a few warm-up questions:
  "What is a fraction?" "Can you give an example of ½ or ⅓?"
- Show a simple fraction model in GeoGebra (e.g., a pizza divided into parts).

Development (30 minutes)

Step 1: Demonstration (10 min)

- Show two fraction bars and demonstrate adding **½ + ¼** using visual models.
- Use the slider tool to adjust fractions and compare their size.

Step 2: Student Exploration (15 min)

- Give students tasks to complete on GeoGebra:
- Add: ⅓ + ⅓
- Subtract: ¾ − ½
- Find an equivalent fraction for ⅖
- Guide students to use color-coded bar models to compare and operate on fractions.
- Encourage students to discuss in pairs what they observe.

Step 3: Discussion (5 min)

- Ask volunteers to share what they found using GeoGebra.
- Reinforce understanding by showing a few common fraction problems on screen.

Conclusion (5 minutes)

- Summarize the key points: adding and subtracting fractions using visual aids.
- Ask exit questions:
  "How did GeoGebra help you understand fractions better?"
- Assign homework: Use GeoGebra at home to practice adding ⅔ + ⅖

lesson No:5

Introduction (5 minutes)

- Greet students and introduce the topic: *"Today we will learn how to add and subtract fractions using GeoGebra!"*
- Recall prior knowledge about:
  - Like and unlike denominators
  - Concept of numerator and denominator

Objectives

By the end of the lesson, students will be able to:

- Visually represent fractions using GeoGebra tools
- Add and subtract fractions with like and unlike denominators
  - Understand fraction operations through dynamic models

Lesson Development (25 minutes)

Step 1: Visualizing Fractions (5 minutes)

- Use GeoGebra's *Fraction Strip* or *Number Line* tools to represent simple fractions like ½, ⅓, ¼.

Step 2: Addition of Fractions (10 minutes)

- Model **like denominators** (e.g., ⅓ + ⅓ = ?):
- Show both fractions using visual bars
- Combine the shaded parts and count total shaded over the denominator
- Model **unlike denominators** (e.g., ½ + ⅓ =?):
- Use the *LCM* tool to find a common denominator
- Show equivalent fractions and then add

Step 3: Subtraction of Fractions (10 minutes)

- Model **like denominators** (e.g., ¾ − ¼ =?):
- Use fraction bars to subtract shaded parts
- Model **unlike denominators** (e.g., ⅔ − ¼ =?):
- Use LCM to equalize denominators
- Show equivalent fractions and subtract

Encourage students to practice with different examples on their own devices.

Conclusion (5 minutes)

- Recap key steps of adding and subtracting fractions
- Ask 2–3 oral questions for assessment
- Assign simple GeoGebra practice for homework

Lesson No:6

Topic: Multiplication of Fractions

Grade: 5
Subject: Mathematics

Duration: 40 minutes

Objectives:

By the end of the lesson, students will be able to:

- Visualize and understand multiplication of fractions.
- Use GeoGebra tools to represent and solve fraction multiplication problems.
- Develop conceptual clarity through interactive models.

Lesson Structure:

Introduction (5 minutes):

- Start with a discussion: *"Can we multiply parts of a whole? Let's explore using GeoGebra!"*
- Explain how digital tools help visualize abstract concepts.

Demonstration (10 minutes):

- Open **GeoGebra** (Geometry or Fractions tool).
- Demonstrate 12×23\frac{1}{2} \times \frac{2}{3}21×32 using area model:
- Shade a rectangle 1/2 horizontally and then 2/3 vertically.
- Overlapping area represents the product = 2/6 = 1/3.
- Repeat for 34×25\frac{3}{4} \times \frac{2}{5}43×52.

Guided Practice (10 minutes):

- Ask students to open GeoGebra on their own computers or tablets.
- Provide problems and guide them step-by-step:
- 23×34\frac{2}{3} \times \frac{3}{4}32×43
- 56×12\frac{5}{6} \times \frac{1}{2}65×21
- Observe and support as they use tools to shade, multiply, and interpret.

