# USE OF GEOGEBRA IN ENHANCING STUDENTS' CONCEPTUAL UNDERSTANDING OF CIRCLE THEOREMS: AN ACTION RESEARCH STUDY

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A Dissertation

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AN ABSTRACT

of the dissertation of *Purna Bahadur Kshetri* for the degree *of Master of Education in Mathematics Education* presented on *28 November 2025* entitled *Use of Geogebra in Enhancing Students' Conceptual Understanding of Circle Theorems: An Action Research Study.*

APPROVED BY

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Asst. Prof. Indra Mani Shrestha
Dissertation Supervisor

This research study aimed to determine how GeoGebra can improve the Grade 10 students' conceptual understanding of circle theorems. The research was motivated by the consistent decline in the mathematics performance of the students in Nepal's Secondary Education Examination (SEE) by the Ministry of Education (MOE, 2016). As a subject teacher and researcher, I created a 15-day intervention that employed one of the ICT tools, GeoGebra, to examine how the simultaneous visualization through technology helped in motivating, reasoning, and understanding the students. The study was conducted within 15 days at an Institutional English Boarding School in the Kaski District, in which 32 students were involved. I purposely selected six students as key participants who had to be very different from each other to watch carefully how each learner interacted with GeoGebra and how each one grasped the circle theorems valuation, and at the same time, to give all 32 students full intervention and an equal chance to learn.

I used an interpretivist paradigm with a qualitative data approach, used pre- and post-tests, observed students in the classroom, used parts of reflective journals, and interviewed six purposefully sampled students who vary in ability level. The findings displayed specific progress in the way students improved their conceptual understanding, the ability to perform well on tests, and the way they engaged with and felt about geometry. They showed that they could argue better, and they could read a

diagram more correctly about theorems of circles. When employing thematic analysis, I could interpret those changes by looking at what students did with GeoGebra: they moved objects, they tested theorems, they perceived relationships, and they developed significance as a result of their work in groups. These creation of meaning processes showed how lively settings for math helped learners to move away from just memorizing theorems to knowing in a deeper way why they work. The research found that GeoGebra helps teaching circle theorems by making the learners understand more, encouraging them to ask questions and answers, and fostering a good attitude. It also changed how I, as a teacher, used to be. I moved from being a person who only told to a person who helped learners find their own answers and allowed them to make a classroom where different ones play a part. Findings from this study reflect the importance of GeoGebra tools in mathematics classes, listening to lessons on GeoGebra pedagogy, and using GeoGebra in lessons based on the curriculum. Another research might build on this work with more detailed, extended time frames to determine the amount that persisted, in comparison with lessons that involved computers and lessons that didn't, and how useful GeoGebra is in other areas of math, such as when employing Sets, Algebra, Transformations, and Coordinate Geometry.

…………………………. 28 November 2025

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शोध सार

गणित विषयको स्नातकोत्तर डिग्रीको लागि पूर्ण बहादुर क्षेत्रीको शोध प्रबन्धको शीर्षक "वृत्तका साध्यहरूमा विद्यार्थीहरूको अवधारणात्मक बोध अभिवृद्धि गर्न जिओजेब्राको प्रयोग एक कार्यमुलक अनुसन्धान" १३ मङसिर २०८२ मा प्रस्तुत गरिएको थियो।

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उप. प्रा. श्री इन्द्र मणि श्रेष्ठ
शोध निर्देशक

प्रस्तुत अनुसन्धानको उद्देश्य कक्षा १० का विद्यार्थीहरूको वृत्तसम्बन्धी साध्यहरूमा अवधारणात्मक बोध अभिवृद्धि गर्न जिओजेब्राले कसरी सहयोग पु¥याउन सक्छ भन्ने कुरा पत्ता लगाउनु थियो । यस अनुसन्धानको प्रेरणा नेपालमा माध्यमिक शिक्षा परीक्षामा विद्यार्थीहरूको गणितीय उपलब्धिमा देखिँदै आएको निरन्तर गिरावट (शिक्षा मन्त्रालय, २०१६) बाट प्राप्त भएको हो । विषय शिक्षक तथा अनुसन्धानकर्ताको हैसियतले १५ दिनको एक कार्यमुलक कार्यक्रम तयार पारियो जसमा सूचना तथा सञ्चार प्रविधिका उपकरणहरूमध्ये जिओजेब्रा प्रयोग गरिएको थियो । यस अध्ययनले प्रविधिमार्फत हुने समसामयिक दृश्यीकरणले विद्यार्थीहरूको प्रेरणा, तर्कशक्ति तथा बोध क्षमतामा कसरी सहयोग पु¥याउँछ भन्ने कुराको परीक्षण गरियो । प्रस्तुत अध्ययन कास्की जिल्लाको एक संस्थागत अंग्रेजी माध्यमको विद्यालयमा १५ दिनसम्म परीक्षण गरी समापन गरिएको थियो जसमा जम्मा ३२ जना विद्यार्थी सहभागी भएका थिए । तीमध्ये छ जना विद्यार्थीहरूलाई उद्देश्य मुताविक मुख्य सहभागीका रूपमा चयन गरिएको थियो जसले एक–अर्काभन्दा धेरै फरक क्षमता राख्थे ताकि प्रत्येक विद्यार्थीले जिओजेब्रासँग कसरी अन्तरक्रिया गर्छन् र वृत्तका साध्यहरूको मूल्याङ्कन कसरी बुझ्छन् भन्ने कुरा सूक्ष्म रूपमा अवलोकन गर्न सकियोस् भन्ने उदेश्य राखिएको थियो । यसका साथै सबै ३२ जना विद्यार्थीलाई जिओजेब्रा प्रयोगमा पूर्ण स्वतन्त्रता दिइएको थियो र विद्यार्थीहरुले समान रूपमा सिक्ने अवसर पाएका थिए ।

प्रस्तुत शोधमा व्याख्यात्मक प्रतिमानअन्तर्गत गुणात्मक अनुसन्धान विधि अपनाइएको छ । तथ्याङ्क सङ्कलनका लागि पूर्व–परीक्षण र पश्चात–परीक्षण, कक्षा अवलोकन, प्रतिबिम्बात्मक

जर्नलका अंशहरू तथा क्षमताका आधारमा फरक–फरक छ जना उद्देश्यपूर्वक चयन गरिएका विद्यार्थीहरूसँग अन्तर्वार्ता लिइयो । अध्ययनका निष्कर्षहरूले विद्यार्थीहरूको अवधारणात्मक बोध, परीक्षणमा राम्रो प्रदर्शन गर्ने क्षमता र ज्यामितिप्रति उनीहरूको संलग्नता तथा दृष्टिकोणमा उल्लेखनीय सुधार देखाएको पाइयो । विद्यार्थीहरूले वृत्तका साध्यहरूबारे राम्रो तर्क प्रस्तुत गर्न सके र साध्यहरूका चित्र तथा ज्यामितिय आकृतिहरूलाई अझ सही रूपमा पढ्न सक्षम भए । थीमेटिक विश्लेषण प्रयोग गर्दा जिओजेब्राका माध्यमबाट विद्यार्थीहरूले गरेका क्रियाकलापहरू जस्तै ज्यामितिय आकृतिहरू सार्न, साध्यहरू परीक्षण गर्न, सम्बन्धहरू पहिचान गर्न तथा समूह कार्यमार्फत अर्थ निर्माण गर्न सिके र त्यसबाट परिवर्तनहरूको व्याख्या गर्न सके । यी अर्थ निर्माण प्रक्रियाहरूले गणित शिक्षणमा सक्रिय र जीवन्त वातावरण निर्माण गर्नृका साथै केवल साध्यहरू कण्ठस्थ गर्ने अभ्यासबाट विद्यार्थीहरूलाई गहिरो बोधतर्फ कसरी उन्मुख गराउँछ भन्ने कुरा प्रस्ट भयो । प्रस्तुत अनुसन्धानले जिओजेब्राबाट वृत्तका साध्यहरू सिकाउन विद्यार्थीहरूको बोध अभिवृद्घि गर्ने एवम् प्रश्न–उत्तरमा सक्रिय बनाउने तथा सकारात्मक सिकाइ दृष्टिकोण विकास गराउन सफल भएको निष्कर्ष निकालेको छ । यसले शिक्षकको भूमिकामा पनि परिवर्तन ल्याएको अनुभव गरायो । साथै शिक्षक केवल जानकारी दिने व्यक्तिबाट विद्यार्थीहरूलाई आफै उत्तर खोज्न सहयोग गर्ने सहायक शिक्षकको भूमिकामा रूपान्तरण गरायो जसले समावेशी कक्षाको वातावरण सिर्जना ग¥यो ।

प्रस्तुत अध्ययनका निष्कर्षहरूले गणित कक्षामा जिओजेब्रा उपकरणहरूको महत्व जिओजेब्रामा आधारित शिक्षण पद्घतिमा तालिम तथा पाठ्यक्रमअनुसार जिओजेब्रा प्रयोगको आवश्यकता उजागर गर्दछ । भविष्यका अनुसन्धानहरूले यस अध्ययनलाई विस्तार गर्दै लामो समयावधिमा यसको प्रभाव कति टिकाउ रहन्छ भन्ने कुरा कम्प्युटर प्रयोग गरिएको र नगरिएको कक्षाहरूबीचको तुलना तथा समूह, बीजगणित, स्थानान्तरण र निर्देशाङ्क ज्यामिति जस्ता अन्य गणितीय क्षेत्रहरूमा जिओजेब्राको उपयोगिताको अध्ययन गर्न सक्नेछन् ।

.......................... १३ मङसिर २०८२

पूर्ण बहादुर क्षेत्री

उपाधि उम्मेद्वार

This dissertation entitled *Use of Geogebra in Enhancing Students' Conceptual Understanding of Circle Theorems: An Action Research Study*, presented by *Purna Bahadur Kshetri* on *28 November 2025*.

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Prof. Bal Chandra Luitel, PhD

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I understand and agree that my dissertation will become a part of the permanent collection of the Kathmandu University Library. My signature below authorizes the release of my dissertation to any reader upon request for scholarly purposes.

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Purna Bahadur Kshetri

Degree Candidate

DECLARATION

I hereby declare that this dissertation is my original work, and it has not been submitted for candidature for any other degree at any other university.

…………………………. 28 November 2025

Purna Bahadur Kshetri

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# DEDICATION

This dissertation is solely dedicated …

To my parents, Chandra Bahadur Kshetri and Radhika Kshetri, a source of inspiration and motivation

To my loving better-half, Laxmi Karki Kshetri, and my little angel, Prekshya Kshetri, whose ever-consistent guidance and encouragement shaped the direction of my endeavors.

&

To all the educators who have taken up the high calling of the teaching profession and are making diligent efforts toward changing and innovating pedagogic practices.

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I also thank Asst. Prof. Binod Prasad Pant, PhD, Head of the STEAM Education department, my internal course supervisor, and the teacher of teachers, for his kind review and gentle help, which made my work much easier and shorter. My deepest thanks go to Prof. Bal Chandra Luitel, PhD, the Dean of the School of Education, for his kind encouragement and invaluable feedback.

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# ABBREVIATIONS

| | |
|---|---|
| AFL | Assessment for Learning |
| BLE | Basic Level Examination |
| CDC | Curriculum Development Centre |
| CEDRD | Center for Education and Human Resource Development |
| COVID | Coronavirus Disease |
| CRMT | Culturally Responsive Mathematics Teaching |
| DDLE | Data, Discussion, Literature, and Experience |
| DoL | Department of Labor |
| ERO | Education Review Office |
| FGD | Focus Group Discussion |
| IBL | Inquiry-Based Learning |
| ICT | Information and Communication Technology |
| KU | Kathmandu University |
| KUSOED | Kathmandu University School of Education |
| LCR | Learning Centre Research |
| MEd | Master of Education |
| MKO | More Knowledgeable Other |
| MoE | Ministry of Education |
| MoEST | Ministry of Education, Science, and Technology |
| NASA | National Assessment of Student Achievement |
| NCTM | National Council of Teachers of Mathematics |
| PBK | Purna Bahadur Kshetri |
| PBL | Project Based Learning |
| SAMP | Sainik Awasiya Mahavidyalaya, Pokhara |
| SEE | Secondary Education Examination |
| SLC | School Leaving Certificate |
| STEAM | Science, Technology, Engineering, Arts, and Mathematics |
| STEM | Science, Technology, Engineering, and Mathematics |
| TPACK | Technological Pedagogical and Content Knowledge |
| ZPD | Zone of Proximal Development |

LIST OF FIGURES

# CHAPTER I
# INTRODUCTION

This research study, titled "Use of GeoGebra in Enhancing Students' Conceptual Understanding of Circle Theorems: An Action Research Study," examines how technology, especially GeoGebra, supports secondary school students in learning Geometry. This study tries to tackle the problems that have been around for many years. Especially, an issue of students' conceptual understanding of circle theorems is a requirement, but an abstract component of the Grade Ten compulsory mathematics curriculum in Nepal. For the case of this research, GeoGebra, an interactive math software that combines geometry, algebra, and calculus, was used as an innovative educational tool to visualize and manipulate theorems related to circles. The main goal of the research was to develop students' conceptual understanding and engagement, and to draw their interest to learning circle theorems through ICT integration in the context of traditional classroom teachings. The research included data collection through classroom observations, interviews, students' reflections, and achievement tasks, thereby allowing the researcher to validate and compare qualitatively gathered data and learning outcomes qualitatively. The dynamic and interactive features of GeoGebra offered a very engaging learning environment where students could play with figures, different applets, and try out the value of angles, and consolidate mathematical concepts in a better way. Hence, this chapter presents an outline of the research, which gives a summary of its background, aim, and importance. It forms the foundation for the careful debates in the next chapters, beginning with the background of the study, which elaborates too much on the problem statement, research propose, research question, significance of the study, and delimitation of the study.

## Background of the Study

Mathematics is supposed to be among the core subjects within the schooling population, and its contribution should not be left out. Science, Physics, and Chemistry depend on mathematics to enhance their knowledge and research, and as such, it is a key requirement for the majority of other courses. I am originally from Taprang Village, a highly rural but beautiful place located in the western part of Nepal. My secondary school teaching profession started in 2010, the time when I really got linked with mathematics for all time. I was under a prescribed curriculum since childhood to schooling, and thus learned to manage myself in a very challenging educational environment. I had never seen a single computer or even a laptop in the class when I was studying in a government school. The only way to learn mathematics was by rote memorization and learning from textbooks. In the present scenario, it is exactly the opposite. Students of this post-modern age know much more about smartphones, tablets, computers, and the internet. At the same time, though some schools use digital boards, the majority use overhead projectors to teach the lessons.

I believe it is a demand and a necessity of modern times that the usage of ICT tools like GeoGebra for teaching mathematics has to be a priority in not only private schools but also in many public and government schools as well. I believed that through the use of GeoGebra, teaching theorems related to circle become much more interesting, engaging, and motivating to learn mathematics than the traditional methods. The use of GeoGebra has been shown in studies to improve visualization, build up conceptual understanding, and create a positive attitude towards the learning of mathematics (Bayaga et al., 2019; Chimuka, 2017; Kugblenu, 2022). In addition to that, the application of ICT tools such as GeoGebra fosters the creation of interactive and student-centered learning environments that are compatible with the educational goals of the 21st century (Stein et al., 1996). In addition, they enable the students to have a more abstract and lifelong feeling of mathematical knowledge and concepts. GeoGebra assists the learner to view abstract theorems using mathematical relationships in a dynamically created way, hence aiding in developing a conceptual comprehension that is much deeper than memorization (Chimuka, 2017; Kugblenu, 2022). Studies have revealed that ICT-based tools like GeoGebra have the power to enable students to establish connections between the procedural and conceptual elements of mathematics and therefore develop the capacity to retain and store mathematical concepts for a long duration (Bayaga et al., 2019; Gilmore, 2023). This helps students to get better grades and, at the same time, helps to further advance their knowledge at a higher level. I am also a math teacher with more than 15 years of teaching experience in mathematics to secondary school students. I also occasionally use GeoGebra to teach math, especially geometrical theorems related to circles. I feel that students prefer teaching with ICT tools like GeoGebra and Demos Graphing Calculator rather than just whiteboards. Some students simply don't listen to me and don't even copy down the answers from the whiteboard. Sometimes I ask students why they were disengaged in the class, and most students have the same answer: *"What will happen when we read mathematics?"* These questions really made me think about the use of mathematics in real life.

Some students also reported to me that they are having trouble understanding the concepts. Almost all students do not want to learn mathematics because some students only fail in mathematics. This is also one of the reasons that I want to explore why the students really don't want to learn mathematics. I always check students' learning outcomes with numbers, but never delve into their deeper conceptual understanding because the school management and parents are satisfied with their results in numbers and grades. *"Sir, I'm always afraid of mathematics in the SEE exam because of the subject like Mathematics."* This is the voice of one of the average students in the 10th grade. After joining Kathmandu University in 2023, my thoughts on how to teach students with better teaching methods have changed. I realized that I was only teaching mathematics problems instead of real-life knowledge. It is clear to me that the conventional algorithmic method of solving mathematics problems has been an obstacle to developing the ability to exercise critical thinking and problem-solving skills by the students, because it does not allow them in any way explore the different mathematical concepts and their proper use in new situations as well. Hence, it requires a change in the instructional method as well as some novel modes of teaching mathematics as a subject.

Teaching geometrical theorems has always been a tougher task compared to other concepts in mathematics. The issue came noticeably in the second term of September 2024 when I taught circle-related theorems of grade ten at one of the institutional secondary schools in the Kaski district. I found that circle theorems have posed a major challenge in teaching and learning mathematics. Formative assessments also undertaken during this time showed that even though students had memorized most of the theorems and could perform routine problems as required, reasoning and problem-solving tasks that targeted deep conceptual understanding always posed a significant challenge. During my teaching, I found that students seemed not to understand the conceptual basis of circle theorems, yet had memorized adequate procedural steps necessary for solving the problems. The students were from different socio-economic backgrounds, but there was sufficient emphasis on excellence in academics. However, the conventional mode of teaching mathematics, including my own initial strategies, relied heavily on textbooks and board illustrations, which were apparently very insufficient in bridging the conceptual gaps relating to circle theorems.

This problem became more noticeable when it emerged to me that even the best-performing students occasionally used their knowledge of circle theorems if put in unfamiliar contexts, showcasing once more how conceptual understanding is lacking. Though trying my best, I could see many of them were disengaged; neither were they listening nor copying the solutions that I demonstrated. I was shocked by the information in this question as I ended up retreating to consider over the method by which I had been taking my classes. That left me thinking that all those years, all those lessons and chapters I took into class only applied in one method, and probably those won't do the job for all.

The constant problem of students being unwilling to learn geometrical theorems, especially those on circle-related theorems in grade 10 compulsory mathematics, made me rethink my teaching strategy. It was crystal clear that another technique or tool was required to win their attention. Later, I was introduced to the GeoGebra application after joining Kathmandu University, providing interactive ways of teaching geometry, especially circle-related theorems. This made me wonder if the integration of ICT tools like GeoGebra would really support the students in developing better understandings and creating more interest. Since 13 marks are allocated to Geometry in the latest specification grid of the SEE, 2024 examination, including questions to test knowledge, understanding, application, and higher-order thinking skills, students need to be well equipped with a sound understanding of geometric concepts. It has importance in raising test scores as well as in getting better grades. As a teacher, I take up the task of helping my students understand this and also challenge them to find solutions to problems on those concepts. This, in fact, has led me to examine whether teaching with tools like GeoGebra indeed makes a difference in their learning outcomes.

I am fully aware of the problems that students face daily when classes were shifted online due to the pandemic. In this unexpected shift, many issues surfaced, including the varying levels of the students' digital literacy, the lack of training of instructors on ICT tools, and inadequate access to technology. These findings are supported by literature, which purports that adequate infrastructure, training, and curriculum adjustment for the effective integration of ICTs in education are just as important as having the technology itself available (Salehi & Salehi, 2012; Tondeur et al., 2012). There are multiple stakeholders in this matter. As I know, educational institutions are often underfunded to provide the necessary infrastructure, along with a comprehensive ICT policy. Policymakers would not be in a position to make ICT training for educator's mandatory, nor would the curriculum change to accommodate technology effectively.

Recently, ICT integration has gained much attention; not only in the field of education, but also, more importantly, in improving mathematics learning. The purpose of this project, therefore, is to gain a deeper knowledge of how the use of GeoGebra affects teaching and learning of secondary mathematics, with particular emphasis on the increase in students' understanding and performance regarding the circle-related theorems. I have noticed that many students still struggle to connect mathematical ideas and produce adequate results, even with the abundance of teaching resources available. When I was a graduate student who was studying the effects of ICTs on Mathematics Education, I realized that most of the time, the old methods did not grab students' attention or meet their personal needs of learning, which is why an innovative teaching pedagogy is required.