Independent Activity (5 minutes):

- Students solve 2 new problems using GeoGebra independently and save their models:
- 35×23\frac{3}{5} \times \frac{2}{3}53×32
- 12×38\frac{1}{2} \times \frac{3}{8}21×83

Conclusion (5 minutes):

- Discuss: *What did we learn through the model?*
- Ask students to share their screen and explain one solution.
- Homework: Create one GeoGebra model at home and take a screenshot.

Lesson No:7

Topic: Division of Fractions

Grade: 5
Subject: Mathematics

Duration: 40 minutes

Objectives:

By the end of this lesson, students will be able to:

- Understand the concept of dividing fractions.
- Divide fractions by whole numbers and other fractions.
- Apply the reciprocal rule to solve division problems involving fractions.

Lesson Structure:

Introduction (5 minutes):

- Ask review questions:
  "What is a fraction?"

  "What does division mean?"
- Introduce the topic with a real-life example:
  "If you have half a pizza and want to share it with 2 friends, how much does each get?"

Presentation/Explanation (10 minutes):

- Explain that dividing by a fraction is the same as multiplying by its reciprocal.
- 23÷14=23×41=83\frac{2}{3} \div \frac{1}{4} = \frac{2}{3} \times \frac{4}{1} = \frac{8}{3}32÷41=32×14=38
- Provide simple rules:
- **Keep → Change → Flip** (Keep the first fraction, Change ÷ to ×, Flip the second fraction).

Guided Practice (10 minutes):

- Solve examples on the board:
- 12÷14\frac{1}{2} \div \frac{1}{4}21÷41
- 35÷23\frac{3}{5} \div \frac{2}{3}53÷32
- 23÷2\frac{2}{3} \div 232÷2
- Use fraction strips or paper models for visual understanding. Student Activity (5 minutes):
- Students solve similar problems in pairs.
- Provide worksheets or write on board:
  45÷23, 56÷12\frac{4}{5} \div \frac{2}{3},\ \frac{5}{6} \div \frac{1}{2}54÷32, 65 ÷21
- Assessment (3 minutes):
- Oral questioning or quick written quiz (2 problems).

Conclusion (5 minutes):

- Summarize rules of fraction division.

- Homework: Solve 5 division of fraction problems in notebook.

Lesson Plan:8

Grade: 5
Subject: Math

Topic: Numbers up to One Million, Multiplication, Division, and Number Patterns
Duration: 40 minutes

Objective:

- Revise and memorize place value up to one million.
- Reinforce multiplication and division through visualization.
- Identify and extend number patterns using GeoGebra tools.

Introduction (5 mins):

- Ask students to recall the largest number they've learned.
- Brief discussion: "Where do we see large numbers in real life?" (e.g., population, money).

Lesson Structure (30 mins):

Place Value Grid Activity (GeoGebra):

- Use GeoGebra place value blocks to show numbers up to 1,000,000.
- Students drag and build numbers using visual base-ten blocks.

Multiplication & Division Visual Demo:

- Use the GeoGebra number line tool and array models to demonstrate 3-digit × 2-digit multiplication and long division.
- Let students perform 2 problems interactively.

Number Pattern Exploration:

- Use sliders in GeoGebra to show patterns (e.g., multiples of 5, 10, doubling sequences).
- Ask: "What's the rule?" and let students create their own patterns.

Conclusion (5 mins):

- Recap key revision points.
- Ask students to summarize what they visualized through GeoGebra.
- Homework: Practice with custom-made GeoGebra file at home (shared via link).

Lesson Plan:9

Grade: 5
Subject: Math

Topic: Addition, Subtraction, Multiplication, and Division of Fractions
Duration: 40 minutes

Objective:

- Use visual models to revise all fraction operations.
- Support conceptual clarity through interactive simulations.

Materials:

- Laptops/tablets with GeoGebra
- Fraction tools preloaded

Introduction (5 mins):

- Ask: "What does 1/2 + 1/4 look like?" Let students guess.
- Open a fraction bar model on GeoGebra.

Lesson Structure (30 mins):

Fraction Addition & Subtraction (10 mins):

- Use fraction bars to model problems like 2/5 + 1/5, 3/4 – 1/2.
- Show how like denominators are needed.