Based on my teaching experiences, it's not easy to understand circle theorems for students; it is beyond their ability in my class. It has been documented that geometry is one of the most challenging areas for secondary school students across the globe. For instance, Jones (2003) says poor understanding of geometric object concepts results from students having insufficient opportunities to observe and play with geometric objects in a way that promotes the development of a concept. Likewise, Mariotti (2000) has added that traditional teaching has been criticized on many counts. The most important being the focus on rote learning rather than on relational understanding. His observations are also in line with our experiences in the classroom with the static diagrams as well as verbal explanations. These have not helped in making the conclusions relevant to the students.

This problem arose for two reasons: first, traditional teaching of mathematics was strongly oriented towards procedural knowledge without properly developing the reasoning behind the theorems; second, because technology was used in a very limited way in mathematics classrooms, students could not visualize and explore geometric concepts dynamically. Through the process, I came to understand that my explanations, coupled with static diagrams, could not close the gap between procedural fluency and conceptual understanding. Although this issue represents a bigger systemic problem in mathematics education, I take partial responsibility as a teacher for the strategies that were adopted as teaching strategies in my classroom. Secondly, the problem is partly an issue of a lack of professional development regarding integrating technology in teaching geometry. At the institutional level, little support and resources have been made available to adopt innovative teaching tools.

The problem mainly arises because traditional pedagogies emphasize procedural understanding rather than conceptual learning, which often leads to students' inability to transfer knowledge when faced with new or complex problems. Notably, these challenges have motivated me to undertake this action research study: Use of GeoGebra in Enhancing Students' Conceptual Understanding of Circle Theorems. In this research, integration of GeoGebra in teaching circle theorems is done in order to find out its impact on the conceptual understanding of students. I hope that through this work, I might be able to contribute not only toward the academic development of my students but also toward general discourses relating to effective pedagogies of mathematics in Nepal.

It has been suggested that ICT provides interactive and individualized learning opportunities which can bring impacts on enhancing the mathematical conception and performance of learners (Cheung & Slavin, 2013; Voogt & Knezek, 2008). The bottom line is other issues that factors associated with socio-economic disparities, where all students do not have equal opportunities to access digital devices and the Internet. The causes emanate from many elements. The accelerated pace of technical development outpaces the growth and adaptation of education. Second, there is inequality in the distribution of resources: richer schools are much better equipped with ICT tools than schools in poorer areas. In addition, the traditional frameworks of education have hardly reformed and are often unwilling to accept new pedagogies using technologies.

## Problem Statement

The main issue addressed in this research touches on the ongoing problem put forward by Grade 10 students in Nepal on their consistent problems in grasping geometry, especially the theorems related to circles, which are still one of the most difficult parts of the overall mathematics syllabus that the learners have to learn in compulsory mathematics. I also followed traditional teaching methods in my several years of teaching. These methods mainly stressed algorithmic solving of problems, memorizing the solutions, and preparing the students for the examination. As a result, students could not understand the applications of geometry to real life, and were very unkeen on solving geometry problems. This problem is seen in national examinations, as well as in SEE, where students always do worse in geometry. Both Education Review Office (ERO) (2020) and National Assessment of Student Achievement (NASA) (2022) put across the same message that poor mastery of mathematics by students leads to other problems that will affect their high school studies. There are significant effects on students who aspire to pursue their studies or careers in STEAM at higher levels. Despite what the country's policies put forward for a focus on learners and the use of ICT (Curriculum Development Center [CDC], 2021; Ministry of Education, Science & Technology [MoEST], 2018), the inclusion of digital devices like GeoGebra has yet to sell very well. This limited implementation was mainly because teachers did not get enough professional development, there was no need for much technology infrastructure, and a culture of examination-oriented teaching was deeply rooted in the school system. My experience with teaching is in line with the challenges posed by the systems of the schools where I worked. I did focus on passing SEE and not deep conceptual understanding, and like many teachers, I fell into that cycle where procedural fluency holds greater than math reasoning.

At the same time, curriculum frameworks and national education policies point very clearly to how the teaching of mathematics should be facilitated in an environment that is built on the need for technology, for an environment that is rich in inquiry to allow visualization, to serve as an aid for exploration, and to facilitate problem-solving (CDC, 2019; MoEST, 2019). Dynamic tools, like GeoGebra, aid understanding, active involvement, and long-term memorability in some part of geometry, research says (Hohenwarter et al., 2008; Mariotti, 2000). They also help to build skills in a digital world, such as those needed for careers of the future (ERO, 2022). There are, however, few solid facts from Nepali classrooms, particularly on how little use of computer technology varies, if at all, student interest levels, ability to get a point across, and their scores in the area of lines. This gap becomes all the more urgent in view of the gaps in students' access to worthwhile digital learning (Higgins et al., 2012; Tamim et al., 2011). It is because of this that the focus of this study is on how the integration of GeoGebra can help grade 10 students to develop a more in-depth understanding of the circle theorems, to carry out better work, and to become more involved with learning. As a teacher-researcher, with the help of my colleagues, working on a 15-day action research project, I want to spread local data to a wide audience, i.e., worldwide: how can technology-dense, student-focused teaching methods change how we learn mathematics and create new doors for students to move forward with their education and careers?

## Research Purpose

The main purpose of my research study was to investigate the use of GeoGebra to enhance grade ten students' conceptual understanding of theorems related to circle.

## Research Question

How does the use of GeoGebra enhance grade 10 students' conceptual understanding of theorems related to circle?

## Significance of the Study

The study was important because it attempted to handle the eternal problem of effective teaching geometrical theorems; more importantly, in a situation where traditional approaches have failed to effectively engage students and make them understand this area of mathematics. I was trying to explore possibilities with GeoGebra. The present study aims to contribute to the general area of mathematics education by providing inputs on possible benefits that the integration of ICT tools might bring about in teaching challenging mathematical concepts. In fact, mathematics educators in general will profit from the research findings, as these provide evidence-based approaches to improve students' learning in geometry. Students would also benefit from the enhancement in instructional methods suitable to many learning styles, which might lead to a better understanding of concepts and perform well academically.

Also, it might indicate to the National Curriculum Developers and policymakers how worthwhile it is to make such dynamic software as GeoGebra a part of the mathematics curriculum, to enhance the learning environment interactively and effectively. It may help inform, in particular, teachers of the secondary level who have been facing problems in teaching mathematics and are unable to develop deeper conceptual understanding. Since our teaching techniques are mostly run through old education methods that have lecture as their base, several schools in Nepal continue to learn from a form of education that places the teacher as king, while providing little chance for students to take part (Pant & Tiwari, 2012). This study will help teachers to be professional in their teaching of mathematics at the school level, so that the teachers and educators may select the appropriate teaching methods and techniques that can make the students' learning meaningful. This research study will add to the theoretical and practical aspects of geometry teaching for secondary teachers. In practice, it provides specific, useful insights for mathematics teachers and curriculum developers, and policymakers in Nepal and elsewhere.

My incorporation of GeoGebra in my class has taught me the great impact of technology in changing the way students learn across the entire spectrum of formal education. For my students, geometry was more real, explorative, and exciting. It was also more understandable, engaging, and led to deeper math understanding. I learned through using GeoGebra for myself that I could be a better teacher and that technology is much more than an add-on; rather, it is a powerful, student-centered, life-giving way to develop lessons. It also shaped my planning for the future; it showed me how important it is to make lively lesson settings. To those making laws and teaching kids, the findings remind us how important it is to fit digital stuff like GeoGebra into lesson planning and how we train teachers. Thus, it is very important to carefully develop lessons that are similar to the good way of teaching and learning, making this similar to the primary thing to think about when teaching mathematics in today’s day-to-day classroom.

## Delimitation of the Study

In this research, I have limited my research to the study of only GeoGebra as an ICT tool in teaching geometrical theorems related to theorems of circles. I have chosen one of the secondary schools in the Kaski district. The research was limited to a chapter, i.e., Circle from the compulsory mathematics of class 10, and has not been extended to other areas. The research was confined to one class section, i.e., section D only, and 32 students out of five sections of a school, and thus, generalization cannot be inferred in other groups of students. This research was conducted only for 15 days, during which the effectiveness of GeoGebra was tested. Only theorems of circles included in the curriculum (CDC, 2022) were discussed. The use of GeoGebra has been carried out in this research, including theoretical proofs and experimental verification of theorems. Since this was action research, my main concern was to improve my teaching methods using GeoGebra applets and help my students’ theoretical understanding of theorems in my own classroom. The research did not mean to set up any broad cause-and-effect links, but it meant to reflect on and update the ways of teaching. The tests mainly aimed at assessing the students’ theoretical understanding of theorems and not their speed of doing the rules, their creativity, or their long-term memory. The data was taken through classroom observations, students’ worksheets, interviews, and pre- and post-tests without the parental and administrative ones. English and Nepali were used as the medium of instruction, which might have influenced the way students expressed their understanding of mathematics.

## Chapter Summary

The context and background of the research problem were outlined in this chapter. The outline elaborated on the difficulties that were faced during teaching theorems related to geometry in the chapter, Circle, to the students of class ten in one of the secondary schools of Kaski district. The real problem is that students do not maintain their interest or understand what these ideas are about, mainly because old-fashioned whole-class teaching methods are still used most of the time today. The chapter had also specified the exact research purpose of researching the impact of GeoGebra on student engagement in understanding geometry. This chapter also established the boundaries of the study, narrowing it down to investigating the usage of GeoGebra in teaching theorems of geometry concern to circle for the specified group of students within a set timeframe. Basically, this chapter lays down the foundation for the study in establishing the problem, the purpose, the research questions, the significance, and the scope to guide subsequent chapters regarding the effect GeoGebra has on teaching and learning geometry within the context. My study seeks to explore how well GeoGebra supports their understanding of geometrical concepts related to circles in acquiring mathematical knowledge that will translate to better academic performance. It is framed by one research question: how does the use of GeoGebra enhance grade 10 students' conceptual understanding of theorems related to circles? This study has significance for the contribution to make valuable insights of teachers, learners, and policymakers, and in encouraging new strategies and professional development for educators.

# CHAPTER II
# LITERATURE REVIEW

In this section, I have discussed different literature that assists me in shaping my study in this form. These include brief reviews of literature related to the problem encountered by teachers and learners while teaching and learning circle theorems. I have looked at some articles, Journals and Dissertations on geometry teaching, circle theorem teaching and learning, and simple geometry through different perspectives of different contexts of secondary level. As a researcher, literature has guided me to achieve my goals. While reviewing the literature for this study, I closely examined research articles, dissertations, and research reports related to GeoGebra and the use of ICT in teaching mathematics, with a specific emphasis on how these digital tools can be used to teach theorems of circles and other mathematical concepts. Firstly, I was to get to know the conceptual and theoretical base of ICT in the teaching of Math, with the constructivist and visualization-based learning theories that support the teaching by means of ICT. They allowed me to better appreciate in what way digital means help learners to improve conceptual comprehension and be more engaged with the topic. Secondly, I reviewed empirical studies that tested the use of GeoGebra to teach geometry. Common findings from these studies showed that GeoGebra helped students' motivation, helped students' visualization, and helped students' understanding of the nature of properties of geometry. Thirdly, I examined the matters of teachers' views and teaching procedures, how teachers use GeoGebra, the problems that come with it, and practices that help teachers work better with ICT. These insights allowed me to come up with a plan with which I could expect good but realistic results. Lastly, I conducted a review of research on students' conceptual understanding and achievement that shed some light on the ways interactive tools affect learning outcomes and conceptual retention in mathematics. I have continued with this section into four subheadings: Thematic review, Theoretical review, Empirical review, and Research Gaps.

## Thematic Review

In reviewing the literature for my study, I used a thematic approach to classify and combine knowledge on my research topic. Instead of giving a brief overview of each of the studies, I emphasize identifying constant themes, major ideas, and trends that were seen across the different sources. I started by gathering academic articles, dissertations, and reports related to the use of the ICT tool, GeoGebra, and Conceptual understanding of GeoGebra in mathematics education.

**Themes in the Proposed Research**

The following five themes have been identified from the proposed research: "Use of GeoGebra in Enhancing Students' Conceptual Understanding of Circle Theorems: An Action Research Study".

***GeoGebra Integration in Mathematics Education***

GeoGebra has changed traditional ways of teaching math into a better one, where students learn better. They provide learners with new levels of excitement and insight into mathematics. As (Center for Education & Human Resource Development [CEHRD], 2019) states that mathematics education for the 21st century should develop a deep understanding of concepts as well as new ways of solving questions by joining the powerful tools of technology while working with students. Stein et al. (1996) argued that students can learn better when they use computers and related equipment in class, because they can picture what they cannot see with their eyes and make sense of more advanced mathematical ideas. Smith and Stein (1998) say that math exercises that use technology are great tools for helping learners to get better at combining concepts with methods. In math teaching, ICT acts as a bridge from flimsy concepts to a real picture. Gilmore (2023) states that digital means boost the math brain by giving many pictures for thought and solving problems. GeoGebra is a means for this since it combines math, drawing, and shape pictures on one stage, so learners can change figures and view connectedness always. Introducing GeoGebra to mathematics education enhances learning and teaching aspects such as engagement, conceptual understanding, and student problem-solving capacity (Li & Ma, 2024). Use of interactive visualizations, for instance, GeoGebra, makes it possible to do a more concrete probe into what would otherwise be considered a highly abstract mathematical concept. The integration of these resources will, in the near future, depend on the reinforcement or not of Mishra and Koehler’s (2006) idea of Technological Pedagogical Content Knowledge (TPACK) in the daily procedures of teachers.

For developing countries like Nepal, using ICT is somewhat new, but it can be an alternative way of teaching mathematics and learning, which might arouse interest in the learners. When ICT is well applied to teach mathematics, it can encourage learners, turn what is intangible, like theorems for circles, more into something they can work with, and provide learner-centered ways to teach. As Krathwohl (2002) says, technology-enhanced learning can give learners a chance to go through different stages of mental participation, from memorizing and understanding to breaking down and putting back together. In this research, ICT, especially through GeoGebra, was used to improve the understanding of theoretical concepts of circles. I wanted to use GeoGebra while teaching in what way ICT can make geometry more interactive, visual, and meaningful for grade ten students.

### *Conceptual Understanding in Mathematics*

Mathematical conceptual understanding is an understanding that grants an individual insight into the underlying connections, relationships, and structures that exist among mathematical concepts, and which do not depend on memorization or procedural proficiency. It is thus a network of interrelated concepts that can be applied to solve new contextual problems (Hiebert & Carpenter, 1992). Developing conceptual understanding is, therefore, very important in any efforts to improve the quality of mathematics education in Nepal, where, for a long time, rote memorization constituted the dominant means of learning in its education system. The opposite research shows globally that students who have a strong conceptual understanding tend to be better problem solvers with long-lasting retention of the knowledge they gain (National Council of Teachers of Mathematics [NCTM], 2000). For the students in Nepal, who have difficulties relating abstract mathematical concepts to concrete applications, a strong focus on building conceptual understanding can provide them with the knowledge and skills they need that bridge the gap to enable them to solve real-life problems and major academic issues.

One of the key issues in teaching mathematics is differentiating between conceptual and procedural forms of knowledge (Rittle-Johnson et al., 2001). Conceptual fluency relates to knowing a mathematical concept and how things connect together, whilst procedural fluency refers to knowing the procedures and steps to work through problems (Rittle-Johnson et al., 2001). The current study investigates the effect of GeoGebra on the development of either of the fluencies, particularly in the understanding of theorems in circles. Education action research is a reflective and iterative investigation into teachers' practices with a view to improving students' outcomes of their work (Kemmis & McTaggart, 1988). It fits the objectives of the research study because the teacher-researcher can try out, observe, and refine

GeoGebra-based teaching strategies regarding circle theorems in an authentic classroom. In support, Stringer & Aragon (2020) suggests that key components of action research in addressing educational challenges involve collaboration and a cyclical process. It has been established that engagement significantly increases the learning outcome, especially with such abstract subjects as geometry. For instance, the use of GeoGebra, an interactive tool, has provided more motivation, participation, and retention among students, as observed by Clements & Battista (1992).

GeoGebra in the teaching of theorems of circles is an alternative way to make teaching and learning more practical, where mathematics is used in everyday life. Practical learning means helping learners to make links between what they learn and their lives, which gives them fun and a deep understanding of what they learn. In this context, GeoGebra included in the curriculum allows teachers to construct interactive and dynamic visualizations demonstrating real-life applications of theorems of circles, which students may appreciate to understand the relevance of their school learning of mathematics. Among the relevant aspects of meaningful learning in the realm of mathematics is the distinction between knowledge as procedure and conceptual knowledge. Procedural knowledge deals with the application of algorithms and procedures in solving mathematical problems, whereas conceptual understanding deals with a deeper, more practical way of knowing than more principle-based concepts of procedural knowing (Hiebert & Lefevre, 2013). Students in the learning process require the development of both kinds of knowledge in mathematics, especially in an interconnected subject like geometry.

GeoGebra allows students to make a distinction between procedural and conceptual learning through exploration and manipulation. For example, in class, when the students are introduced to theorems of circles, using GeoGebra, they can change points on a circle, observe the relations across the angles and arcs, and test out the theorems themselves by experimenting. This activity will help them achieve appropriate procedural fluency in using the theorems correctly, but at the same time be conceptually understanding why those particular theorems should hold. According to Skemp (2006), well-set conceptual learning allows students to apply these concepts in other contexts and problems, thus building their problem-solving capabilities. Conceptual and procedural knowledge indeed form a foundational aspect of teaching mathematics, concepts that, over time, have been cemented through research, for instance, using conceptual knowledge to derive procedures. This can be derived from the study undertaken by Baroody (2003), which established that students who understand the conceptual underpinning are more likely to apply procedures correctly and flexibly. This is particularly important in teaching geometric concepts, where one can appreciate the need for multiple theorem implementations along with chains of reasoning strategies to afford complex problem solutions. In that respect, GeoGebra becomes a very useful tool as it affords insight through visual feedback and allows the students to investigate relationships among the different concepts in geometry.

In addition, GeoGebra contextual learning enhances the logical comprehension of students and thereby develops relational knowledge, described as the ability to understand how the concepts flow from one to another. Rittle-Johnson & Star (2007) have mentioned that relational understanding allows students to perceive how different mathematical ideas relate to each other, which is an important way of developing an overview in mathematics. For instance, it aids in the application of circle theorems in actual design situations, such as designing a circular park or analyzing the path of a satellite. During the action plan, I have observed that GeoGebra can assist the learners in identifying the importance of mathematical ideas outside school as well. The implementation of GeoGebra while teaching circle theorems not only implements cooperative learning among children but also shows how children work on problems hungrily and discuss each other's work, maintaining the same. There are more of their other school skills, such as how to talk with others and how to make decisions, even when questioning or when they have understanding, and that leads to an increase in the number of ideas the learners can have. Through discussions and peer interactions, misconceptions could be cleared and shared understandings of geometric concepts built. Hence, using GeoGebra in teaching circle theorems provides a potent means for fostering both procedural and conceptual understandings. One of the ways educators might invite learners into meaningful learning experiences with regard to relevance in their life situations is by placing the mathematical concepts into context for real-world applications. This focus on concurrent procedural fluency and conceptual understanding is critical in helping students develop as well-rounded mathematical thinkers who then have the capability of flexibly and creatively applying their knowledge in a variety of situations.

### ***Circle Theorems in Mathematics Education***

A very important topic in any secondary school mathematics curriculum is the circle theorems, and these are being studied worldwide, including in Nepal. These theorems investigate angles, chords, tangents, and arcs in a circle in relation to one another to form the foundation of the larger stipulations in mathematics. The circle theorems in Nepal are included in the Class 10 mathematics curriculum, but it is difficult for the students, as they experience roundness very intensely as a conceptual notion. Misconceptions such as confusing central and inscribed angles, solving with an incorrect theorem, and memorizing without understanding (Panthi & Belbase, 2017). These misconceptions are not unique in the context of Nepal; they have been reported in other studies elsewhere in the world, calling for alternative pedagogical methods to introduce the circle theorems more simply. These misconceptions are resolved with students once addressed, and they have a solid foundation in geometry, beneficial both in academics and career development. Circle theorems with geometry fall into the middle of secondary level mathematics as it helps think, see, and tell others what they think in the space, step by step, hands-on. Before long, learners find this thing really hard to get if it is told to them the way they are often told.

Stein et al. (1996) explained that high-level thinking in geometry comes and is done by learners when there are nice ways to do circles to do something and then be allowed to do it in their own way, to try it in their own way. Learners without something to see or feel find it really hard to get things like what is in the circle theorem. Studies have found that quality visual and interactive methods can improve learning shape. Kugblenu (2022) states that many students have wrong ideas about circle rules when they only memorize. They do not understand ideas. The study further showed that using moving acts such as GeoGebra will let students change and watch shapes, thus strengthening their understanding of the rules of angles, arcs, and chords. Likewise, Chimuka (2017) found that using GeoGebra to teach about circle shape significantly enhanced learner understanding and achievement over traditional teaching. Use of static images and algebraic proofs is common in teaching the circle theorems in Nepalese classrooms and is inadequate to enhance the visualization skills of learners. Accordingly, this research attempted to bridge the gap through employing GeoGebra as an ICT-based teaching aid to improve the conceptual understanding of circle theorems for Grade 10 learners. Dynamic exploration enabled learners to visualize the relation between the central and inscribed angles, understand the pattern, and validate the theorems on their own, which contributed to the shift in teaching from memorization to reasoning. Here, the focus is on showing how we need to rethink how we teach circle theorems.

***GeoGebra in Mathematics Education***

GeoGebra is a dynamic software for geometry, providing a platform for learners to understand geometry meaningfully. The reason for this is that it brings geometry, algebra, and calculus into a single platform and thus becomes very convenient in teaching abstract concepts such as theorems about circles. Nepali education is slowly adopting technology, and GeoGebra provides life to the old chalk and talk teaching styles, because it makes learning fun and interesting for Nepalese students. The use of GeoGebra has shown how these features of dynamic visualization, interactivity, and multiplicity of representation can be utilized by students to learn practical mathematical concept development, thus enhancing understanding and motivation (Hohenwarter & Jones, 2007). For example, students may interactively move geometric figures and see the result and effect of one variable on another, creating a more tangible link in what seems an abstract relationship. The introduction of GeoGebra into the classroom helps provide a more pupil-centered teaching-learning environment, which is moving to keep pace with a global trend in education. According to Hohenwarter et al. (2008), GeoGebra is a dynamic mathematics software widely used in teaching geometry because it allows interactivity. The students can change the geometric construction, thus offering an active way of learning and discovery. Research by Zengin et al. (2012) indicates that GeoGebra enhances the understanding of geometric theorems among students and helps in developing a positive attitude toward learning mathematics.

## Theoretical Review

A theoretical review is a component of any research study as it forms the basis on which the study is established (Chukwuere, 2021). When I looked at ideas to guide me while I went about this study, I looked at a few of the ways people learn that tell us how students come to know and understand mathematics. My goal was to learn how GeoGebra could act as a tool to help students think and get involved in building their own knowledge. After careful consideration, I realized that the understanding of Vygotsky’s Social Constructivism Theory was the best match for my way of learning, as it suggests that learners learn while working with someone else, with the focus on talking and working together, passing knowledge between each other, and gaining little bits of new knowledge as they do so. As Vygotsky (1978) states, learning occurs via social interactions and communication through which knowledge is shared and constructed collectively, rather than transmitted directly. The theory highlights the

Zone of Proximal Development (ZPD), which shows the closeness between what a student can do on their own and what an individual can do with assistance from teachers or peers. Here, it refers to learners in mathematics classrooms who have the highest level when they participate in authentic discourse by questioning and solving problems together, the processes that deepen conceptual understanding. This theory spoke to how I value research and teaching.

In this research, I used GeoGebra as an alternative tool for children working together and practicing what they learnt. As they worked as partners and then as small teams to find and prove circle theorems, they talked, collaborated, tried, and helped each other to see why it is so. As a teacher been there, watched what they were doing, why it worked, and why it did not, and carefully showed them how to get bigger heights of their level of understanding in their ZPD. This process, which I watched, was the same as how Vygotsky said research in step-by-step action is best, and also the same as the action research process for this research that I set up and did. My research was based on social constructivism, and I saw learning not as the discovery of the truth, but as the co-construction of the meaning of the truth. While wielding GeoGebra, I was able not only to see geometrical relations in two dimensions but also to make room for discourse, to negotiate on things, to learn through suggestion, to work through questions and answers, and to learn our worked-through questions and answers together. In the context of these types of interactions, Vygotsky's Social Constructivist Theory offers the basis to show how the use of interaction, communication, and technology work together towards the promotion of students' conceptual understanding of circle theorems. Through the analysis of theories, a researcher comes to understand how theoretical stands could influence their methodology, analysis, and interpretation. I have chosen the following theories for my dissertation.

**Vygotsky's Social Learning Theory**

In planning and implementing my action research, I found Vygotsky's (1978) Social Constructivism Theory to be particularly relevant because it emphasizes that learning is fundamentally a social and collaborative process. Vygotsky argued that cognitive growth takes place if one portion of the dialogue takes place for learning within the Zone of Proximal Development (ZPD). The ZPD is where a learner can learn more if assisted by More Knowledgeable Others (MKO), which are teachers and friends. The main idea of scaffolding is the need for support to be eased up on as the person gets good at the task. This framework influenced my design of GeoGebra tasks over a two-week of time period of my involvement and ensured that students would work in pairs, would work through the circle theorems and concepts interactively, and would learn from their student partner and me as the teacher-researcher. Supporting learning in the ZPD, GeoGebra was not simply a technological gadget; rather, it was a mediating device that enabled students to handle and demonstrate geometric ideas that could have been problematic to present even in a typical learning environment.

GeoGebra, here, perfectly fits the constructivist method as it allows real hands-on learning, group-based work, and making knowledge. Learners could work together or alone with geometric shapes, check their ideas, and see the instant help, similar to the scaffolds described by Vygotsky (1978). The ZPD system gave a way to change help according to each student's needs so that the learning was tailored yet group in scope. Using GeoGebra as part of a social constructivist framework, this study not only led to better conceptual understanding but also supported learners' ability to solve problems, think critically, and increase their knowledge of what they knew about what they did know (Black & Wiliam, 1998; Vygotsky, 1978).

**Constructivist Theoretical Orientations**

My research is based on some constructionist theories that jointly explain how students develop, change, and understand math knowledge. At the center is Piaget's constructivism, which holds that learners make meaning actively by the use of interaction, exploration, and reflection, and not passively receiving information (Piaget, 1970). The claim that understanding comes from the amount we know already and the new things we learn in the future is in stark contrast with what is found in geometric learning. When I created investigations in GeoGebra, I made sure to make tasks where students had to move figures, test their assumptions, and prove properties of geometry. This method supports Piaget's claim that a real increase in thinking occurs when people do things that matter to them on their own. As they did these things, they found out some rules about how the sides of a circle relate to find out more about these relations and to make their thinking stronger and last longer.

The Social Constructivism of Vygotsky (1978) conforms to Piaget's ideal of knowledge creation but expands the scope of learning into the social. Vygotsky believed that language, interaction, and collaboration privilege the classroom community as a means for cognitive development. A prominent notion in his learning view is the Zone of Proximal Development (ZPD), which is the distance that a learner can get to on their own and with assistance. This lens had an immediate impact on the digital setting I planned with GeoGebra. Students worked with other students, challenged each other’s work, and worked with others through their ideas. I was the one who carved out support for them when they needed it. GeoGebra was an artifact that mediated interaction in the zone of proximal development (ZPD). It allowed students to see, test, and fix their ideas, receiving instant feedback and help from playmates. The feedback and assistance obtained within the ZPD were sensitive to time; as soon as learners were able, they could work without assistance and continue to work toward forming their own understanding of circle theorems.

## Empirical Review

For me, the empirical review was about more than just quoting what others had already learned. It was about how what I was learning could help and improve what I do in my classroom. I carefully reviewed and examined journal articles related to GeoGebra, student reflections, and previous studies that researched how GeoGebra helps students gain ideas in geometry, their formats of learning styles, and how well they did in the course. Through this process, I had the chance to see how five different researchers had tackled the way time was spent using technology to teach the subject of planes and figures. I was curious about what results there were to be observed, as well as where problems could be faced. I was better able to see the benefits of GeoGebra and its shortcomings as a teaching aid. By doing this review, I was also able to make clear where there was a gap in research into the subject of the mathematical teaching practices involving GeoGebra. Many previous studies have shown the potential abilities that significantly increase students’ grasp of what geometrical ideas are all about. However, few had looked into students' learning about when circle theorems are a figment of their imaginations, taught in the context of the secondary Nepali classrooms. Hence, this part of my research critically looks into the former work to find out what is already known and what requires further research. While relating these past findings to my real-life situation in the classroom, I made a connection on why my study on the use of GeoGebra to deepen one’s understanding of circle theorems is both relevant and urgent in the context of contemporary teaching.

### Review of Related Studies

My first review is the "Effect of Using GeoGebra on Senior High School Students' Performance in Circle Theorems" by (Tay & Mensah, 2018) which designed a quasi-experiment that assessed the impact of learning circle theorems with

GeoGebra software on performance. The study was carried out in Ghana with two groups: one experimental group receiving instruction in circle theorems taught with GeoGebra, whereas the other control group received instruction without the new technology. Results showed that the experimental group outperformed the control group by a large margin. It concluded that GeoGebra significantly enhances the conceptual understanding and improves the geometric problem-solving capabilities and engagement of students. It recommended the inclusion of the use of dynamic geometry software into mathematics instruction in order to improve students' results of learning results.

The second review is recent research that shows the theoretical use of GeoGebra as a dynamic math software instrument has greatly increased students' knowledge of geometry when compared to old ways of learning. Parajuli and Koirala (2024) ran a constructivist lesson experiment conducted with ninth-grade students in Pokhara, Nepal, and tried to find out what effects GeoGebra-tiered models might have on students' learning of triangles and lines running side by side. Qualitative data showed that GeoGebra assisted student generating a better understanding of concepts, perceiving better reasoning in observing, and keeping students engaged in geometry lessons through the use of visual meaning, demonstration, construction, and checking. Students learned more by way of interactive visualization and reflective perception when GeoGebra reps in lesson delivery and disapproving model were used to construct the instructional setup.

The third review is on the master's thesis done at Cape Coast University in Ghana. Badu-Domfeh (2020) examined *"the effect of using GeoGebra software when teaching circle theorem on students' outcome".* The research used a quasi-experimental design with pre-test and post-test measures with two groups of senior high school learners. Findings revealed that learners who learned with GeoGebra outperformed their colleagues who learned traditionally. The work has shown that to improve learners' mathematical reasoning, there is a need for more active learning tools, and learning settings infused with technology have the potential to improve understanding of the geometric concepts.

Similarly, the review of the effectiveness of GeoGebra in teaching math in the secondary schools of Kenya was another study by Mukiri (2016). In this study, students' performance and attitudes toward learning mathematics with GeoGebra were studied using a mixed-method approach. The results indicated that the students who used GeoGebra outperformed their peers who were taught by traditional methods and developed a more positive attitude toward mathematics. It is recommended that mathematics educators be trained in how to effectively use GeoGebra in their teaching to maximize its full potential.

An empirical review, therefore, would mean the analysis of past research that has gathered data through observation, experimentation, or other forms of inquiry. This contextualizes the current research problem, highlights various gaps in past studies, and shows how other similar studies have found their results. Results: In my research, I will review the literature relating to the use of ICT in mathematics education, particularly the studies about geometry and circle theorems. Such a review will provide insights into how technology has been put into place to enhance students' learning. For example, the study by Zengin et al. (2012) aimed to establish whether the use of GeoGebra, a dynamic geometry software, enhances the achievements of students in geometry. The study was carried out in one of the high schools in Turkey; the researchers tried to solve the problem of students receiving low levels of success in geometry. In the study, there was one traditionally taught group and another group that made use of GeoGebra. The research findings proved that students who used GeoGebra significantly outperformed their peers on the tests in geometry. The researchers have argued that ICT tools embedded in GeoGebra geometrical concepts enhance the understanding of students through active participation and observation. This research will inform my study by showing how GeoGebra can be used to enhance students' achievement in geometry, something very relevant to my focus on circle theorems.

In this study, Shadaan & Leong (2013) discuss how technology can support teaching circle theorems to improve students' understanding of geometric conceptions. The research was carried out in a secondary school in Malaysia by providing the researchers with ICT facilities such as GeoGebra and interactive whiteboards to teach circle theorems. The problem they tried to address is that students have difficulties in building and internalizing abstract geometric relations. Indeed, the results showed that the students who learned by the use of the ICT tool demonstrated significant improvements both in conceptual understanding and problem-solving skills compared with the traditional students. From these results, the authors concluded that ICT tools enable students to visualize and explore in real-time the geometric relationships they have to learn, thus making learning more effective and engaging. This study is directly related to my problem statement because this research provided the evidence of how integration of ICT can be really effective for teaching circle theorems, which are my main focus in this action research.

Another relevant study was conducted by Drijvers et al. (2010) to investigate the impact of technology on improving the mathematics achievements of students. The case study used secondary school students in the Netherlands. They investigate whether technology, represented by the usage of dynamic geometry software, can enrich mathematical knowing. Students learning in that environment performed better compared to those learning within more traditional settings. The authors felt that technology enhanced mathematical insight by allowing students to explore and experiment with mathematical objects. Indirectly, it then affirms that technology could well enhance the performance of students in mathematics. Evidence from the research supports arguments on the effectiveness of ICT tools, such as GeoGebra, in enhancing student performance.

Özçakır (2013) researched the effectiveness of ICT on the geometric concepts about circles among students in high school in Turkey. The students' poor comprehension of properties and theorems concerning circles was investigated. Traditional teaching was compared with ICT-supported teaching by using software like GeoGebra. Indeed, the results revealed a remarkable improvement in the understanding and retention of geometric concepts in students who used ICT. These results made the researchers draw the conclusion that ICT tools narrow the gap in students' understanding and mathematical abstract conceptions through an interactive and visual way of expressing the properties of geometry. The given study is closely related to my research objective because it deals with the impact of ICT on students' understanding of circle theorems and also provides empirical evidence for the benefits associated with the use of technology when teaching geometry.

From what I have understood, action research based on inquiry-based approaches has been shown to influence educational practices and the results of students. The inquiry-based action research refers to teachers' cyclic systematic inquiry about their practice through planning, acting, observing, and reflecting. I believe that in that respect, such an approach provides a teacher with opportunities to act as a researcher in his or her classroom and thus allows more relevant and timely enhancements in teaching strategies and student engagement. Indeed, Cochran et al. (2009) have shown that teachers engaged in inquiry-based action research possess heightened confidence in their decisions about instruction and a deeper knowledge about students' learning processes. Apart from this, Dana et al. (2020) cite that inquiry-based action research nurtures among educators a culture of continuous improvement and collaboration that assists in accomplishing student success and the improvement of school climate.

Empirical evidence also suggests that inquiry-based action research enhances the development of critical thinking and problem-solving skills in learners. In that respect, for example, Anderson (2002) conducted a survey which showed that inquiry learning in the classroom results in better and more active students compared to traditional pedagogies. Furthermore, Mills established that an integration of inquiry-based learning through action research on the part of the teachers resulted in students taking greater ownership of their learning and elicited higher-order thinking skills. This falls in line with the larger aims of education that not only prepare students for the challenges facing them in the modern world but also equip them with lifelong learning and adaptive skills. Collectively, all these studies tend to demonstrate that the use of GeoGebra is effective in enhancing performance in circle theorems and geometry among students.

## Research Gap

While reviewing current literature, I saw that many studies have previously focused on GeoGebra and other Information and Communication Technology (ICT) tools in the field of teaching mathematics. Nonetheless, research gaps still exist, especially in the area of action research. Past research like the ones conducted by Zengin et al. (2012) and Shadaan and Leong (2013) clearly prove that use of ICT improves students' grasp of geometry, but these researches mainly bother with triangles, polygons, and coordinate geometry and say little about circle theorems in which the type of space does require a slightly different form of spatial reasoning in secondary level mathematics. Most of this research was in high technology schools by means of experiments or quasi-experiments, and leaves unanswered how teachers in settings with little resources, like in Nepal, can improve what they do in teaching in practical ways through repeating, reflective phases of action research. Also, the articles say a lot about near effects of GeoGebra on success but little about whether these near effects stay long or whether they lead to deeper understanding on a more conceptual level (Shadaan & Leong, 2013; Zengin et al., 2012). In addition, most studies have privileged using achievement data that are easy to count while ignoring how students sharpen their skills in space, think about what they see, and relate with one another as they carry out inquiry with the use of ICT. There is a second, practical breach: although frameworks such as (Piaget,1970; Vygotsky, 1978) support learner-centered ICT-enabled settings, teachers in Nepal too often do not have the provision of ICT infrastructure and also are limited by curriculum pressures, and so tend to confine their use of technology into rote use (Buabeng-Andoh, 2012; Seago et al., 2018). Existing com even more geographically mannered, with most of the evidence coming from locations such as Turkey, Malaysia, and the Netherlands (Drijvers et al., 2010; Shadaan & Leong, 2013; Zengin et al., 2012) and the Nepali sites where Learning Centre Research (LCR) manifests in the classroom. Finally, earlier research used a control-treatment design that works for measuring how students learn, but almost never describes how teaching and learning change over time in classroom practice. To fill these empirical, contextual, theoretical, and methodological gaps, my study employed action research to explore how GeoGebra can meaningfully and contextually enhance Grade 10 students' contextual understanding of circle theorems in an authentic Nepali classroom. along with documenting changes in my own teaching practice throughout the intervention.

## Chapter Summary

Chapter II summarized the research literature under main themes based on ideas that seem to tie directly to how I have used GeoGebra as a means to improve students' grasp of the circle theorems. This chapter was initiated by a theoretical basis drawn from Vygotsky's social constructivism, a theory of learning that stresses social interaction, collaboration, and guided discovery as a way of learning. This theory still formed a major foundation that logically justified the part GeoGebra can play as an interactive learning device through which students can participate actively and learn collaboratively through dialogue. The manner in which the thematic review proceeded looked at three broad groups of issues: the integration of ICT within mathematics. The role of GeoGebra on students' conceptual level of understanding, and the difficulties teachers encounter when endeavoring to use such technology within their actual classroom situation. Within all of these themes, prior research has always shown that GeoGebra largely improves students' motivation and attentiveness, but also assists in better mathematical thinking via visualization as well as through experimentation. Furthermore, the empirical review critically looked into international and local studies conducted over the years that have studied the use of GeoGebra on students' scores regarding learning. Though a majority of the studies validated the positive effect on the grasping of ideas and performance, the review found that some gaps still exist, especially the dearth of research on the Nepali high school environment, centered on the circle theorem, and a thin command of action research as a meaningful mode of teaching. By recognizing these data, methodological, and contextual gaps, I justified the need for my study. Thus, Chapter II does not put my research within the bounds of prior theoretical and practical frameworks, but it also lays the ground for moving forward by illustrating how my research would bring insights into how technology, mainly GeoGebra, can transform the quality of learning and teaching mathematics in Nepal.

# CHAPTER III
# RESEARCH METHODOLOGY

This chapter describes the method for this study. It describes the study's design, nature of the work, the students involved, and the techniques and methods I used to gather data. I state why I used action research and how each step of the work was done with GeoGebra in the Grade 10 math class. This chapter also describes the ways in which I examined the qualitative data. These parts of the chapter act as a clear map of this study, so that it is trustworthy, consistent, and delivers useful new clues about what students understood about circle theorems.

## Philosophical Considerations

An action research framework guided this research study, aiming to apply innovative pedagogy by implementing GeoGebra into classroom practices of geometric theory, concentrating on circle theorems of class ten. Action research offers a cyclic process of planning, acting, observing, and reflecting, which can deal with some problems faced in the classroom and can also aid the real, continuous growth of teaching. This is an appropriate design for my study, since it involves real-time engagement with the students and immediate application of insights into teaching strategies. My study is based on the constructivist paradigm, which purports that through active experience and interaction, learners construct knowledge. It nurtures an interactive, engaging, personalized learning environment wherein students get an opportunity to develop a real interest in and understanding of new ideas of mathematical concepts. Three major philosophical assumptions motivate this research, and these are ontology, epistemology, and axiology. These assumptions have provided the parameters within which reality, knowledge, and value are located in respect to teaching integrated with GeoGebra. I guided this research work in my study based on the assumptions of philosophy related to knowledge, reality, and values that design, methodology, and findings interpretations are drawn upon. Below are the ontological, epistemological, and axiological considerations for the direction of this research work.