Fraction Multiplication (10 mins):

- Area model with shaded rectangles in GeoGebra.
- Example: 1/2 × 1/3 = ? (Show overlapping areas)**Division of Fractions (10 mins):**
- Use number line model to show how many 1/4s are in 1.
- Visualize division as repeated subtraction.

Conclusion (5 mins):

- Ask: "Which operation was easiest to visualize?"
- Encourage home practice using interactive GeoGebra fraction tool.

APPENDIX B: Lesson Plans for Traditional Teaching Method (Control Group)

Lesson Plan 1

Subject: Mathematics

Grade: 5

Chapter: Whole Numbers and Operations
Topic: Whole Numbers and Operations
Duration: 40 minutes

Objectives:

By the end of the lesson, students will be able to:

1. Identify and write whole numbers up to one million.
2. Accurately solve addition, subtraction, multiplication, and division problems involving whole numbers.
3. Recognize patterns in sequences of whole numbers.

Lesson Structure:

Introduction (5 minutes):

- Greet students and introduce the topic with examples (e.g., price tags, population figures).
- Write a few large numbers on the board and ask students to read them aloud.
- Ask: "What is the largest number you have ever seen?"

Development/Presentation (25 minutes):

Teacher Explanation and Board Work:

- **Step 1:** Define whole numbers and explain their properties.
- **Step 2:** Write examples on the board:
  - Large numbers (e.g., 456,789) and how to read/write them.
  - Operation problems (e.g., 345,123 + 123,456; 900,000 - 345,000).
- **Step 3:** Explain and solve step-by-step examples of all four operations.
- **Step 4:** Discuss number patterns:
  - E.g., increasing by 10,000; patterns in multiplication tables.

Student Practice:

- Students solve 5 questions from the board in their notebooks.
- Example:

1. Write the number 789,654 in words.

2. Add 234,000 and 156,000.
3. Subtract 111,111 from 999,999.
4. Multiply 234 × 56.
5. Identify the pattern: 1000, 2000, 3000, ___, ___.

Conclusion (5 minutes):

- Review key terms and summarize operations.
- Ask oral questions to reinforce the concepts.
- Assign homework: Solve a worksheet with mixed problems on whole numbers and patterns.

Lesson Plan 2:

Subject: **Math**

Grade: **5**
Chapter: **Whole Numbers and Operations**
Topic: **Numbers up to One Million**
Duration: **40 minutes**

Method: **Traditional (Chalkboard/Textbook-Based)**

Objectives:

By the end of this lesson, students will be able to:

- Read, write, and identify numbers up to one million.
- Understand the place value of each digit in 6-digit numbers.
- Compare and order large numbers.

Lesson Structure:

Introduction (5 minutes):

- Greet students and write a large number on the board: e.g., **892,541**.
- Ask: "Can anyone read this number aloud?"
- Briefly introduce the goal of the lesson: Understanding numbers up to one million.

Development (30 minutes):

Step 1: Explanation of Place Value (10 minutes)

- Write several 6-digit numbers on the board.
- Discuss the value of each digit based on its position.
- Use a place value chart to illustrate (Millions, Hundred Thousands, Ten Thousands, Thousands, Hundreds, Tens, Ones).

Step 2: Comparison and Ordering (10 minutes)

- Write three 6-digit numbers. Ask students to compare using >, <, or =.
- Arrange given numbers in ascending and descending order.

Step 3: Written Activity (10 minutes)

- Distribute worksheets.
- Students complete exercises like:
  - Fill in the place value table.
  - Read and write numbers in words.
  - Compare pairs of numbers.

Conclusion (5 minutes):

- Summarize today's lesson with a quick oral quiz:
  - "What is the value of 5 in 458,721?"
  - "Which number is greater: 789,654 or 798,456?"
- Assign textbook exercises for homework.

Lesson Plan:3

Grade: 5
Subject: Mathematics

Topic: Whole Numbers and Operations
Sub-topic: Numbers up to One Million
Duration: 40 minutes

Objectives:

By the end of the lesson, students will be able to:

- Read and write numbers up to 1,000,000.
- Identify the place value of digits in large numbers.
- Compare and order numbers up to one million.
- Represent numbers in standard, word, and expanded forms.

Lesson Structure

Introduction (5 minutes):

- Greet the students and write the number **345,678** on the board.
- Ask questions like:
- Can you read this number?
- What does the digit 4 represent?
  - Explain that today's topic is about understanding large numbers up to one million.

Development (30 minutes):

Step 1: Place Value Chart (10 minutes)

- Draw a place value chart up to 7 digits on the board.
- Use different numbers and have students identify place values.
- Example: 672,491 → 6 is in the hundred thousand place.

Step 2: Reading and Writing Numbers (10 minutes)

- Demonstrate reading numbers in words:
  701,324 → Seven hundred one thousand, three hundred twenty-four.
- Ask students to practice with their own numbers.

Step 3: Expanded Form and Comparison (10 minutes)

- Show examples of expanded form:
  345,678 = 300,000 + 40,000 + 5,000 + 600 + 70 + 8
- Compare numbers using <, >, = signs (e.g., 456,789 vs. 654,321)

Conclusion (5 minutes):

- Recap key concepts.
- Oral quiz:
  - What is the value of 6 in 653,211?
  - Which is greater: 789,654 or 798,654?
- Homework: Write 5 large numbers and show their place values and expanded forms.

Lesson No:4

Topic: Fractions

Grade: 5
Subject: Mathematics

Duration: 40 minutes

1. Introduction (5 minutes)

- Greet the students and write the topic *"Fractions"* on the board
- Ask students:
- What does a fraction represent?
- Who can draw a fraction on the board?
- **Objectives**

By the end of the lesson, students will be able to:

- Define and understand fractions as part of a whole
- Compare and create equivalent fractions using real-life examples and visuals

Lesson Development (25 minutes)

Step 1: Understanding Fractions (10 minutes)

- Explain definition of a fraction using real-life examples (pizza slices, chocolate bars)
- Introduce numerator and denominator with visuals on the board
- Show physical cut-outs of ½, ⅓, ¼

Step 2: Equivalent Fractions (10 minutes)

- Draw circles or rectangles on the board showing how ½ = 2/4 = 4/8
- Ask students to color or shade parts in their notebooks or with cut-outs

Step 3: Comparing Fractions (5 minutes)

- Write two fractions on the board and use LCM to compare
- Use real-world context (e.g., ½ of a cake vs ⅓ of a cake)

Conclusion (5 minutes)

- Review the concepts taught: parts of a fraction, equivalence, comparison
- Oral questions:
  - What is the numerator?
  - Is 2/4 equal to ½? Why?
- Assign homework: Draw and label 4 different fractions in notebooks

Lesson Plan 5:

Topic: **Addition and Subtraction of Fractions**

Grade: **5**
Subject: **Mathematics**

Duration: **40 minutes**

Introduction (5 minutes)

- Welcome students and write the topic on the board.
- Quick revision: What is a fraction? What is a numerator and denominator?

Objectives

By the end of this lesson, students will be able to:

- Add and subtract fractions with like and unlike denominators
- Solve real-life problems involving fractions
- Understand the concept of equivalent fractions and LCM

Materials Required

- Chalk/Whiteboard and markers
- Fraction circles/strips (physical models)
- Textbooks and notebooks

Lesson Development (25 minutes)

Step 1: Addition of Fractions (10 minutes)

- **Like denominators:**
  - Write examples like $\frac{2}{5} + \frac{1}{5} = ?$
  - Show using fraction strips or diagrams
- **Unlike denominators:**
  - Example: $\frac{1}{2} + \frac{1}{3}$
  - Teach how to find LCM, convert to equivalent fractions, and then add

Step 2: Subtraction of Fractions (10 minutes)

- **Like denominators:**
  - $\frac{3}{4} - \frac{1}{4} = ?$ (use board and visual aids)
- **Unlike denominators:**
  - $\frac{5}{6} - \frac{1}{3} = ?$ (Explain using steps: LCM, equivalent fractions, subtract)

Step 3: Practice (5 minutes)

- Give 3–4 problems to solve in notebooks

Conclusion (5 minutes)

- Review main rules
- Emphasize LCM and equivalent fractions
- Give homework: 5 questions from textbook

Lesson No:6

Topic: Multiplication of Fractions

Grade: 5

Subject: Mathematics

Duration: 40 minutes

Objectives:

By the end of the lesson, students will be able to:

- Understand the concept of multiplying fractions.
- Multiply proper and improper fractions.