### Ontology

My research is rooted in the ontological belief that reality is neither singular nor static but is transformed continually by learners' meanings that are derived as they communicate with their tools, people, and tasks. Such a belief finds support in the constructivist position that learning involves learners actively building understanding from experience (Piaget, 1970). In the setting of my classroom, students' understanding of the circle theorems results from their dealings with GeoGebra, each other, and me as the teacher. The side effects of GeoGebra to learn are not rules, but personal things that change from one student to another, depending on their history, former knowledge, and need for help. Vygotsky (1978) states that learning beats pass by talking and working together within the Zone of Proximal Development, which fits the idea that learners form distinct "realities" as they draw near, talk, and perform GeoGebra models. Dewey (1933) also claims that learning results from reflective experience, which puts back the point that all that happens in a classroom is always changing by students' way of thinking, questioning, experimenting, and changing their ideas. Even in the much wider Nepali picture, where ICT use is still not even (Buabeng-Andoh, 2012; Koirala, 2023; Marasini & Paudel, 2024), the realities of those who learn with digital tools are very much dependent on access, support, and classroom settings. Based on these ideas, my study is guided by the ontological position that reality is multi-layered, situated, and socially constructed in nature. Consequently, the mathematical ideas that students generate in GeoGebra during action research cycles can be thought of as solutions to the problem of meaning and are well grounded in social interaction, technological meditation, and reflective thinking rather than a unique and situated version of the truth.

**Epistemology**

Epistemologically, I believe that our knowledge is based on what we do with our lives, and these ideas form the heart of my work. Based on the idea that what we know is made up of what we each make of it and how we put the ingredients together (Piaget, 1973; Vygotsky, 1978), my research takes the view that everyone learns circle theorems in their own way as they work with GeoGebra, others in their classes, and me as the guide. Social interaction within the Zone of Proximal Development is at the heart of Vygotsky's (1978) idea that learning occurs outside of the classroom. Creativity and learning happen is a deep desire that there is that knowledge is not simply given in the classroom but rather built here. Dewey's (1933) focus on reflective experience adds to this point, as it made me recall that students learn not only through changing what they see on screen with technology, but also learn from coming up with ideas, asking questions, and talking about what they see. Especially in the Nepali context, where access to and incorporation of digital technologies remain uneven (Joshi & Ayer, 2024; Tripathi, 2024), students' interpretation and use of digital tools vary considerably, mainly because each student is different from the others. In the role of teacher-researcher, trying out a planning, acting, observing, and reflecting on what was done (Kemmis & McTaggart, 1988), I know that the knowledge created in this study is not only a result of what students experienced but also my own understandings, judgments, and reflections. Our joint class exchanges, their work, our talk, and our written work tell us how students learn about circle theorems with GeoGebra. Evidence from other GeoGebra research also shows that learning with ICT is very much affected by how learners interpret and work with digital representations (Drijvers et al., 2010; Shadaan & Leong, 2013; Zengin et al., 2012) which supports my own subjective opinion about knowledge. So, knowledge in this study becomes something that is formed by students, technologies, and the social environment of the classroom, rather than something that sits as a thing to be found.

**Axiology**

Axiologically, I am fully aware of the fact that my research is value-laden, and I am not shy about the role of my beliefs in the formulation of this research. As a teaching-researcher who strongly believes in meaningful understanding of mathematics, I am committed to, I firmly believe in the possibility of GeoGebra to enhance conceptual learning on the topic of circle theorems. This belief is not abstract as it is based on my experience in my own class and confirmed by studies that say that tech-made digital tools can help students learn math better, see objects more clearly, and understand the ideas of shape better (Drijvers et al., 2010; Shadaan & Leong, 2013; Zengin et al., 2012). My true desire to use technology for locking in learning is also in line with ideas from Vygotsky (1978), Piaget (1970), and Dewey (1933), who said that interaction, experience, and idea are the 3 main parts of good ideas in learning (Piaget, 1970; Dewey, 1933; Vygotsky, 1978). The values clearly affected my ways of planning lessons, watching students, and grading their learning through action research, as the authors Kemmis and McTaggart (1988) suggest. I value fair access to learning and I see how many Nepali classrooms are without ICT (Joshi & Ayer, 2024; Tripathi, 2024), and this made me think about ways I can try allow students to experience teaching with GeoGebra that because of their context, they might not otherwise have. At the same time, however, I knew that my confidence in ICT does not mean that I expect all the students to respond positively. I look at the different responses they give me as data, rather than bad news. My axiological stance is therefore that, like all research, research cannot be free of value. My value judgments, expectations, and hopes determine the types of questions that I ask and the interpretations that I make of data. In order to be morally correct, I think about how my lens keeps on affecting me, I admit about my motives, and I hear students when I work with them in hopes of creating more aware people. For the most part, my values of engagement, collaboration, reflection, and tech-enabled empowerment steer the course of my research and drive me to change my pedagogies constantly. So, I continually adapted my teaching to better meet students' learning needs.

## Research Paradigms

My research was guided by interpretivism and criticism as paradigms for highlighting improved understanding of circle theorems using GeoGebra in an integrated teaching among students. These are in good fit with the approach of qualitative action research since the methodology centers upon the meanings of participants' experiences and improvement of educational practices. A research paradigm serves as the fundamental basis for conducting the study, affecting the researcher's assumptions regarding knowledge, reality, and method (Creswell, 2018). A study paradigm comprises ontological (the nature of reality), epistemological (the nature of knowledge), and methodological (the means of knowing) perspectives that illuminate the research process and product (Guba & Lincoln, 1994). My dissertation, "Use of GeoGebra in Enhancing Students' Conceptual Understanding of Circle Theorems: An Action Research Study," adopts a 15-day action research approach to investigate the potential of using GeoGebra to facilitate Grade 10 students to obtain higher conceptual understanding of circle theorems. Because of the nature of the study, Criticalism and Postmodernism are the most appropriate paradigms to be used as research paradigms.

### Interpretivism

In this research, I adopted the interpretivist approach, where reality was viewed as a personal view and made by using other people (Cohen et al., 2002; Taylor & Medina, 2011). My choice of paradigm here was used because it fitted with my qualitative approach, taking into account my action research. Interpretivism investigates social dealings by means of seeing the world through someone's eyes and how they have lived through it themselves. It thus best looked at how students go about their learning about circle theorems when they do this with GeoGebra. In contrast to positivist designs that emphasize objectivity and measurable results, the interpretivist approach appreciates the learners' subjective means of making sense of the world around them (Cohen et al., 2002). Focusing on the students' experience, I was able to examine how their understanding of the geometrical theorems changed when they learned through the use of digital gadgets. In order to record these rare sequences, I did different forms of action research, like watching classes, using semi-structured interviews, student journals, and GeoGebra tasks. These enabled me to get quality thick descriptions of the representation's students used in drawing and visualizing the circle theorems memorized, and how they went through cognition, feeling, and the use of technology. Through this way of looking at things, the study not only records what was learned but also sheds light on how GeoGebra helped in other small but important ways in mathematics, such as working with others, solving problems, and even better understanding abstract ideas.

Interpretivism emphasizes the joint creation of knowledge between the researcher and those taking part (Taylor & Medina, 2011). This affected the way I worked with students, teachers, and others working on the study. Social constructivism, based on Vygotsky (1978), I found that learning math is social and is shaped by what students knew in the past, how they work together with friends, and how teachers teach (Gredler, 1992). Here, GeoGebra was studied not only for how it increased students' learning, but also for how it increased what students understood about ideas, how they solved problems, and how they got involved, giving a unique, learner-centered view on teaching circle theorems in the Nepali high school skills. Hence, my view is that the interpretivist paradigm fits tightly with my strong belief in student voice, student experience, and student construction of mathematical knowledge. Having taken this view, it was easy to see how each student interacted with GeoGebra in a very particular manner, always strengthening my conviction that only through collaboration, exploration, and reflection can real understanding happen.

**Criticalism**

Criticalism critiques traditional, authoritarian forms of knowledge and holds learners as the ones with agency in learning environments that are participatory and interactive (Kincheloe & McLaren, 2011). The critical perspective was used to interpret the use of GeoGebra during the 15-day teaching intervention of this study, where all students had the opportunity to interact with the tool, as learners did not passively receive theorems about circles but experienced them firsthand. GeoGebra provided an interactive, visual, and flexible learning experience that allowed students to ask questions, analyze, and develop mathematical knowledge with one another instead of just memorizing (Freire, 1970). The lens of critique made me think about inequalities in access to and use of technology and resources at Nepali schools and how socio-economic and institutional factors impact students' experiences with GeoGebra. Reflexivity, one of the core practices of criticalism, forced me to think about who I was as a teacher-researcher and how my positionality, cultural, and pedagogical background played a part in how I used GeoGebra and how my students interacted with it (Taylor & Medina, 2011). With a critical eye, I could view the over two-week intervention not only in terms of student understanding of the circle theorems but also regarding the issues of equity and access to ICT tools. This left many questions in my mind about how to alter the system to ensure all students and teachers alike have access to technology and are anywhere from mid-way to experts at using tech for teaching and learning, so much so that GeoGebra can be used in a classroom lesson without great difficulty. This research adopted both the interpretivist and critical perspectives, as it described not only students' individual experiences with GeoGebra, but also revealed the broader social and cultural issues surrounding these sets of experiences that can be used to develop new ways of teaching that promote deep learning and social justice in the teaching of mathematics.

## Action Research as Research Method

In this qualitative research approach, action research was applied to explore the understanding of the abstract concept of geometry using GeoGebra as an alternative tool regarding the circle and its theoretical understanding from the perspectives of learners. It has sought to explore students' learning experiences and conceptual development using GeoGebra and classroom engagement with this activity by qualitative means, through classroom observation, semi-structured interviews, and the students' reflective journals. Action research is a very good way for teachers try to articulate learning differently and improve ways to teach in their classrooms. Improved in the sense that it might be more improved than the conventional chalk-talk and rote-recall culture of learning geometry. It is about the teacher having a different role. That different role is the person who teaches students, and also the teacher who looks at what they do and changes it to do it better. The teacher does several times what they plan as education, observes the students' understanding and growth, and then they take time to think to help with the next step to improve the previous mistakes for the betterment of helping students learning and achieve. In this context, Kemmis and McTaggart (1988) said, "action research is doing this cycle of planning, doing, watching, and thinking about it, and it hopes to improve the teaching in a group of students" (p.14). It helps teachers look at their group of students and the teaching of that group of students, wisely and based on good evidence. In the field of math teaching, action research has been especially useful in linking theory and practice.

As Mills (2011) shows inquiry by teachers allows teachers to find troubles with students' learning, follow through with specific plans, and check if those plans worked when they are working with students. This kind of research has not only spread better ways of doing the job of teaching but has also fostered growth. It has also helped students achieve their goals. As this sort of research is iterative, I used it to improve each lesson based on how students performed and what I observed during class. This is very much in the constructivist vein, as both advocate active learner participation, reflection, and ongoing improvement. To this end, the action research plan is designed in an attempt to investigate how GeoGebra improves students' understanding of circle theorems, with an idea about the applicability of research into practice at the classroom level. Indeed, Kemmis & Taggart (1988) argue that through action research, teachers can improve their practices to enhance the improvement of their students' learning processes. As a result, by using action research for this study, I was able to keep this enquiry hands-on, self-checking, and rooted in real-life issues. It was not only beneficial for my teaching experience but also provided important knowledge on how communication technology tools, such as GeoGebra, can change how we teach and learn about the teaching and learning of different shapes in geometry in our high school children's classrooms. The action research aims at improving the teaching practice and enhancing students' outcomes.

In my research, I used an action research approach. As far as I can tell, action research is participatory and iterative since it looks for improved practices in attempts to solve practical problems within a context. It involves planning, acting, observation, and reflection in a cycle so that the researcher may adapt and refine the practices in real time (Kemmis et al., 2014). The action research will be especially suitable for my research entitled Enhancing Students' Understanding of Circle Theorems through GeoGebra Integrated Teaching, since it enables me to continuously assess and refine the teaching strategies for the purpose of realizing optimum learning achievement for students. Action research is a type of reflective practice - cyclical and systematic- meant for the improvement of instruction and learning through problem-solving, intervention, and impact assessment (Kemmis & Taggart, 2000; McNiff, 2017). According to prior research, GeoGebra results in effective improvement of students' conceptual understanding and spatial reasoning in the field of geometry. Laborde (2001) claims that dynamic geometry software enhances students' understanding of math relationships. According to Hohenwarter and Preiner (2007), who state that GeoGebra helps students on that level via its ability to manipulate an image interactively. Holzl (1996) states that dynamic geometry gives learners a chance to make their purposes through experimentation and, as a result, become more completely engaged with the content. Bruner (1965) also demonstrated with his studies that when students explore first before given instructions to learn, they find it to be more productive. The findings of Suh and Moyer (2007) showed that interactive technology leads to greater student motivation and mathematical engagement. In the same vein, research done in 2020 found that when students learn with tools like GeoGebra, they are more likely to think they are in charge of what they learn. My background as a lecturer-researcher totally frames how I see this data. When I saw what students did, and how they got into it, in lessons that used GeoGebra, I read the data as time in real scenarios. To do so, I took into account my experiences, that I was making sure that the context of what was happening was central to my interpretation, to ground my findings in ongoing classroom practice. Action research best fitted my study, because it is supported by continuous observation, reflection, and improvement of instruction in an effort to develop students' conceptual comprehension of circle theorems in a 10th-grade math classroom over a span of 15 days through GeoGebra. The following diagram describes the five steps of the research methods:

**Step 1: Identification of the Problem**

The initiation of action research stems from identifying problems that require intervention efforts. The study discussed more about how students are unable to understand the concept of circles in relation to the concept of theorems without having to memorize first. Different teaching approaches to the existing teaching methods in geometry that hinder students from being able to think and see theorems are to be transferred between learning contexts. The geometric exploration capabilities of GeoGebra create an opportunity to connect student learning gaps by showing them computerized dynamic representations. Classroom observations and geometry assessments of students revealed specific conceptual challenges with circle theorem understanding, which required structured educational interventions.

**Figure 1**

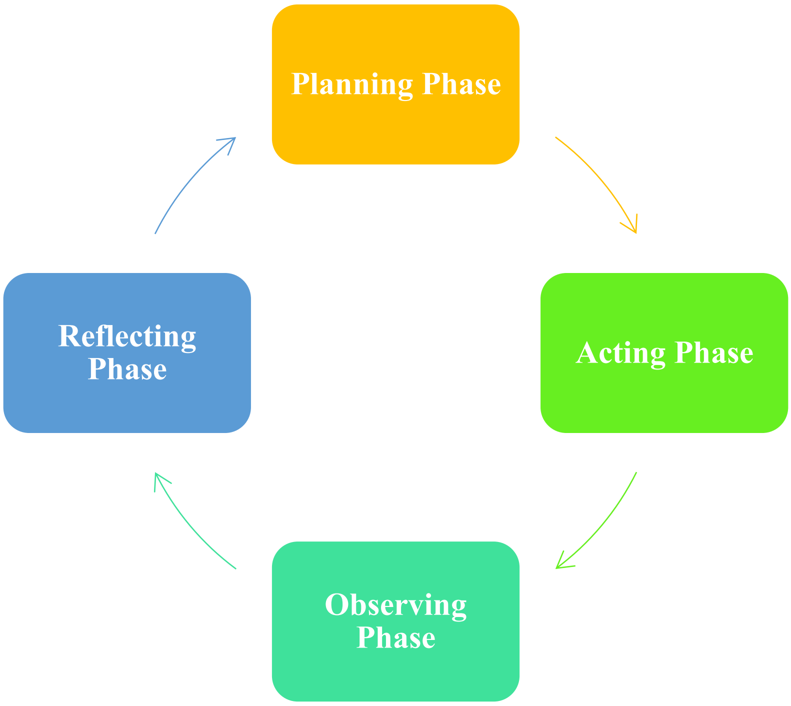
*Diagram Representing Five Steps of Action Research Methods*


**Step 2: Plan of Action**

To solve the learning problem, I planned and structured a 15-day GeoGebra-based instructional framework that fostered improved understanding of circle theorems among students. I showed students how to use GeoGebra and provided simple steps for using its tools to make geometric constructions. Students used the GeoGebra learning plan, which had the ability to have students explore the properties of circles and their inscribed and central angles, as well as the cyclic quadrilaterals. The use of interactive curriculum was taken up by GeoGebra, where it gave students an opportunity to look into circles, properties of inscribed angles, and help explore the areas of cyclic quadrilaterals, as well as central angles. Students completed problem-solving projects guided by teachers while their geometric interests were dynamically controlled to spot patterns and create theoretical statements. I also set up talks and tests that helped students see how they learned.

**Figure 2**

*Diagram Representing Action Research in the Cycle of Research*




**Step 3: Data Collection**

To assess the impact of GeoGebra on students' conceptual understanding, various data collection methods were employed, including:

***Pre-test and Post-test***

Students took the first test before the intervention to assess their circle theorems knowledge, but afterwards completed the post-test to determine improvements.

***Classroom Observations***

As a researcher, I recorded students 'GeoGebra interaction activities, their growth, and trouble levels by making careful observations.

***Student Reflections and Interviews***

Students who participated in this study discussed their GeoGebra experience along with how well the tool facilitated their understanding of circle theorems.

***Teacher Reflection Journal***

One of the biggest helps to me on the theme creation process was these journals. All through the research from day 1 to day 15, I kept a journal every day.

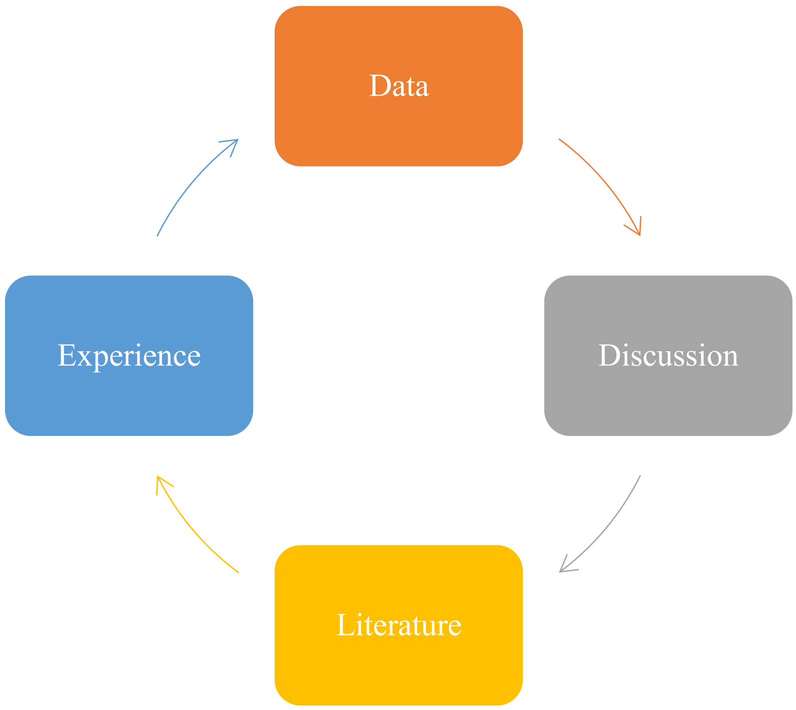
Likewise, future practices could value the teaching change notes we kept, with student reactions and lessons tried to make improvements.

**Step 4: Meaning Making from the Data**

Data analysis and interpretation within my research were done through the DDLE Method. DDLE represents Data, Discussion, Literature, and Experience. In that way, I was able to consider a multidimensional analysis to make sure that the findings reflect not just the raw data but also the contextualized understanding derived from the broader perspectives.

**Figure 3**

*Diagram Representing Data Analysis Process Cycle*




The DDLE Method identifies that GeoGebra makes a huge contribution to the improvement in the conceptual understanding of students about school mathematics, especially regarding circle theorems. Once the data were gathered in the form of classroom activities, pre-tests, post-tests, observations, and interviews, the quantitative and qualitative analyses were conducted to obtain the overall picture of the effect of GeoGebra on learning circle theorems in students. The quantitative analysis mainly concentrated on the data in terms of numbers that were obtained using the pre-test and post-test outcomes. A pre-test was used before the session of the implementation of the GeoGebra-based lessons to determine how much students knew about circle theorems before the intervention and how much they had learned after 15 days of intervention. The scores were compared against each other in order to determine the enhancement of conceptual knowledge among the students. To determine the efficacy of the intervention, the mean, percentage change, and the general performance changes were computed. The pre-test and post-test results were compared, which gave objective data of the student' progress, which demonstrated the extent of the integration of GeoGebra on their understanding of mathematics and the power to solve mathematical problems.