- Solve word problems involving multiplication of fractions.

Lesson Structure:

Introduction (5 minutes):

- Greet the students and introduce the topic.
- Ask questions like:
  "What happens when we multiply whole numbers? Can we multiply fractions too?"
- Use real-life examples (e.g., *half of 1/4 pizza*).

Presentation/Explanation (10 minutes):

- Define multiplication of fractions (Numerator × Numerator, Denominator × Denominator).
- Show examples on board:
  - 23×45=815\frac{2}{3} \times \frac{4}{5} = \frac{8}{15}32×54=158
  - 56×34=1524→58\frac{5}{6} \times \frac{3}{4} = \frac{15}{24} \rightarrow \frac{5}{8}65×43=2415→85
- Explain with fraction strips or a paper diagram for visual aid.

Practice/Activity (15 minutes):

- Give students practice problems to solve individually and in pairs:
  - 12×23\frac{1}{2} \times \frac{2}{3}21×32
  - 35×47\frac{3}{5} \times \frac{4}{7}53×74
  - Solve 1–2 word problems.

Assessment (5 minutes):

- Ask students to solve 2 problems on the board.
- Use a short quiz or oral questions to evaluate understanding.

Conclusion (5 minutes):

- Review key points.
- Ask students to explain in their own words how to multiply fractions.
- Give homework: Solve 5 multiplication fraction problems.

Lesson No:7

Topic: Division of Fractions

Grade: 5

Subject: Mathematics

Duration: 40 minutes

Objectives:

By the end of this lesson, students will be able to:

- Understand the concept of dividing fractions.
- Divide fractions by whole numbers and other fractions.
- Apply the reciprocal rule to solve division problems involving fractions.

Lesson Structure:

1. Introduction (5 minutes):

- Ask review questions:
  "What is a fraction?"

  "What does division mean?"
- Introduce the topic with a real-life example:
  "If you have half a pizza and want to share it with 2 friends, how much does each get?"

Presentation/Explanation (10 minutes):

- Explain that dividing by a fraction is the same as multiplying by its reciprocal.

  23÷14=23×41=83\frac{2}{3} \div \frac{1}{4} = \frac{2}{3} \times \frac{4}{1} = \frac{8}{3}32÷41=32×14=38
- Provide simple rules:
- **Keep → Change → Flip** (Keep the first fraction, Change ÷ to ×, Flip the second fraction).

Guided Practice (10 minutes):

- Solve examples on the board:
  - 12÷14\frac{1}{2} \div \frac{1}{4}21÷41
  - 35÷23\frac{3}{5} \div \frac{2}{3}53÷32
  - 23÷2\frac{2}{3} \div 232÷2
- Use fraction strips or paper models for visual understanding.

4. Student Activity (5 minutes):

- Students solve similar problems in pairs.
  - Provide worksheets or write on board:
    45÷23, 56÷12\frac{4}{5} \div \frac{2}{3},\ \frac{5}{6} \div \frac{1}{2}54÷32, 65 ÷21

Assessment (3 minutes):

- Oral questioning or quick written quiz (2 problems).

Conclusion (5 minutes):

- Summarize rules of fraction division.
- Clarify common mistakes (e.g., forgetting to flip the divisor).
- Homework: Solve 5 division of fraction problems in notebook.

Lesson No:8

Grade: 5
Subject: Math

Topic: Addition, Subtraction, Multiplication, and Division of Fractions
Duration: 40 minutes

Objective:

- Revise all fraction operations.
- Enhance memorization using written and oral strategies.

Materials:

- Fraction charts, flashcards, whiteboard, notebooks

Introduction (5 mins):

- Oral drill of fraction definitions and equivalents.
- Ask students to give real-life examples involving fractions.