The detailed study of this research involved a lot of analysis of classroom visits, student interviews, journals, and the teacher’s comments about the field, which together shed light on the way students were able to and understood the circle theorems by the use of GeoGebra. The observation notes were analyzed to show students’ changes in their curiosity, coordination, and trust as they played with the GeoGebra applets, which is like the rule from constructivism that people learn by doing and talking with others (Piaget, 1970; Vygotsky, 1978). Six main persons took part in the study, answers they gave were put down and looked at to find important ideas that helped understand what they thought, the problems they met, and their reasons for using the intervention. Three things that stood out were the visual help GeoGebra gave, how easy one could see the other shapes, and how it made one want to learn math more. Connection was made between classroom practices and the use of theoretical ideas, with the use of teacher reflections, in particular, the scaffolding and guided peer interaction concepts of social constructivists (Vygotsky, 1978). This way of taking a close look at what happened also led to us understanding better how and why students learned a lot from using the computer tool called GeoGebra (Chimuka, 2017; Kugblenu, 2022). Overall, the method revealed some subtle knowledge about how GeoGebra can be used in creating an environment where students can learn through active collaboration. The environment will stimulate students to work with each other and learn how to think deeply about the locations of the parts of the circle theorems.

### *Comparison of Pre-test and Post-test Results*

A detailed comparison of the pre-test versus post-test scores showed a big change in students’ basic knowledge of circle rules after using GeoGebra in class. The pre-test showed that most students only knew the steps to solve a problem, with little ability to tell why or prove how things work geometrically. This was especially true of inscribed angles, cyclic quadrilaterals, and arc qualities. Most of their answers were based on memory alone. The post-test, by contrast, showed a switch from memorizing everything to understanding the concepts. Students could see how to describe what they saw, connecting the parts, make sounder evidence, and use what they learned in new problems. The class did better on the whole as the class average rose significantly. This is strong evidence that the GeoGebra lesson helped you learn. The fact that GeoGebra showed an exciting behavior meant that students' ability to manipulate geometric shapes, see how this change right away, proved their ideas about what they are seeing, increased, and students had a better insight into their understanding of math ideas.

***Coding and Thematic Analysis of Observations and Interviews:***

The analysis of the classroom observation data, in addition to the student feedback, established the repeating themes that students encountered alongside the technical issues and advantages of GeoGebra.

***Triangulation of Data***

Triangulation is a major approach in qualitative essays that helps to make sure that findings are reliable, believable, and more detailed by using several data sources to learn about the same thing (Cohen et al., 2002). In this study, triangulation was used to fully learn how GeoGebra-integrated teaching affected students' understanding of circle theorems. As a researcher, I collected data systematically from different sources such as pre- and post-tests, classroom observations, reflective journals, student interviews, and teacher field notes. All these tools made it possible for the researcher to see different sides of the teaching-learning process, taking both the cognitive and affective facets of learning into consideration. Observations made quick and instant feedback on how students engaged, worked together, and used their minds to find solutions while they played with the GeoGebra applets. Student journals and teacher field notes gave a picture of how students continued to receive and make sense of mathematical ideas, built their own understanding, and responded to helpful hints, in line with Vygotsky's (1978) idea of the Zone of Proximal Development (ZPD). Participants' responses in face-to-face interviews with six of them added more to the data, bringing in their thoughts, problems, and drive, and showed how GeoGebra was able to fit into state by state, and learn from each other as they built on each other's ideas. The use of triangulation in this study enhanced the validation of findings from different sources of data, which increased the credibility of inferences made on the importance of GeoGebra as a means of teaching and learning (Chimuka, 2017; Kugblenu, 2022). For example, the improvements seen in participating in class and working with others were backed up by students' answers to questions about their own experiences and their work in tasks that were made with big, broad ideas in mind. This agreement of proof also played a role in finding small things, like using spatial thoughts and reasoning, thinking over things, and forming new ideas, and these may have gone unnoticed if I had only checked through tests alone. When several kinds of proof were brought together, the study measured not just a measure of learning but also showed how learners had made sense of things. It brought to light how learners could really change when they used computer-based, social places where learning was seen as part of everyday life.

**Step 5: Reflection and Plan for Future Action**

As the last step required a reflection on the intervention's effectiveness, together with planning modifications for upcoming improvements. Key considerations were: A method, laid out clearly, for carefully judging what was good and what was bad about the GeoGebra-enriched lesson plan. Likewise, assessment of how student understanding of concepts changed over the course of fifteen days of measurements, improved planning consists of a scaffolding device aimed at helping struggling learners, and would also include an examination of capabilities of GeoGebra for teaching more advanced ideas; and recommendations regarding the use of ICT devices for teaching in general mathematics outside the scope of this project should be presented.

## Data Collection Tools and Techniques

Different data collection tools and techniques were used in this 15-day action research in order to achieve a comprehensive picture of how GeoGebra supported students' conceptual understanding of circle theorems. The methods below ensured capturing students' experiences with learning, their engagement, and conceptual development from different angles.

**Classroom Observations**

Each observation at the lesson has been systematic as far as student interactions with GeoGebra levels of engagement in problem-solving and conceptual discussions were concerned. Field notes of all critical incidents, challenges, and noteworthy students' responses have been kept throughout. Observation was the main method during the research. I observed classes to see how students use the ICT tools in GeoGebra and how such usage influences their learning of circle theorems. I also observed moments of engagement, problem-solving processes, and collaborative attitudes from the students. An observation checklist has been used to help with observations systematically.

**Semi-Structured Interviews**

The six significant participants were, therefore, the objects of observation and participants during different phases in the investigation and semi-structured interviews in deepening insights into the experiences encountered by students of their insights into the Circle Theory, GeoGebra tool efficacy, and barriers encountered when manipulating this learning device. Semi-structured interviews with a few selected students were carried out to explore their individual experiences of the use of ICT-integrated teaching. The interviews allowed a better capture of detailed insights into how the use of GeoGebra applets contributes to their conceptual understanding and problem-solving abilities. The semi-structured nature allowed flexibility in exploring student thoughts in depth, while at the same time allowing key topics to be covered.

**Focus Group Discussions (FGD)**

I commonly used group discussion among selected students that could facilitate an open engagement. This decision issue for improvement indicated how the students understood each other's comments and whether they participated in peer discussion in the context of their learning. This was followed by one or two FGDs with the selected group of students to delve deeper into the experiences of the students. These FGDs allowed the students to discuss, in groups, challenges as well as benefits related to the use of GeoGebra applets, providing qualitative data on how group dynamics and peer interactions give insight into the circle theorems.

**Field Notes and Researcher's Reflections**

I kept a comprehensive field note with personal reflection of the teaching-learning process, hindrances while introducing GeoGebra, and where adjustment was needed in instructional strategies. It greatly assisted me in modifying the intervention stage. I maintained field notes during the whole research on the major things I observed that I reflected on and learned in classroom sessions. Field notes were very useful in capturing immediate reactions, challenges, and successes throughout the integration process of GeoGebra applets. This also helped me to keep a running record of the research process invaluably useful to reflective cycles in the action research.

**Photography and Videography**

I used photography and videography with prior consent to capture real-time students' engagement and interaction with GeoGebra. The recordings are visual data useful in the analysis of students' participation and problem-solving approaches, or the use of dynamic visualization tools. All the classroom activities within lessons were recorded by videography and photography. Videos captured how students interact with GeoGebra, with their co-students, and how the classroom environment unfolds throughout the lesson. These visuals allowed me a very thorough review of specific moments that contributed to students' learning, and hence provided valuable data during post-lesson analysis and reflection.

**Written Work and Worksheets of Students**

The conceptual development of the students was traced by collecting and analyzing students' responses to worksheets, problem-solving tasks, and classroom activities. The learning gain was understood through the comparison of responses in the pre-test and post-test questions.

**Informal Conversations**

I also conducted some informal discussions with the students in order to learn their spontaneous reactions to the use of GeoGebra. The informal discussions showed some aspects that may not have been brought out during the structured interviews or FGDs. It was easy for me because almost all the students of class 10 live in hostels for their SEE preparation, so it was very easy for me to interact with them informally in detail. I have collected much information during these discussions.

**Student Reflections**

This involved students in writing short reflections about their experiences in the use of ICT tools while learning circle theorems. This helped me in understanding the effectiveness of the tools in realizing a deeper understanding of mathematical concepts in students' views. Through this, I was able to measure the impact of GeoGebra on student learning from a student perspective. In addition to documenting student perceptions, such reflections provided an opportunity for students to identify how they learn and in what ways using the GeoGebra tools, in this case GeoGebra, has influenced learning about circle theorems. By inviting students to highlight difficulties and achievements, it allowed for insight into where the integration of

GeoGebra is working best or where it may need further refinement. This approach guaranteed the active involvement of students with reflective thinking in respect to their own learning, besides substantial feedback on refining teaching methodologies, reinforcing the engagement with the concepts, while solidifying their confidence levels in solving problems.

**Teacher-Researcher Reflections**

As a teacher-researcher, I wrote regular reflections regarding the process of teaching itself, concerning challenges and successes related to integrating GeoGebra tools in my lessons. In this respect, these reflections assisted me in the critical assessment of my own teaching practices as I developed and changed along with the action research cycle. Reflective journaling was the most contributing instrument in capturing how my instructional strategies are adjusted throughout the course of the study, and how they related to the learning outcomes of my students.

## Theme Generation Process

### Background of the Class and Study Implementation

At the outset, students showed prior knowledge concerning circle theorems, some of which had limited possibilities for the students to conceptualize abstract geometrical properties. Traditional teaching at schools, generally based on aspects of procedural knowledge, favored mere memorization rather than conceptual understanding. Within this framework, GeoGebra was introduced within everyday lessons to support the approach of exploratory student-centered learning. I also maintained a daily reflective journal during the experiment about observations of student engagement, challenges, and learning progress. Audio recordings, photographs, and videos about students' interactions and responses were also collected. Later, these data were transcribed, coded, and analyzed to generate key themes reflecting the impact of GeoGebra on learning circle theorems. Therefore, this research report, "Enhancing Students' Understanding of Circle Theorems through ICT-Integrated Teaching," in essence uncovered a series of themes, comments, and explanations related to the research question. It critically examined qualitative data obtained from the three students involved in the study, and provided a detailed analysis of the responses that can help to give answers to the research question and achieve the set objectives. Themes that we discussed from a variety of sources, such as observations, field notes, student reflections, interviews, FGDs, and video recordings. This process of transcription, coding, and categorization results in key themes that represent students' learning experiences and how the use of GeoGebra enhances understanding of circle theorems.

### Data Transcription

Data were collected through multiple sources, like audio and video recordings from FGDs, interviews, and pictures of classroom sessions captured through video, and this fully developed me and helped me to deepen my understanding of how students experience their learning. Recordings of class discussions, reflections among students, and question-and-answer sessions were held, for which audio and video recordings were made, and then, a transcription was also done. Some Photographs were taken and screenshots: Key points observed during GeoGebra explorations done by the students to supplement the analysis carried out, to develop themes. Next, this was formed as the precise record of conversations and interactions and would therefore present data in a more accessible manner. Simultaneously, I also re-examined my field notes and reflective journals that have comprehensive details regarding observations of student behavior, engagement, and learning progress.

**Writing Reflective Journals**

From the transcriptions and observations, I wrote reflective journals to emphasize some of the key insights coming out during classroom sessions and interactions with students every day. These reflections helped me understand how students were involved and engaged in the GeoGebra tools, their challenges of understanding circle theorems, and how I adapted my own teaching practices. This further helped me refine my understanding of the data in readiness for coding. I've maintained day-by-day notes based on student responses, misconceptions, and illuminations.

**Student Feedback and Written Reflections**

Students responded to open-ended questions regarding the GeoGebra experience about the hindrances and insights.

**Field Notes**

I kept field notes on uninhibited student responses as well as peer discussions that occurred, so as to capture incidents of informal learning.

**Coding and Categorization**

Data coding was done through the identification and labeling of major ideas or concepts that emerged from the transcriptions, field notes, and reflective journals of both students and teachers after every class. That is, in coding, labels or short phrases were assigned to segments of data that capture specific patterns or concepts. As I did, examples of such codes were *"improved visualization, "peer collaboration," "GeoGebra engagement," and "conceptual struggles"* based on recurring ideas in the data.

**Categorizing Similar Ideas**

After coding, I formed a group of similar code into broader categories representative of related ideas or patterns. Coding was summarized by clustering codes that represent common themes or are conceptually related. For example, all those codes describing the student level of engagement when using GeoGebra were grouped under such a category as "*GeoGebra and Active Learning,"* whereas codes describing barriers to understanding circle theorems fell under *"Challenges in Conceptual Understanding.* After transcribing, the data gathered were subjected to a step-by-step coding procedure:

***Printing and Initial Reading:*** I printed all the transcriptions, journal entries, and student feedback in order for me to annotate by hand and analyze closely.
***Open Coding:*** The data were read intensively, and the substantial statements were highlighted. Keywords and phrases that came up frequently in student reflections include "visualized easily, "interactive," and "confused at first. These were noted.
***Axial Coding:*** Codes of a similar nature were grouped into categories to reflect common patterns in student learning.
***Selective Coding:*** I integrated the refined categories into themes that encompassed scenarios familiar to these students.

**Emerging Themes**

The way I made themes for my action research follows both analytical and reflective approaches. I used these to change the plain data that I got from the class into lessons. After I took data from watching the class, the students' work, talking to people, and from my journal, I just started to read all the data over and over. I did this so I would know what I was looking at. While I did this habit, I began to find words, ideas, and ways of saying things. These identified what the students felt before I was more than just a visitor in how they used GeoGebra for the circle theorem lesson. Then I assigned the first codes to the converts of meaning. I gave names to the individual words or behaviors of engagement, comprehension, collaboration, and difficulties. Once all coding was completed, I grouped similar codes to create categories that reflected larger patterns in the data. These groups made it easier to see links among students' actions, attitudes, and what was learned. Slowly, under continual comparison and reflection, larger themes started to show up, each representing a rich aspect of how GeoGebra affected teaching and learning in my classroom. From this systematic work, six main themes emerged:
Theme 1: Enhanced Engagement and Satisfaction in Learning
Theme 2: Improved Conceptual Understanding of Circle Theorems
Theme 3: Developing Problem-Solving Ability and Mathematical Confidence
Theme 4: Overcoming Learning Barriers and Self-Actualization
Theme 5: Enhanced Peer Interaction and Cooperative Learning
Theme 6: Effectiveness of GeoGebra in Mathematics Education
Each of these themes was not just a topic, but indeed, they were a real picture of classroom change in the real world where I lived and saw the continual change take place. In this way, I came to have an overall sense of the data and to have an answer

to my question about the effect of using GeoGebra in class by showing that the use of GeoGebra facilitated increased student understanding of concepts, increased student co-operation, and enjoyment in the students' lives.

## Meaning Making from the Data

My work on this project was both step-by-step and thoughtful, to find real learnings from my students' experiences when they learned the circle theorems while working with GeoGebra. Once data from observing students in class and talking with students was available, and students wrote and kept a diary, I started typing and sorting this while making sure it was correct and clear. After this, I read the data carefully several times, looking for repetition, likeness, or variance in the students' answers. Applying a qualitative paradigm, I conducted coding in which important quotes and acts were tagged in order to tell what was most important about them. These codes were then clustered into three groups, which represented recurring ways in which students engaged, made sense of, and developed their problem-solving. The codes provided the foundation for larger ideas that captured the essence of my research. Moving from the small detail back to larger ideas, back to the evidence, then to the larger ideas, back down to the evidence, to the larger ideas, through this cycle continued throughout coding, analysis, interpretations, and linking the results, careful not to lose the students' voices in interpretation. Lastly, I represented the themes with Vygotsky's (1978) social constructivist theory and related the students' social collaborative experiences to their learning. This painful yet deep way of checking helped me to turn bare classroom moments into useful thoughts that not only answer my questions, but also show how well GeoGebra taught circle theorems.

## Quality Standards

In order to make sure that my research met the quality standards and could be trusted, I used several ways that clearly followed the ideas of credibility, dependability, transferability, and confirmability. At every stage of the research process, I was critically aware of and open about issues related to my role as teacher-researcher. To keep others' trust, I triangulated data from multiple data sources, such as classroom observations, interviews, students' imprints, and journals, to verify my findings as well as to lessen bias. I also did member checking, which I shared the interpretations and the themes that arose with the informants. This was to validate what I gathered and to see if their voices are rightly heard.

**Credibility**

My research utilized a combination of student reflections, together with interviews, and observational notes in order to create a detailed understanding of GeoGebra's impact on student conceptual understanding. Real-time feedback from students about their GeoGebra learning experiences validated the study's findings after I allowed continuous discussions about their learning experiences. My research study followed an interpretivist paradigm, which could ensure the credibility through triangulation, that is, by using different data sources, for example, observations, interviews, FGDs, and methods, such as video recording or reflective journals, to cross-check findings. The participant's involvement in the review and validation of findings to ensure their perspectives and experiences are accurately represented.

**Transferability**

To increase transferability, I provide rich, thick descriptions about the teaching setting, the learner's data, and the learning activities, so anyone can judge whether these results may reflect other educational contexts. I have given enough about where I researched, who was involved, and what I did, to help others decide if any form of what I found could be in different places. It must contain sufficient details with regard to the site and participants in the research for others to contextualize the particular conditions under which the findings were established. The extent to which the research findings can be generalized across diverse contexts is what transferability is all about. Even though this study is located in one school context, detailed descriptions of the teaching and learning environment, participants involved, and methods adopted were provided to enable other educators or researchers to evaluate the transferability of the findings to settings other than where the study was conducted.

**Dependability**

In order for the study to be dependable, I kept a detailed, step-by-step account of the research process, which included the lesson plans, the field notes, the procedures of coding, and the reflective memos to allow others to audit or even replicate the process of my research study. The documentation on the research plan unfolded, including GeoGebra use, lesson plans, and assessment tools. I kept a reflective journal to document my developing thoughts and observations through which I was able to assess the dependability of the process and adjust my strategies accordingly. Also, this study's activities were designed and conducted in a way that other researchers could follow. In my research study, this can be ensured by detailed records about the research process, such as data collection, decisions, and changes that took place during the study. Reflection on and documentation of how the background, assumptions, and decisions of the researcher may have influenced the research process and results.

**Confirmability**

In order for my research study to achieve confirmability, member checking was conducted for me, allowing students to make reflections of the experiences and lesson interpretations concerning the use of GeoGebra, which is in the process, and made conclusions from data that accurately represent the experiences of participants. I triangulate to minimize the influence of individual researchers' biases. I also held periodic review meetings with key participants and some of the students to talk about how research goes on, to find out how we might find solutions to any problems, and to have checks and balances about the quality of work. I asked for comments from the students participating in the review and from the others I knew about the whole process of research, how it could be made better, and about the weak points we could fix. In the same way, I kept full records on research work, I mean data collection, analytic procedures, and the study itself, in order to be open and responsible. Finally, I put confirmability proof in place and kept a reflective journal through the study. This helped me to think about and question my ideas and judgments critically. These quality assurance strategies boosted the soundness of my work and helped me prove that my work satisfied the set academic standard. Also, the results of my work authentically showed the way GeoGebra changed how the learners understood the concepts of circle theorems.

## Ethical Considerations

My research followed strictly ethical principles by getting participants' informed consent in addition to studying the research objective and maintaining the volunteers' status for all participants. I explained to students that their research answers would remain confidential, and they had the free choice to leave the study without facing penalties at any point. Standards of ethics to be followed in conducting research ensure it is conducted within the principles of integrity, respect for participants, and adherence to established norms of scholarly conduct. First, right from the start, I got informed consent for the research as well as all the activities participants would be doing and the data produced. I warned the students that their participation in the research was strictly voluntary, and at liberty, and totally up to them when they want to withdraw from it without facing any adverse repercussions. A lot of care had been given to make sure that participation was free and fair; hence, there was complete transparency on what was involved for each of the data taken. I always think about my role, not only as a teacher but also as a researcher, as teachers' actions may impact the way students learn and respond. As an additional step, I used the participatory approach to provide the students with the opportunity to reflect on both the GeoGebra experience and the lessons. Such feedback would provide voices that must be listened to with respect and thus create a relationship of trust. In doing so, I was respecting the rights of persons, giving them the avenues in which to be engaged with the research process, thus extending their learning.

The following are the ethical standards that were observed during my research study:

**Informed Consent**

Before starting the research, I have taken written informed consent from the school, students, and their parents or guardians before enrolling the students into the study. As a researcher, I explained the purpose of the research, the procedures to be involved, potential risks, and the right of participants to withdraw from this study at any time without penalty. Consent in this research was absolutely voluntary; no student was pressured or obligated to participate in this research. Students could withdraw at any time without receiving an adverse academic reflection.

**Confidentiality**

The data collected were anonymized so that participants' identities were protected. Personal information is regarded as confidential, and access to the storage is strictly limited to authorized persons. Results were served exclusively for research purposes and were not to be passed on to third-party persons unless clear consent is given by the subjects themselves.

**Reflexivity**

The essential concept of reflexivity applies specifically and strongly to action research due to its requirement of practitioners also functioning as researchers. The fifteen-day period provided opportunities for introspection about my classroom methods, together with student engagement and GeoGebra implementation assessment. Regular ongoing assessments, along with observations, guided my adjustments to teaching strategies that maintained a flexible research process, which remained student-centric.

**Privacy**

The research attempted to uphold the privacy of students during observations and recordings in the classroom. No video or photographic materials were made of the students individually unless it was highly necessary. Personal or sensitive information, as might be disclosed by the respondents in an interview or FGDs, was kept discreetly and as a part of the research only if relevant and upon people's consent.

**Respect and Integrity**

The participants' rights as human subjects in the research process were treated with dignity and respect. Their views and experiences were accurately and valuably represented in the findings. The findings were honestly reported without manipulation or production.

**Understanding Students' Learning Needs**

Among the most important features of pedagogical thoughtfulness is an awareness of the variability in students' learning. In this respect, my research brought me to the realization that, very often, students have difficulties in visualizing and conceptually understanding circle theorems; many of them memorize rather than deeply understand. That's how I found out about the GeoGebra use of an interactive tool, through which the students could relate to and make geometric properties from the features of its changes.

**Concept and Procedure Learnings**

While making mathematics, a fair balance of idea awareness and step-by-step facility is very important. Traditional teaching strategies were more inclined toward the steps to be followed while proving theorems, thus leaving the students devoid of an intuitive feeling as to why things hold. Therefore, with GeoGebra, I tried to focus students' experiences of learning toward relational understanding via experimentation with dynamic construction, testing of conjecture, and observing patterns, so that the learning of concepts or procedures is established.

**Approach to Inquiry-Based and Active Learning**

Pedagogically thoughtful, learning needs to move beyond passivity to inquiry-based experiences in which the students themselves take an active part in knowledge construction. Thus, there was encouragement on the part of students to ask questions and explore some of the conjectures concerning circle theorems. Similarly, to make guided discoveries using GeoGebra through the dynamic manipulation of geometrical figures that model properties of and peer collaboration: discussing and justifying findings with peers, thereby enhancing mathematical discourses and reasoning. A constructivist approach that entirely aligns with social constructivism by Vygotsky (1978) and radical constructivism by Glasersfeld (1995), through social interactions and digital tools, in which learning is viewed as an active process of meaning-making rather than an act of passive hearing or imitation.

**Differentiated Instruction and Scaffolding**

Students don't all have the same knowledge and learn at different speeds. I tried different ways of teaching to give an equal chance to learn to all students. My work was: First, I gave the students a very clear explanation on how to use GeoGebra since they had never used it before. Next, I gave students tasks that got harder because advanced students can learn to connect the dots between the theorems more deeply. Third, I used peer-assisted learning. The three steps are an example of scaffolding that prepared all my students to use and learn this topic.

**AFL and Reflective Teaching**

At every interval, it has been part of a reflective practitioner's concern that assessment would fall regularly to diagnose and take corrective measures on the learning curve. In assessing the growth of conceptual understanding in my students, I tried pre-tests and post-tests, besides regular formative assessment with student reflections, in-class activities, and discussions. A teacher's reflection journal about problems found, findings, and how to change teaching to do better. Though the center of the pillars of action research, the repetition of teaching, grading, recording, and improving, as it must be done to move forward with every decision that is made in terms of teaching. All of which must originate from data and be able to change and help students.

**Growth Mindset and Mathematical Resilience**

One of the pedagogical aspects of my investigation has been trying to instill in students a view propounded by Dweck (2006), described as a growth mindset: one that does not view mistakes as failures but opportunities for learning, through the usage of GeoGebra in exploring circle theorems dynamically. This consolidated a mathematical resilience where trial and error, testing a hypothesis, and self-correction of problems were consolidated.

**Sustainability and Future Implications**

Beyond the research treatment over 15 days, I was interested in knowing what the long-term effect would be of embedding ICT tools, GeoGebra being one of these tools, within regular mathematics instruction. It will bring out how the process of dynamic visualization enhances learning at an abstract geometric conceptual level. Similarly, how does technology support deeper levels of mathematical reasoning? And the potentiality of extending such a GeoGebra-based -based approach to any mathematical topic for any grade. This study documents research findings and reflects on the pedagogical effectiveness to contribute to broader discussions related to technology-enhanced mathematics education and provide pragmatic recommendations for future instructional improvements.

## Chapter Summary

This chapter covers research design, philosophical assumptions, paradigms, methods, and ethics in a detailed manner that represents the framework within which the study is conducted. The critical paradigm helped to study how power is distributed and whether a possible imbalance occurs with the use of GeoGebra in education. The research was qualitative and employed an action research design with repetitive phases of planning, acting, observation, and reflection. In this research, I collected data from interviews, observations, FGDs, videos, and journals. The transcription, coding, categorization, and analysis are done through an orderly procedure to elicit themes. The key themes that have been identified include enhanced visualization and conceptual understanding, promotion of collaborative learning, challenges of integrating GeoGebra, and adaptation and reflective practice of teachers. Through DDLE, analysis and interpretation were drawn through presentation of data, discussion of meaning, relating findings to existing literature, and reflecting on personal experiences. The quality standards ensured accuracy and validity through credibility, transferability, dependability, and confirmability. Chapter III has described the methodology of the research that guided both the design and the implementation of the study. In this methodological approach, philosophical assumptions, research paradigms, and ethical standards have been woven together to draw insights on how GeoGebra integrated teaching can help students explore and improve their understanding of circle theorems. Ontologically, I have acknowledged the diverse nature of realities at educational institutions, where any single factor has a multiple impact on the learning environment. Epistemologically, I am a constructivist;

the students gained knowledge by using GeoGebra tools, thus enhancing their understanding and development of skills in mathematics. Axiologically, the aspect that guided me in the present research is educational equity and ethical treatment of participants, which made my investigation contribute to a more inclusive practice and ensured that the ethical premises were based on scientific requirements. My qualitative approach in this research study has focused heavily on in-depth interviews, observations carried out in classrooms, and reflective skills among both students and teachers. I have collected descriptive data that were very rich in providing insight into the effect of integrating GeoGebra on enhancing students' mathematical creativity and academic achievement. Data analysis and interpretation, therefore, involved coding and thematic analysis to come up with patterns that could provide meaningful conclusions from the qualitative data collected. Ethical considerations involved consent from all participants, protection of confidentiality, and respect for participant rights and welfare throughout the process of the research.

# CHAPTER IV
# A JOURNEY OF CHANGE: PRACTITIONER – RESEARCHER EXPERIENCES IN MATHEMATICS CLASSROOMS

This chapter outlines the implementation of an action research study aimed at enhancing students' conceptual understanding of circle theorems using GeoGebra, a dynamic geometry software. This chapter provides a comprehensive overview of the intervention process, including data collection, analysis, and reflective observations on the teaching and learning experience. The findings are organized around classroom observations, student engagement, pre-test and post-test results, and qualitative feedback from the students.

This chapter discusses the celebrations of data collection during fieldwork, while this chapter synthesizes the important issues that must have emerged from the execution of the project. It includes some information about the participant and accompanied interpretations of my experiences. This presents a view in line with the objectives of the study, based on texts from participant reflections, self-reflections, and daily records. My understanding had already existed that the students faced difficulty in understanding abstract geometrical concepts; therefore, I wanted to find out whether it would help the students if I added GeoGebra into the lesson plan and made them understand geometry in reality. As a teacher and action research practitioner-researcher, I also reflect on motivators to inquire into the problem. Based on observational notes from across the entire experimental phase, I discuss and present all of the major themes according to headings arising from the data analysis. With views as to the participants' places in as well as contributions to the project, the major ideas would be summarized in support of engaged learning.

The data collection stage was a conscious act in this study that I carried out as a teacher-researcher involved in interpretivism. I started by creating conducive classroom conditions so that the learners could interact with the GeoGebra applets comfortably while learning mathematics, allowing the real-time capture of their interactions, questions, and thinking processes. Systematic observations were made during lecturing when students interacted with, collaborated on, and manipulated the software tools of GeoGebra in constructing and testing circle theorems. At the same time, students were interviewed and participated in reflective discussions to explore their subjectivity in using the software, as well as their digital literacy, motivation, and difficulties. Through the use of field notes and reflective journals, I documented my own thoughts, decisions regarding how to teach, and what I thought my students' feedback was, allowing me to constantly think back on and change my teaching ideas. When I was able to do the data collection in such a real and collaborative way, I was able to get thick rich descriptions of how learning occurred ground up, in a way that provided the best shot at powerfully bringing together what I saw, what I tested, and what I thought to understand both the thinking and the feeling parts of using Geogebra to learn (Chimuka, 2017; Kugblenu, 2022; Vygotsky, 1978).

**Preparation for the ICT-Based Involvement**

To understand differently theorems-related circle learning through GeoGebra dynamic geometry software according to Kemmis et al. (2013) planning-action-observation-reflection model, I focused on designing lessons that were interactive and visually rich. To find out students' starting level of circle theorems, I took a pre-test that I could then use to plan intervention accordingly. Lesson plans were designed that included traditional teaching and GeoGebra simulation. Lessons were designed such that each lesson was tailored to address one theorem and accompanied by problem-solving exercises that elicited procedural and conceptual understanding (Stein et al., 1996). Preparing was exciting as well as a bit overwhelming. It looked like I was about to do new teaching work. I prepared a pre-test to show how much each person knew, and then I used those scores to come up with a lesson plan just for each learner. Each lesson tried to put theory together with some fun hands-on finding out about what everyone can do with GeoGebra. I was especially interested in ensuring that the content would engage visual, auditory, and kinesthetic learners.

**Teaching and Learning Process**

GeoGebra was used in the implementation to show the geometrical relations dynamically. In this activity, the students tried to learn the theorems through their own efforts by doing some activities with the figures rather than just sitting and getting some facts from the teacher. The above argument is supported by the constructivist learning theory, which is the theory of knowledge concerning how what learners bring to the learning place affects their new findings of what they encounter (Piaget, 1970). In one of the classes, students used GeoGebra to investigate the theorem: *"The angle subtended by the same arc at the circumference is equal."* Students dragged points across the circle, and they were able to see the theorem in action. Yamin said, *"Before, I just memorized the theorem. Now I can see why it works."* Group work facilitated discussion, collaboration, and mutual support. The social interactions engendered active learning and operated to reinforce Vygotsky's social constructivist theory (Smith & Stein, 1998). I took frequent formative tests, like small quizzes and exit reflections, to check how well we were all doing in our classroom, so I could change my future class in time. Once I got started, the class was lively and exciting. *"Sir, this is like playing a game!"* Nisha exclaimed as she dragged a point around a circle and observed the angle values dynamically change. The lessons were structured around conceptual exploration using GeoGebra, inductive inquiry where students tested conjectures, and group problem-solving. My first fears about the students struggling with such change melted away while observing them work, even at times arguing over geometrical properties. My student, Jisman, who never did his geometry homework, so confidently explained inscribed angles to his group, I was shocked and delighted.

**Observation and Student's Feedback**

By systematic observation, I documented significant gains in student behavior and participation. As students were more engaged, both historically and actively, than in previous years. In much the same way as students in regular classes, students asked more questions, followed conjectures on their own, and showed more than before, their spatial sense. Some of the students, like Nisha Khadka, said that *"GeoGebra makes everything colorful and alive; I can remember things longer when I see them like this."* All but a small handful did settle well into the new way of thinking, but some struggled at first to get out of their static textbook diagram mindset. The additional support systems that I provided during this time included step-by-step guidance from teachers and peer mentoring sessions. I watched the class very carefully and saw many forms of learner behavior. They asked more questions, proved that more standards with more passion, and handled hard problems more boldly. But problems also existed during the teaching period. My one student, Bipina, became confused at first when I put her in control of models that were not moving (GeoGebra applet) and then gave her control of models that were moving (simulations). *"I get confused when too much happens too fast,"* she said. So, I let them move, started them slow, let her play, and watched how fast it could be and how far they could go. Nothing but fun was enjoyed by the students in the first and second sessions of interviews and journals. Feedback given revealed that the students not only liked GeoGebra but also had fun with it. After the class, Anish expressed that *"It is clear how it will work now, rather than just imagined. Sir, it really helps me to understand. I love it. "*

**Reflection and Pedagogical Adaptations**

This was what I needed to change my way of teaching. Many changes were made following a review of students' comments along with the formative assessment data. I slowed the plan when the students needed to learn a new idea and show that they could use it. As extra help, I gave students handouts on how to use/understand dynamic geometry figures with respect to theorems, as well as allowing additional time for them to work through figures and check theorems. One of the students, Ayush, added that, *"GeoGebra has taught me about the relationship between angles and arcs-and I think I can apply the same to learning other theorems."* It was the hub of my professional growth. Based on the responses of students, I made a variety of adaptations. I had adjusted the lesson pace, had added revision breaks, and had made overt comparisons between ICT-based and conventional methods. It was in one of these moments that one of the students, Bishal, had asked, *"Sir, can we apply GeoGebra to algebra as well?"* a question that made me very happy. It indicated they were not just learning but thinking beyond the lessons being taught. I also had to learn to relinquish control to some extent, allowing students to find out and explore by themselves.

**Outcomes and Assessment Results**

On a quantitative level, the mean of students' post-test scores increased by 20%, with some made much more than the mean increase. But what pleased me most was qualitative change: increased confidence, improved problem-solving procedures, and enhanced curiosity. Students like Jisman, who initially had complained once or twice, *"Geometry makes my head hurt,"* now smiled during group discussions. They often commented with hindsight about how they had taken in the theorems by seeing the angles and arcs dynamically change.

**Lessons Learned from the Action Research**

Individually, the experience changed me as an educator. I was able to witness firsthand the need for flexibility, the strength of student voice, and the tremendous potential of technology to support learning. There were many challenging moments, technical problems, time limits, and how hard GeoGebra itself was to learn, but the good parts far outweighed the bad. I also saw that the room is not only a place to pass info, but instead it is a lab for inventing, making, and changing for kids and teachers. The research exploration validated numerous essential principles that affect the classroom teaching practice of mathematics. Dynamic geometry software functions to promote inquiry-based learning (Bayaga et al., 2019). As an instructor, I changed my teaching practice from being an information transmitter to taking on a facilitative role. I developed a sense of confidence in students' own inquiry activities, which led me to support their thinking paths more than performing error correction manually. Although this was challenging to manage, it proved to be beneficial.

My time in this type of research showed again that ICT devices like GeoGebra offer a real chance to change how we teach and learn about space (Bayaga et al., 2019; Chimuka, 2017; Kugblenu, 2022). The students in my class were no longer passive learners but physically, mentally, and emotionally active learners. Circle theorems that I had previously assumed were difficult had piqued their curiosity to question and examine. The students' conceptual understanding of the relationships within a circle was significantly increased, and my love for teaching has been refreshed. From this view, ICT is not just a bonus to the old style of teaching but a must-have part that makes math real, hands-on, and clear to see. Though, how well technology works mainly depends on how well it was planned and used properly in teachings; the tool's value is not fully there without the right teaching plan and a real purpose (Barun & Clarke, 2006; Bogdan & Biklen, 1997). To make it work well, schools will have to deal with problems like not enough tech stuff, good places to put it, and learners doing different types of work by coming up with ways to get around the problem and products that fit the situation. The dumbness of the students was measured, after they tried the thing, by autonomous exams, Students said what they thought, looked at what the students were doing in class and had meetings with the students, this all helped us to see how much they learned and how they felt and reacted to what was going on (Bayaga et al., 2019; Kugblenu, 2022).

**Overall Participants**

The participants of the study were identified as Grade 10 students within a heterogeneous classroom at an institutional school in the Pokhara Valley. When the study began, almost three out of four of the people did not want to learn math. They did not try very much in class, and they were not always ready to learn. According to my observation, only a few students regularly finished their mathematics homework, and fewer students regularly came to class and participated in various activities. The

32 students in the class, in total, all took part in the GeoGebra lessons, all completed the pre- and post-tests, and all took part in class activities. Only the six key participants provided richer data for interpretation. In this way, I followed an ethical approach that was sound from a methodological viewpoint and allowed me to learn more about how learning occurs, kept to the slight scope of my dissertation, and ensured that no learner was excluded from the sampling strategy. In spite of this fact, the project included 32 students, and almost 50% of participants demonstrated a total lack of interest in mathematics. Here is a brief description of some of the key informants of the project:

## Key Participants

In this action research, I deliberately selected six students who participated in the study as key informants for this action research. They were purposely selected based on their different levels of mathematics achievement, participation, and attitude towards learning geometry. Those six students were selected very well from one another concerning their mathematical proficiency, class engagement, and responsiveness during discussions. This was done to learn more about how individual learners interacted with GeoGebra and how they changed in their conceptual understanding of circle theorems during the 15-day period of the intervention. Their insights ensure a broad-ranging and multi-perspective view that explores how these students' concept of circle theorems would be influenced specifically by GeoGebra-integrated teaching. Action research is for depth and not breadth. The small, diverse group of six students allowed me to do focused observations, interviews, and reflections. It would not have been possible to work with all 32 students. The six students were a purposeful sample. They were chosen because of the way they learned, which included two strong, two average, and two weak students based on the students' ability to learn, willingness to learn and be a part of this research study, their ability to talk about the learning, and their attendance. Although they provided rich sources of qualitative insights, the intervention itself was carried out on the whole class, which was fair and provided the same chance to learn for all students. This purposive sampling aimed at obtaining a representation of high-average and low achievement students. Their responses, classroom interactions, and learning journey supplied valuable qualitative data, which supported the general outcome of the research. As a classroom teacher, I found this purposive observer had focused on personal learning growth and challenges during the implementation of the intervention.

**Nisha**

Nisha is the most self-motivated, energetic student of in Section D. Among her peers, she is respected as a dedicated learner, one who excels in all subjects, including the compulsory and other subjects as well. She actively participates in all activities in the school, which is a full display of her absolute willpower toward her studies. Conversations with her have shown a very supportive home environment: her parents are both qualified and assist her in her studies regularly. She has been in this school since the sixth grade, even before I came, and is thus well-acquainted with the teaching-learning processes of the school. With her knowledge of both the older and recent practices of teaching, I felt compelled to interview her for the sake of some comparative discussion about the changes in pedagogy regarding mathematics teaching at this school.

Her excitement while we talked about how to use GeoGebra and her momentum in studying theorems about the circle were so great. The way GeoGebra worked dynamically interested her so much that she thought that circle theorems would never be animated. GeoGebra animation and interactivity made her think that abstract ideas became more tangible. The little dash around the geometric shapes and the do-it-ability of GeoGebra brought the ideas that we can think about so much nearer to the basic ideas. The biggest thing to me happened when she was on her experimental verification of the cyclic quadrilateral project and gave a lesson about Cyclic Quadrilaterals. She was able to show the theorem through GeoGebra that brought her knowledge to a new depth and made her lesson better with new awareness and happiness. She commented that on every single day, she can wake up to a new day, looking forward to the next class to see what concept and next hands-on activity the teacher would make up.

GeoGebra made her learning lively and enriching, changing mathematics from an inactive and lazy way to one of learning at one's own pace, of trying out different ways of doing things, and using her ability to reach conclusions. She shared her ideas as *"I think GeoGebra was effective in helping us learn, and I would like to suggest making it more widely used everywhere."* (Reflection on 2nd day during the class, 26 November 2024)

*“GeoGebra is very effective for students to learn. It can unify any issue. It should therefore always be used in every corner of Nepal. Its applets are simple to use and simple to go through.”* Reflection on 14th day after class, Tuesday, December 10, 2024) She added, *“I like GeoGebra applets very much GeoGebra applets because they help me to develop the concept of the theorem very clearly and easily. Sir, could you please teach us the other math lessons as well using GeoGebra?”* (Reflection on 15th day).

These questions really make me realize that GeoGebra really helps her to develop conceptual understanding. My interview with Nisha gave me interesting information on the potential and limitations of the GeoGebra application in the teaching of circle theorems. She was one of the liveliest students in class, constantly coming up with new strategies and ideas daily. Her familiarity and experience with GeoGebra made me appreciate how interactive study software impacts competitive success among students. She related that GeoGebra is a very interactive and effective ICT tool in learning geometry and developing new concepts. Nevertheless, she recommended that I incorporate GeoGebra in all my classes to optimize its use.

**Anish**

Anish is an average student in section D, but his attention and honesty are outstanding. He tends to be quiet in class, but he paid attention and wanted to learn. He may have been bad at Math previously, yet he always tries to improve. I got a chance to meet his mother, who was in distress about his grades in Math. She further added that he scores about at the average level but is eager to do better. She also mentioned that she always reminds him to practice at home, though he sometimes has low confidence in practicing new mathematical concepts. Because of his gradual but consistent growth, I wanted to find out how much GeoGebra had changed the way he learned about circle theorems. During the interview, Anish admitted that geometry was one of the areas that he found difficult, especially imagining how different parts were related to each other in a diagram. However, using GeoGebra changed everything. He learned that the interactive quality of the tool enabled him to see how angles, arcs, and circles are related to each other, so it was easier to understand previously abstract things.