Lesson Structure (30 mins):

Review Table (10 mins):

- On the board, make a chart with key rules:
- Same denominator → add/subtract numerator
- Multiply numerators & denominators
- Reciprocal method for division

Conclusion (5 mins):

- Quick oral review: “Say the rule for…”
- Written exit slip with 2 short questions (to check memorization).

Lesson No:9Grade: 5
Subject: Math

Topic: Addition, Subtraction, Multiplication, and Division of Fractions
Duration: 40 minutes

Objective:

- Revise all fraction operations.
- Enhance memorization using written and oral strategies.

Materials:

- Fraction charts, flashcards, whiteboard, notebooks

Introduction (5 mins):

- Oral drill of fraction definitions and equivalents.
- Ask students to give real-life examples involving fractions.

Lesson Structure (30 mins):

Review Table (10 mins):

- On the board, make a chart with key rules:
  - Same denominator → add/subtract numerator
  - Multiply numerators & denominators
  - Reciprocal method for division

Conclusion (5 mins):

- Quick oral review: "Say the rule for…"
- Written exit slip with 2 short questions (to check memorization).

APPENDIX C: Table of Specification (TOS) for the Achievement Test

Table 7.3-1:

Content Areas	Knowledge (40%	Comprehension (30%)	Application (20%)	Analysis (10%)	Total (100%)
Whole Numbers	6	5	3	1	15
Addition & Subtraction	4	3	2	1	10
Multiplication & Division	4	3	2	1	1
Fractions	6	4	3	2	15
Total Questions	20	15	10	3	50

Rubric for MCQs (Academic Achievement Assessment)

Score Range	Performance Level
90 – 100% (45 – 50 correct answers	Excellent
80 – 89% (40 – 44 correct answers)	Very Good
70 – 79% (35 – 39 correct answers)	Good
60 – 69% (30 – 34 correct answers)	Satisfactory
50 – 59% (25 – 29 correct answers)	Needs Improvement
Below 50% (0 – 24 correct answers)	Unsatisfactory

Pre-test and Post-test MCQs

This achievement test is developed by the researcher to measure students' academic achievement in the context of leaning through Geogebra Software. The test specifically assesses students' understanding of Grade 5 Math concepts, with a structure aligned with key learning objectives. The test consists of 50 multiple-choice questions (MCQs) aligned with the Grade 5 Math

curriculum, covering:

Unit 1: Whole Numbers &Operations Unit 2: Fraction

This test serves as both a pre-test and post-test to evaluate students' academic achievements before and after the intervention.

Grade: 5th

Chapters: Whole Numbers &Operations and Fraction Total Marks: 50

Time: 1 hour

Focus: Academic Achievement

Class:5th Subject: Math

Chapters: Whole Numbers & Operations Fraction

Total Marks:50

Encircle the correct answer.

1. Which is the smallest whole number?

a) 0

b) 1

c) 2

d) 3

2. The sum of 234 and 456 is:

a) 680

b) 690

c) 700

d) 710

3. 45 × 0 =?

a) 0

b) 45

c) 1

d) 450

4. What is the place value of 7 in 7,321?

a) 7

b) 70

c) 700

d) 7,000

5. The product of 12 × 5 is:

a) 50

b) 55

c) 60

d) 65

6. Which number is even?

a) 11

b) 25

c) 34

d) 77

7. 100 ÷ 10 =?

a) 10

b) 20

c) 30

d) 50

8. The successor of 199 is:

a) 198

b) 200

c) 199

d) 201

9. $3 \times 4 \times 5 =?$

a) 50

b) 60

c) 70

d) 80

10. What is 10 more than 85?

a) 75

b) 85

c) 95

d) 100

11. 1,000 – 500 =?

a) 400

b) 500

c) 600

d) 700

12. The predecessor of 800 is:

a) 799

b) 801

c) 802

d) 798

13. $9 \times 9 =?$

a) 72

b) 81

c) 90

d) 99

14. 2,000 + 3,000 =?

a) 4,000

b) 5,000

c) 6,000

d) 7,000

15. What is ½ of 100?

a) 20

b) 50

c) 75

d) 100

16. 15 ÷ 3 =?

a) 3

b) 5

c) 7

d) 9

17. The smallest odd number is:

a) 0

b) 1

c) 2

d) 3

18. 125 × 1 =?

a) 0

b) 1

c) 125

d) 150

19. The sum of 4, 7, and 9 is:

a) 15

b) 18

c) 20

d) 21

20. 500 ÷ 5 =?

a) 50

b) 100

c) 150

d) 200

21. The largest 3-digit number is:

a) 100

b) 500

c) 999

d) 1,000

22. If you multiply any number by 1, the answer is:

a) 0

b) 1

c) The number itself

d) 10

23. 80 + 20 = ?

a) 90

b) 100

c) 110

d) 120

24. The LCM of 4 and 6 is:

a) 8

b) 10

c) 12

d) 14

25. 600 – 100 =?

a) 400

b) 500

c) 600

d) 700

26. Which of the following is a fraction?

a) 3

b) ½

c) 5

d) 10

27. What is ½ + ½?

a) ½

b) 1

c) 2

d) ¼

28. Which fraction is equivalent to 2/4?

a) 1/2

b) 2/3

c) 3/4

d) 4/5

29. Which is the numerator in the fraction 3/7?

a) 3

b) 7

c) 10

d) 1

30. What is 3/4 – 1/4?

a) 1/4

b) 2/4

c) 3/4

d) 4/4

31. What is $\frac{2}{3} \times 3$?

a) 2

b) 3

c) 4

d) 6

32. What is the denominator in 5/9?

a) 5

b) 9

c) 14

d) 4

33. What is $\frac{1}{4} + \frac{1}{4} + \frac{1}{4}$?

a) 1/2

b) 3/4

c) 2/4

d) 4/4

34. Which fraction is greater?

a) 1/3

b) 2/3

c) 1/4

d) 1/5

35. Which of these is an improper fraction?

a) 4/5

b) 6/7

c) 9/8

d) 2/3

36. Convert 5/2 into a mixed fraction.

a) 2 ½

b) 3 ½

c) 4 ½

d) 1 ½

37. What is ½ of 10?

a) 2

b) 4

c) 5

d) 6

38. Which fraction is equivalent to 4/8?

a) 1/4

b) ½

c) 3/4

d) 2/3

39. The fraction 7/7 is equal to:

a) 0

b) 1

c) 2

d) 7

40. What is ¾ × 2?

a) 1 ½

b) 2

c) 2 ½

d) 3

41. Which of the following is the smallest fraction?

a) 1/2

b) 1/4

c) 1/3

d) 1/5

42. Convert 9/4 into a mixed number.

a) 2 ¼

b) 2 ½

c) 2 ¾

d) 3

43. What is ⅘ – ⅖?

a) 2/5

b) 3/5

c) 1/5

d) 4/5

44. 1/6 + 1/6 =?

a) 1/3

b) 2/6

c) 1/4

d) 1/2

45. The fraction 15/5 is equal to:

a) 2

b) 3

c) 4

d) 5

46. What is ⅚ ÷ 2?

a) 2/6

b) 3/6

c) 5/12

d) 6/10

47. Which fraction is greater than 1/2?

a) 1/4

b) 1/3

c) 3/4

d) 1/5

48. What is the simplest form of 6/12?

a) 3/4

b) ½

c) 2/3

d) 1/4

49. What is ⅜ + ⅜-?

a) 3/4

b) 5/8

c) 6/8

d) 1/2

50. Which fraction is equal to 1?

a) 3/4

b) 5

c) 5/6
d) 5

1	A	2	B	3	A	4	D	5	C
6	C	7	A	8	B	9	B	10	C
11	B	12	A	13	B	14	B	15	B
16	B	17	C	18	D	19	B	20	C
21	C	22	B	23	C	24	B	25	A
26	B	27	B	28	A	29	A	30	B
31	A	32	C	33	B	34	B	35	C
36	A	37	C	38	B	39	B	40	D
41	D	42	A	43	B	44	A	45	B
46	B	47	c	48	B	49	B	50	B