*"Hard for me at first was the connection between what I could see in GeoGebra and the normal proofs that we were doing in class. It's easy enough to find correlations here and there, but it still took a little practice to set a proof down on*

*study."* (Reflection on 3rd day, November 27, 2024). He told me that one of the most beneficial things he learned was to prove the theorem "*The angle subtended by a semicircle is a right angle."* Before the lesson, he had committed the theorem to memory but still lacked understanding of what warranted its truth each time. Through GeoGebra, he managed to test multiple circle diameter measurements while observing the theorem interactively. I found his self-worth as a student rose with the experience. During his tenth day of school, Anish started developing an enthusiastic attitude. He said to me, *"It is one of the best apps for teaching Mathematics. It is one of the best apps that helps with learning. Today, when PBK sir showed GeoGebra, I learned how to prove circle theorems, and I learned it properly."* (Reflection on 10th day, December 7, 2024)

Finally, he hesitantly asked, "*Could I make use of GeoGebra for algebra learning while asking for your permission? I believe it will provide me with a clearer understanding of graphs. Using GeoGebra enables me to obtain a better understanding of graphical representations"*. A major development became evident on the 15th day of December 12 2024 because it showed his learning attitude was changing. Although trying to improve his self-confidence, he had a strong interest in the material. My interaction with Anish also proved the theory that interactive learning tools like GeoGebra are not for the highly talented students alone, but can be learned by normal students as well, by breaking complex concepts into simpler ones. His comments emphasized the importance of engaging students in hands-on, visual learning to improve understanding and confidence with mathematics.

**Prajit**

Based on her previous record in examination, Prajit is one of the intelligent and diligent students of Class X. He is very eager to learn and never hesitates to learn something new through different sources. Unlike the majority of his classmates, he is not so vocal in class; instead, he is a diligent listener who listens very carefully. He never comes forward to speak but responds sensibly when asked a question. His reserve is not due to ignorance but his love for thinking and reflection.

Though reserved, Prajit's hunger for knowledge can be seen from the way he learns. He even actively pursues new topics and generally searches for alternative means of learning difficult topics. By means of discussions, study tours, or self-learning, he learns in various styles to improve himself. He is referred to as a learned and reliable friend by his peers, always ready to share his knowledge at their beck and call. Self-study focus, together with his study schedule, distinguishes Prajit as an outstanding student. His desire for success is well testified by those documents of his academic work, even though he would not talk about it. The classroom environment shows his dedicated approach to self-study as he persists in studying independently without drawing much attention. This humble student accomplishes his goals. He said that:

> *Firstly, I was curious about it, like how it looks, how it works, how it helps us in studying/learning theorems. Then, after some time, our respected compulsory mathematics sir showed and explained it with the help of a projector and a laptop using GeoGebra. After observing it, I was shocked for a second, then I was just enjoying the GeoGebra. At last, I found this app really helps students and teachers for the coming days. I hope this method of teaching Geometry will be fruitful. Thank you so much.*

Reflection taken on day 14, Tuesday, December 10, 2024, after the class through the study.

Prajit enjoys learning with GeoGebra and finds it very effective. His favorite part is how well the GeoGebra shows the link between the Centre angle and the inscribed angle on the same arc using interesting animated applets. He learns the most from these visual graphic representations that he can interact with. What I observed is that such an animated diagram really helps him understand the concept better and to learn better. Not just does he love this specific theorem, but he also loves studying all the rest of the theorems of circles through GeoGebra. He believes that the interactive feature of the software helps learn abstract concepts more effectively. As he himself states, GeoGebra has proved especially helpful to run-of-the-mill students in the way it strengthens their knowledge of concepts nicely, and they can recall the same for long durations. For Prajit, it is not just a question of memorizing theorems when he learns with GeoGebra but of actually understanding them in a way that stays with him beyond class.

**Bishal**

Based on the previous record and my observation during the class, Bishal is a student who finds studying quite hard. In my observation, he always hears a little in class and has very little time to study math. I suppose one reason for this could be that he has very weak basic concepts in mathematics. He also writes extremely slowly, producing only a few words per minute. He fights not only mathematics but also both

English and Nepali. Several times, I have had to remind him to listen attentively and stay focused during lessons. But after starting to utilize GeoGebra, I noticed an enormous change in him. He started to get more active, especially when he observed the dynamic, game-like animations. He particularly liked the manner in which the inscribed angles remained the same while I was changing the arcs. The dynamic presentation of concepts within GeoGebra awakened his interest and encouraged him to become more involved in the process of learning. He expressed his voice as

> *I was fully shocked when my teacher, Purna Bahadur. Kshetri shows GeoGebra. I think this is a good app for Mathematics. The best part of this app is that it easily shows angle, arc, central, and inscribed angles properly with colorful visual representation with animation, and it is very easy to use.*

Reflection taken on day 14, Tuesday, December 10, 2024, after the class through the written study.

For the first time, Bishal himself informed me that he enjoyed a math lesson. In my observation, he looked happy and very sure of himself. When we were in class and when class was out, I asked him some questions about what I had taught, and about my guidance and care for him. He was able to tell me what he thought about his ideas. I could believe the effect of a little applet of improving a student like Bishal. I learned from this experience how strong and useful GeoGebra can be in helping students to see and love mathematics.

**Yamin**

Yamin is well known to his classmates because he still tries to learn Mathematics very passionately. He, however, does not easily understand mathematical concepts and finds Mathematics the most difficult of all subjects. His grade for Circle Theorems, however, is fine. He has been learning Circle Theorems using GeoGebra for the past 15 days, and he has been doing well. He has been in this school for five years now and has had a mixed experience with circles from his classmates. Reflecting on his experience with GeoGebra, he informed us:

> *Mathematics is now easier to learn than ever before. I had sufficient chances to share my ideas with my peers and interact with them, which helped to understand Circle Theorems. I also realized that even problems related to circles that we did not know were possible to solve now.*

Reflection taken on day 14, Tuesday, December 10, 2024. He also shared that he never learns mathematics with so much fun and excitement. He loves the cyclic quadrilaterals property “the opposite angles of a cyclic quadrilateral are supplementary,” its animation, and concept. He told me that he will never forget this theorem and is happy to share it with his juniors as well. He also shared with me that

> *"I remember the day we learned that the angles in a semicircle are always 90 degrees. Seeing it in GeoGebra, where I could drag the points, and the angle stayed constant, was like magic. It suddenly all made sense to me."*

Reflection of Day 15, December 11, 2024.

**Garima**

From the very first day, I understood that Garima was a slow learner. She is neat in handwriting, honest, gentle, and disciplined, but not studious. All the teachers in the school believe that she takes time to grasp new things and does not say much in class discussions or present her opinions. The GeoGebra class session gave me the chance to engage with her while gaining insights about her classroom experiences. When I asked about the lesson after the use of GeoGebra, she said that she loved classes more than she had before. She found the GeoGebra application fascinating, as she had never seen or heard of it before. She was curious to know how mathematics could be enriched using technology. *“Sir, I never enjoyed learning Geometry before as I enjoy today, it is only because of GeoGebra.”* She especially enjoyed the GeoGebra animations and the vivid color changes of inscribed and central angles on the screen.

Apart from studies, the use of GeoGebra also helped her have better relationships with her friends. She admitted that she still needs to work harder on various aspects of mathematics and improve her format of answers. To reinforce her math skills, she has decided to spend extra hours studying mathematics each evening. According to her self-report and her self-knowledge, her use of GeoGebra has led to good teaching of her about why the Centre of a Triangle is so important in triangle geometry. Her increased understanding of mathematical ideas, her skill at finding workarounds, and her ability to demonstrate more confidence show us that the action research has had real meaning for what she has learned. It is the best reason of all; her improved performance is a good example of how action research takes the form of a circle, feedback, and response. We make small shifts in teaching that take into account what students need to learn, what they need to know to deepen their understanding of a concept.

## Meaning Making from the Field Works

In this heading, I have discussed the key findings of my study, employing collected data, participant interviews, and reflective journals written by the students. Having carefully interpreted and analyzed, I have drawn primary themes and conclusions with due support from data. For the purpose of furnishing informative and fruitful discussion, I have categorized the findings into six wide-ranging themes, in which each theme describes the main events and ideas that emerged during the research. Other than highlighting how GeoGebra impacted students to learn Circle Theorems, these themes also provide stronger insights into how they felt and surmounted problems, as well as evolved. The evidence contained in the data supports these findings, thus strengthening each conclusion. In the next four parts, I write about these six general trends weaving along students' words and findings together with a reflection on the broad picture of the findings of the study.

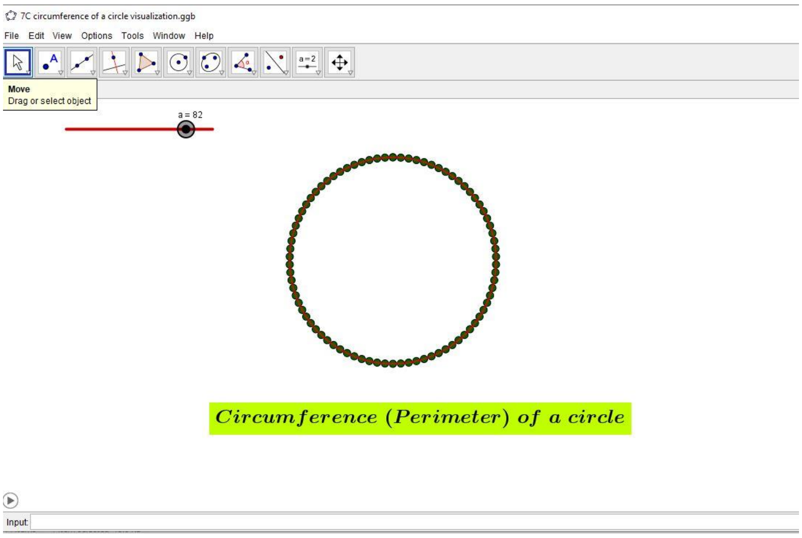
**Enhanced Engagement and Satisfaction in Learning**

On Monday, November 25, 2024, I officially started day one of my action plan on how to teach circle theorems with the help of GeoGebra. This was on that day when all learners did an unexpected 10-mark pre-test about the circles' theorems. The learners could not expect it, as they did not know they were to do it. However, this test, which was not prepared very well, gave me a true measure of what learners knew till today and had been able to prepare for the next lesson. My lesson-opening activity after the quiz was to ask them a simple question that makes their brain think, *"Have you heard the word GeoGebra?"* Responses ranged from no sir! -Most students had, and too few had, the greatest knowledge of this word. That meant I had to present this lovely tool properly. So, I opened the GeoGebra software on my laptop and displayed it on the screen for the entire class. I started with very basic concepts like the Centre of the circle, circumference, radius, diameter, arc, and chord of the circle.

I started the discourse with a question, *"Do you know about the perimeter of a circle? Are the circumference and perimeter of a circle being same?* One of the students immediately replied, "*Sir, the outer part of the circle."* Another added *"Sir, sum of outer length*." The Third replied, "Sir, $2\pi$r". I said you're all on the right track. Let's see in the GeoGebra Applet once. Then I started representing the animated applet representing the circumference. Students observed that with great curiosity. I further discussed the first applet as

**Figure 4**

*GeoGebra Applet Representing Circumference/Perimeter of a Circle*




Teacher: *"Can you notice the first thing you see in this diagram of a circle's circumference?"*

Bishal: *"Is the symbol next to a big circle with a printed number beside it? Is it the circumference we should be considering?"*

Teacher: *"You noticed well! It means the circumference in this situation. We should try to reconsider this approach."*

Prajit: *"Oh! The model expands whenever I increase the value 'a'. What is the best way to determine the radius? "*

Garima: *"Look, there's no radius marked in this diagram. Could we determine its value using only the circumference?"*

Teacher: *"Right! We understand that $C = 2\pi r$. Given C, can we solve for r?"*

Ashmi: *"Although no numerical measurements are given, the relative proportions in the diagram are changing. If I make the value of 'a' smaller, the circle gets less and less of the same amount."*

Anish: *"These graphs and diagrams help me a lot more than just a math formula. Could we maybe display labels for the radius, making it clearer to view both?"*

Teacher: *"That is a strong suggestion to make." It will be done for you on your next visit. For now, what does this visualization help you understand more clearly?*

Yamin: *"Oh, yeah, sir! Doing experiments is much more fun than just trying hard to learn by heart."*

I observed everyone's face. All are in learning mode. I was fully satisfied that everyone loved the idea through their facial expression as well. Then I started showing another applet representing different parts of a circle. One by one, I asked students about different parts of the circle. They enjoyed the concept and learned with fun. I asked one of the less active students in the class whether he was learning or not. Then immediately he replied, *"Today I understood easily, sir. First time I am enjoying learning mathematics, sir."* Without any hesitation, they shared their feelings that they really like GeoGebra.

Teacher: *We will now consider this diagram that explains 'Sector', 'Chord', and 'Segment'. What makes you pay attention to the artwork already?"*

Nisha: *"I know about a chord; it is the line segment that joins any two points of the circumference of a circle."*

Teacher: *I agree with you, Nisha. A chord separates a circle into pieces. Yet, there is nothing in the diagram - how can we represent this? "That's a great observation regarding the terminology! For this example, let's say it represents a chord and its segment. How could you draw this arrangement, Sandesh?"*

Sandesh: *"This shape (circle) gets divided in two by a line, so there are two segments- the larger one and the smaller one!"*

Susan: *Then the chart says 'Sector' at the top. Is it just another way to say segment?*

Teacher: *This is a wonderful question. At times, a sector is described as the region between two radii and its corresponding arc. How is this distinguished from a segment, Pramisha?*

Pramisha: *A sector is defined by its two radii, but a segment is measured by its chord! Is adding colors able to help separate them in the diagram?*

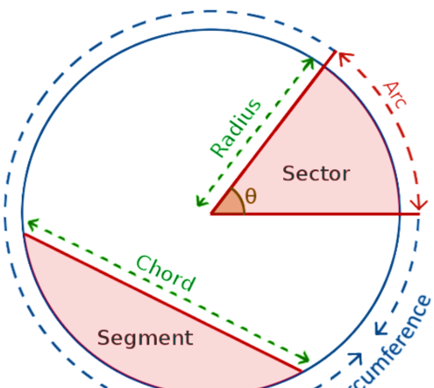
Teacher*: You are right on with what you suggest. This clear diagram makes me ask some important questions. What's the most important thing you've noticed?" Those difficult diagrams encourage us to consider things more closely, but they require corrections to avoid making mistakes.*

Pramisha: *"Collaborations play a big role in tackling unclear cases. Can we rebuild this together as a group?"*

Teacher*: "Perfect! Next, we'll design an updated version using your ideas for corrections, images, and understandable distinctions.*

**Figure 5**

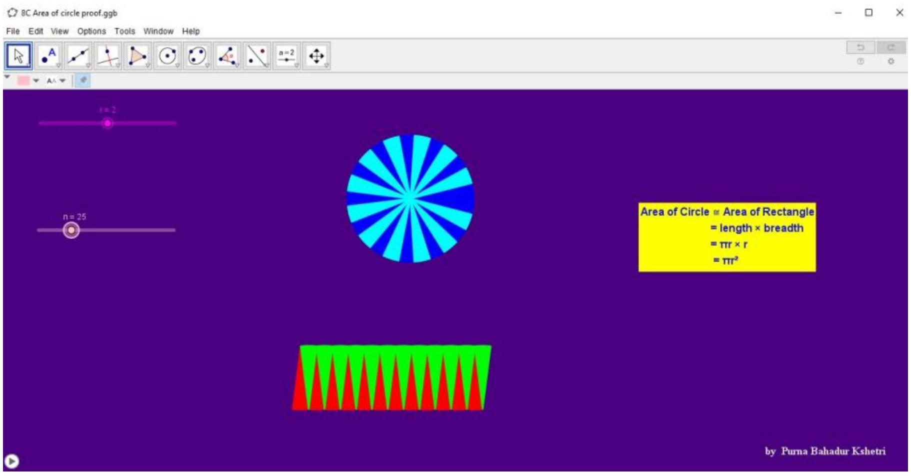
*Screenshot of GeoGebra Applet Representing Parts of a Circle*



Next, I displayed the first lesson of the circle, i.e. relation between the central angle and its opposite arc. I started the relation between the central angle and its opposite arc, which is exactly given in the textbook of class 10 compulsory mathematics. I ask, do you know how we can make $50^{0?}$ Students immediately answered- sir, with the help of the protector. Then I ask one protector and draw $50^{0}$ on the board with the help of the protector. Also, I connect the concept of arc and angle, that the angle formed at the Centre directly depends on its corresponding arc. I also connect a circle formula with GeoGebra. I asked what the formula is to calculate the area of a circle. Everyone replied once, *"$\pi r^2$, Sir"* I said, you all are correct. Then I displayed an applet representing the area of a circle as

**Figure 6**

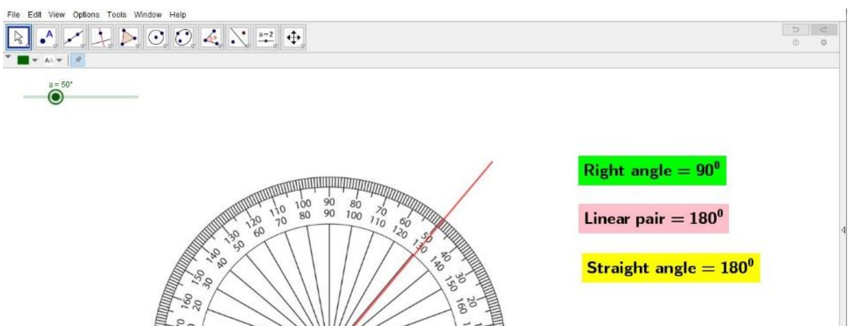
*Screenshot of GeoGebra Applet Displaying Area of a Circle*




Students love the colorful applet displaying the area of a circle. From this activity, I feel that very talkative students as well as those who listened carefully to the animated applet. I also noticed that GeoGebra really connects students' minds to learning.

**Figure 7**

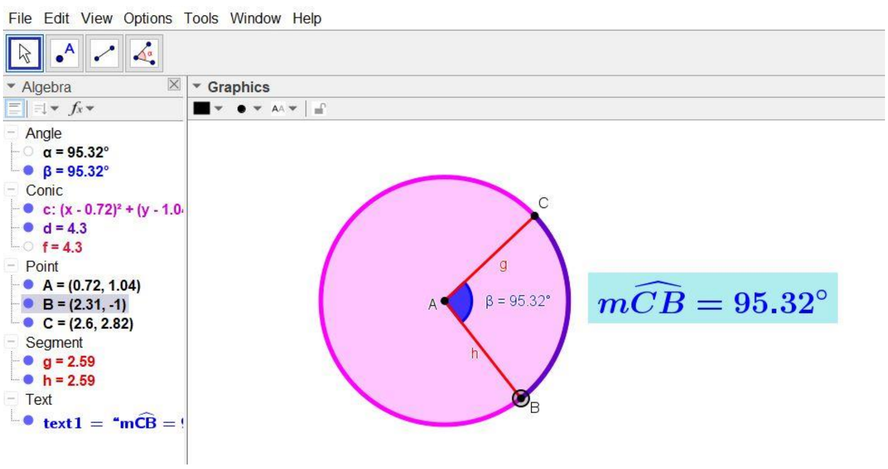
*Central Angle with Corresponding Arc*



Next, I asked the students, "*Do you know how to measure angles?* "Everyone replied, *"Yes, sir."* Then I displayed a slide representing the actual measurement of angles anticlockwise. Then I show another applet representing the relation between arc and central angle. Students show their full interest in observing and learning. I drag point C so that the arc increases or decreases, and also the central angle increases or decreases accordingly. I asked the students whether they understood or not. Most of the students answered that they know the concept. It really makes me happy as well.

**Figure 8**

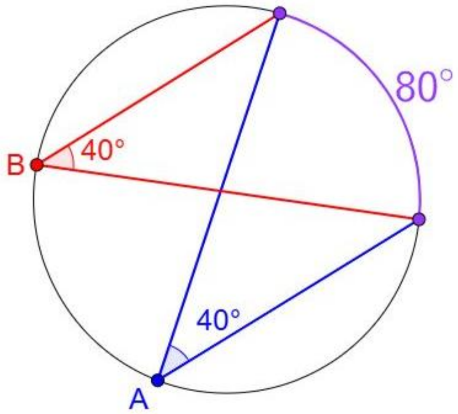
*Relation Between Central Angle and its Opposite arc*




I appreciated and connected the next applet related to the inscribed angle, its opposite arc. I started a visualization by dragging the arc that changes the inscribed angles at the circumference. I seem students were fully engaging and observing the visualization. I noticed that students are really connecting their idea of arc and angle through the applet. I asked, *"What is the size of the inscribed angle if an arc forms $80^0$ at the centre of the circle?"* Most of the students answered $40^0$. I am really surprised that a simple applet helps to connect the abstract concept very easily, and now I knew the actual power of GeoGebra applet.

**Figure 9**

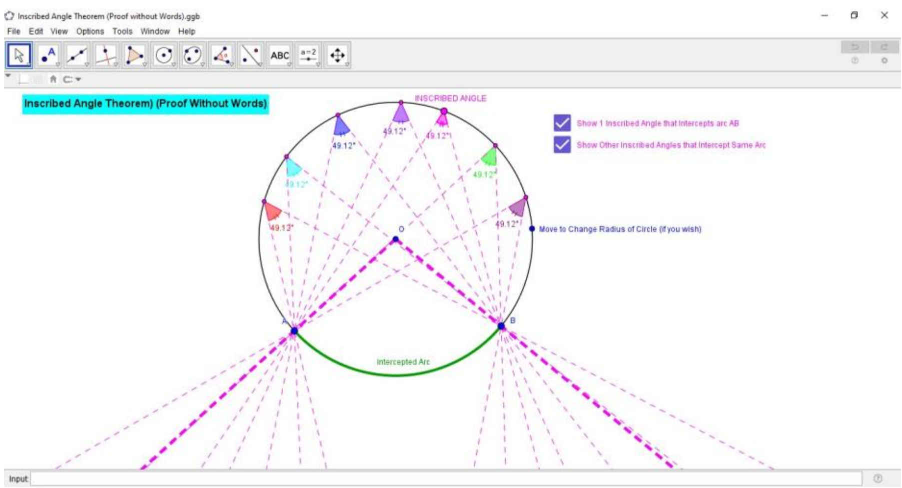
*Relation Between Inscribed Angles and its Opposite arc*




Having sparked their interest, I proceeded to show them the basic features of a circle through GeoGebra. The dynamicity of the software allowed me to show that features like inscribed angles standing on the same arc are equal, which would be very important. I asked what would happen if I dragged the arc AB in the inscribed angles? Students answered, "No *change, sir."* I said, oh yes, correct! Then I do the same in the applet, I dragged A and B, but the size of the angles remains the same. Students seemed to enjoy their correct answers and ideas, what every teacher expects, what I expect. It really made me happy as well. Since the activity was not traditional in terms of the chalk-and-board presentation, seeing live manipulations and relationships between different components of the circle would have helped students form a clearer and more intuitive understanding of the concept. While opening another applet describing inscribed angles standing on the same arc are equal, one of the students, Sneha, got more curious and asked, *"It's just amazing, sir! All angles are equal! Can you drag the circumference points, sir?"* Then, immediately, I started dragging the points, but still the angles remained constant. Then, students understood that inscribed angles always remain equal under the same arc.

**Figure 10**

*Relation among Inscribed Angles Standing on the Same arc*



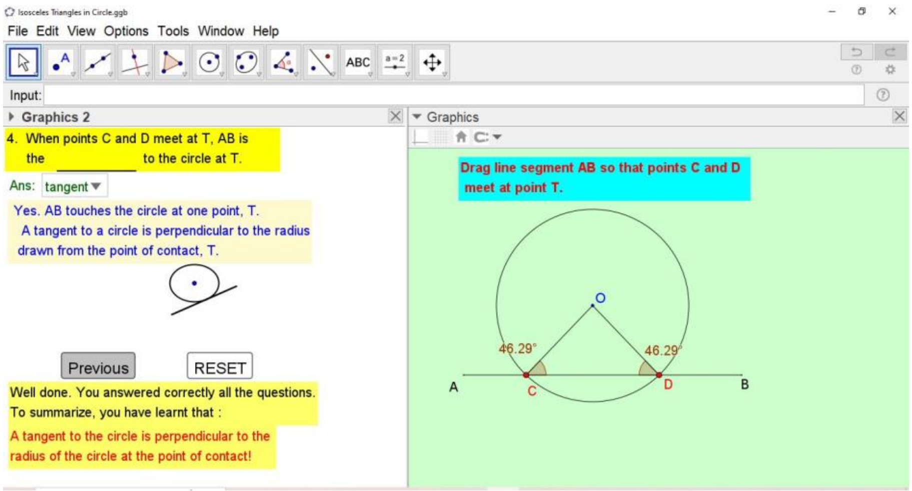
*Teacher: Today, we will be looking into this GeoGebra applet, which deals with the Inscribed Angle Theorem. So, let's see what comes up first in your notice, shall we?*
*Ayusha: There's a circle with angles that all tag along 49.12°. Is this showing how angles are related to arcs?*
*Teacher: That's right! That is the Inscribed Angle Theorem. So, Ayusha, what do you expect to happen when you move A or B around to change the arc?*
*Ayusha: Oh! It is changing the inscribed angle always only to half of the central angle! Though enlarging the circle still!*
*Ayush: Despite where I put the points, the ratio by which it is still difficult? That's attractive, but how does this support our concept?*
*Teacher: Assuming the measure of the central angles was understood as 80°, identify the inscribed angle that takes the same arc.*
*Yamin: Half of 80°, that's 40°!*
*Ayush: Um! It updates on the inscribed angle, always half of the central angle! Even if I make the circle bigger!*
*Jisman: No matter where I put the points, the ratio is still accurate? That's cool, but how does this help with real problems?*
*Teacher: Supposing that the measure of the central angles was known as 80°, determine the inscribed angle that intercepts the same arc.*
*Yamin: Half of 80°, I mean 40°! But what if several inscribed angles intercept the same arc?*
*Teacher: Click on "Show Other Inscribed Angles" what do you see?*
*Ayusha (clicking): They vary in size, but they're all still half the central angle! Even if they're on opposite sides!*
*Ayush: This 'Proof without Words' really works-I can see the theorem without equations, thank you!*
*Teacher: Here is just a visual! Well, now let's get to the real meat of this post. If an inscribed angle is 25 degrees, then what must be the central angle?*
*Yamin: "50 degrees, sir. Doubled it. Other circle theorems can also be dealt with in this way!"*

*Teacher: "Of course! Next, we can check out GeoGebra about the 'Angles in the Same Segment' theorem."*

Throughout the 15-day action research, the students exhibited a dramatic boost in engagement and enthusiasm for learning circle theorems using GeoGebra. Students had their first-ever encounter with GeoGebra on the first day. They spent the day getting familiar with how they could navigate on the screen and experiment with different tools. A few students, including Arjun Chhetr, were uncertain about automation, and they doubted whether it could be used for math. Only a few hours and they changed their minds. In the latter part of the sessions, their interest had turned into passion. It is the second day when students are building properties of simple circles, such as central and inscribed angles, using GeoGebra. Students like Prapti Chiluwal exhibited their eager interest in learning in an interactive and visualization-bent approach, sharing that the process was exhilarating and enjoyable.

**Figure 11**

*Relation between Radius of a Circle and Tangent*




One of the most visible classroom changes resulted from student interactions with GeoGebra applets. As shown in Figure 8, students enthusiastically interacted with points to explore properties of tangents, particularly when lines snapped to precise right angles, and a collective sense of wonder ensued. This was not an isolated aha moment; students huddled in, shared screens, and one exclaimed, *"Before, we used to memorize theorems. Now, we get to watch them happen!"* This idea agrees with Vygotsky (1978) that real learning, both socially and in the context in which it takes place, depends on others. While these tools did indeed increase motivation, I noticed one quiet drawback: some students were captivated by the newness of dragging points without understanding the mathematical basis behind it. To quell this, I added questioning, "*Why does the angle change when you drag point C? This blend of play and deliberate reflection was a turning point in linking engagement with understanding."* GeoGebra is not a pedagogy in itself; its teaching strength lies in its intentional use. As seen in Figure 9, when structured exercises made students discuss patterns observed, their completion improved, not just by shaping, but by becoming familiar with the process.

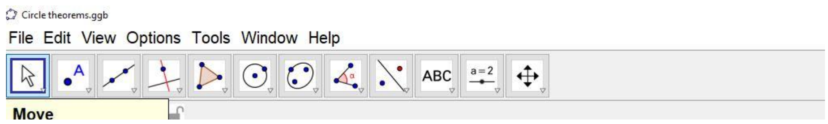
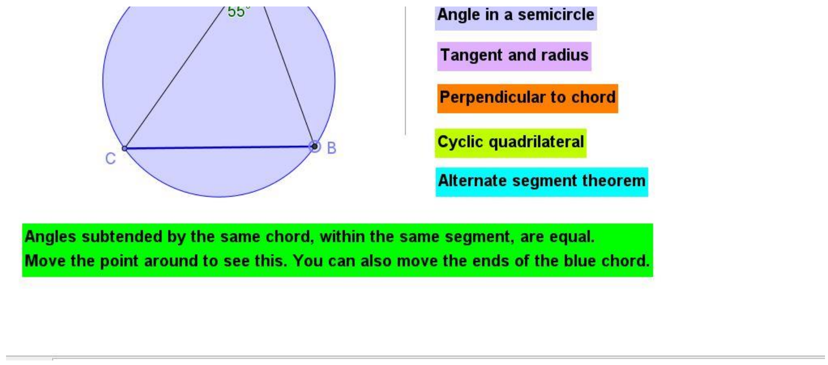



**Figure 12**
*GeoGebra Applet Representing Angles in the Same Segment*




Following this, I introduced them to how GeoGebra works. We started with just plotting points and creating circles, then playing with the options for measuring angles. The visualizations this time looked good enough for the students to figure out what a steady radius looks like in use. Students then played with the program by outlining circles with the tool, and by rough sketching circles with points and then moving around to see what the radius would be. It was very fun for them to sketch points with the program and see how they moved as the points changed their distance relative to the center. For some, it was easy to see how things worked; for others, trying to make things work was enough to keep them occupied. One student was unable to measure angles and required one-on-one instruction. These examples served to illustrate the differences in computer skills that were represented in the class and the further need to revisit the skill issue.

A critical portion of the session was to prove the theorem that inscribed angles subtended by the same arc are equal. I used GeoGebra to show that inscribed angles are the same regardless of their location on the arc. Students re-created what was happening on their own screens, with several students saying things like "Oh! Yes," when they realized the angles stayed on the same arc are equal if they slide points along the arc. This work made more learning happen in the class, and the students said, *"It is not so hard to learn this. We can move arcs around and look at the size of inscribed angles and see what happens."* This is what one of the students, Suman, had to say on day 2, 26 November 2014. Students found it both enjoyable and thrilling to learn circles through the use of chair learners for working with their GeoGebra tasks, and it was fun for those students who used those activities. The educational features relating to circle theorems gave visual and interactive features that eased the students' strained way of learning through mechanisms that were simple to read. Learners were more curious about the encouraging obstacles of steps and how animated live images were used in the content, which made them want to teach the content. Visualization of theorems made the learning process dynamic, where students were engaged throughout the classes. In the final days of the action research, the majority of the students mentioned that they found lessons more engaging relative to the conventional chalk-and-talk method, verifying that GeoGebra helped immensely in boosting engagement and learning satisfaction.

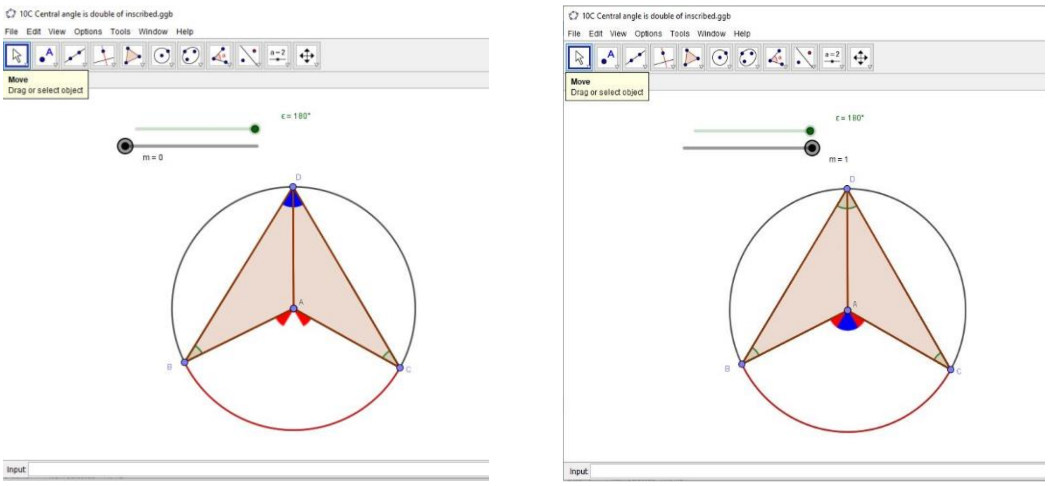
**Improved Conceptual Understanding of Circle Theorems**

Moreover, the students' reflections revealed how GeoGebra was effective in the development of the students' conceptual understanding. In fact, for the first few days, students were exploring general concepts such as the relationship among arcs, angles, and chords. On Day 3, students learned the theorem *"*Inscribed angles standing on the same arc are equal.*"* In that class, the students had been introduced to employing GeoGebra to play with a dynamic and visual shifting situation. Many students, like Anish K.C., reported that they could now focus satisfactorily on proving circle theorems more readily after having utilized the applets.

Certainly, Circle theorems were 'easy' to grasp with GeoGebra because it showed the properties of the inscribed and the central angles. Students could see right away how the Circle theorems work in the real world with the help of lively colored applets, so it became easier to understand. 25th November 2014, was when my fifteen-day action research plan started for improving students' conceptual knowledge on circle theorems with the use of GeoGebra. It began with a pre-test to establish students' prior knowledge, followed by lessons proportioned with the use of ICT tools to illustrate the abstract mathematical concepts to make them more real. The initial period covers foundation building from November 25th to December 1st, 2024. During the first week, students studied students studied about simple terms of circles and their parts. I discussed the Centre of a circle, radius, diameter, chords, sector, segment, and how each increases the perimeter of the circle. Circle rules came before a handout with a colored diagram showing inscribed angles, central angles the lengths of the curves. The lesson began with the opening question, *“Do you know the relation between the central angle and the inscribed angle?”* on Day 3. The participants showed different levels of knowledge about GeoGebra, as most students were unaware, but a few had some understanding. Being aware became crucial about how essential each step is when introducing this tool to the students. Next, I performed the same task using GeoGebra, which gave the students a chance to make endless variations by changing the size of the core section. As I use the slider and try to develop the concept of the actual relation between inscribed angle and central angle. It really makes them happy and surprised. I asked them: Did you understand? Everyone shouted together, *“Yes, sir!”* I also understand that GeoGebra is very helpful for developing conceptual understanding.

**Figure 13**

*Central angle and Inscribed angle before and after the use of Slider*




*Teacher: "Let's have a look at this GeoGebra applet describing a circle with angles. What comes to your mind first?"*

*Bishal says: "The angle at the Centre is really 180°. It makes a straight line; therefore, it is actually a diameter, right?"*

*Teacher: "Next, Bishal, what do you think will happen if we put the slider on (m = 1)?" After Using the Slider (m =01)*
*Bipina (sliding): "Quick! I just saw an inscribed angle shift! It's still marked, and it's linked to the same arc as the central angle."*
*Suman: "The central angle measured is still 180°, but the inscribed angle is 90°. That is why the central angle is twice the inscribed angle!"*
*Teacher: "Very good, Suman! This is a proof of the Central Angle Theorem."*
*Sneha: [pause] Why is this theorem valid?"*
*Teacher: "The central angle spans the whole arc, but the inscribed angle only 'sees' half of the arc from the circumference. [pause] That is why it is always half of the measure! Testing the Theorem Dynamically."*
*Teacher: "Bishal, [pause] what will you do if you change the central angle to 120° through the input box [pause]?*
*"Bishal (sets "c"= 120°):"[pause] Now the inscribed angle will automatically snap to an angle of 60°. [pause] the ratio is still kept: double and a half."*
*Bipina: "This clarifies the theorem completely for me! I would memorize every static diagram, but I can actually see how it works."*
*Garima: "And what if we shift the inscribed angle to some other curve on the circumference?" Teacher: "See! Pull the point and newbie what takes place."*
*Sneha: "Just where I place it, it debunks the same curve as well as the inscribed 77-degree angle, and also the inscribed 77-degree angle is constantly half the main angle!"*
*Teacher: "And also, just how might this be used in the real world? Just how could this be made use of in architecture or design?"*
*Garima: Sir, I observed in the windows of some of the houses.*
*Teacher: That's great!*

Students choose to listen to their friends for the first talk because they 'learned it' better than the talk in the book. The second student said that he had his first real understanding of the link between angle measures and arcs in real time. It was the students' first signs of teaching themselves about dynamic circle relations. What I observed most, however, was the positive class energy. Even students who were shy and quiet took part by changing the applets a lot and writing about what they observed. Even students who were doing poorly due to struggles with abstract thinking claimed the animations made sense. One of them, in fact, said, *"I never* *thought I could understand this theorem, but now it's so clear!"* -Yamin on the 3rd day of the action plan. Several students felt that I should prepare similar applets for other theorems and showed a keen interest in learning from them. *"Can we do all the theorems like this? It makes math so much interesting!"* one student suggested. The student's responses have strengthened my belief in the effectiveness of the approach while encouraging me to go further in developing such resources.

The reactions of the students to the GeoGebra applets were very encouraging. *"Sir, I love these animations. It makes the theorem so easy to understand."* Exclaimed one. *"I had no idea math could be so much fun-the way we can see the angles change and still stay equal is amazing!"* said another. Many students were viewing their ideas very openly for the first time, in a way that I never expected students to share their feelings. One of them said, *"This is my first time using GeoGebra, and I just can't believe how colorful and interactive it is. I wish we could use this for every topic."* The method was so helpful even for those students who usually had big problems with mathematics. I asked several of these for weaker students after class, and the replies were that only when GeoGebra had to be used for the concept click for them. At that very instance, I saw for sure how technology may provide some way of delivering concepts considered most abstract, even for most of the learners.
*"GeoGebra itself should be adopted while teaching things like abstract theorem-anything in math, everything just looks crystal clear*," said Nisha on day 3.

I had presented that the inscribed angles and their corresponding arcs were equal in the Week 2 presentation. Students focused on the theorem about inscribed angles during their class on December 3. The theorem stated that every inscribed angle that lies within a circle equals half the measurement of its subtended central angle. By GeoGebra applets, I facilitated dragging the arc, and it would directly alter the inscribed and central angles. The average student, like Sajan, Aayush, and Nisha were particularly keen, asking, *"Sir, is this applicable for all arcs?"* This provided the curiosity for an exploratory discussion where students tried out different arc lengths and angles. On December 5, I inserted the additional challenge, *"Can you calculate the inscribed angle if the central angle is 76°?"* The students, having played with GeoGebra, then hung their heads and, in resounding unison, shouted, *"It must be 38°, sir!"* The ability of students to generalize the theorem shows their deeper understanding of the concept. I also asked if we take the ratio between the central angle and the inscribed angle, what would be the ratio? They just tried and replied:

“*Sir is 2 or 2:1*”. I replied, Wonderful! This activity helps to prove that an inscribed angle is twice or double, or two times the inscribed angle, if they stand on the same arc.

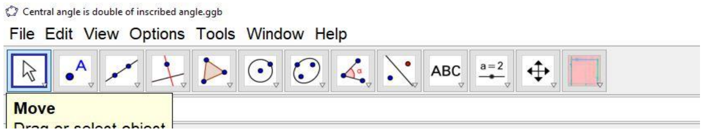
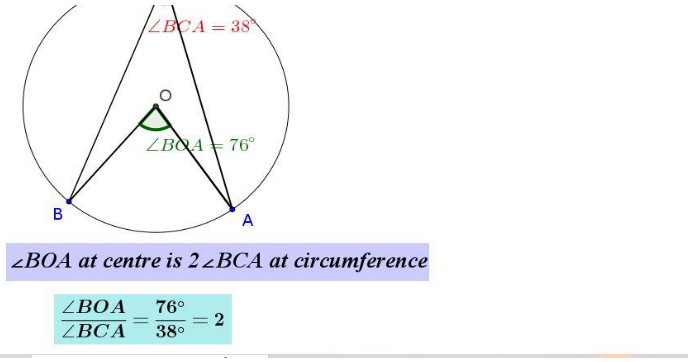


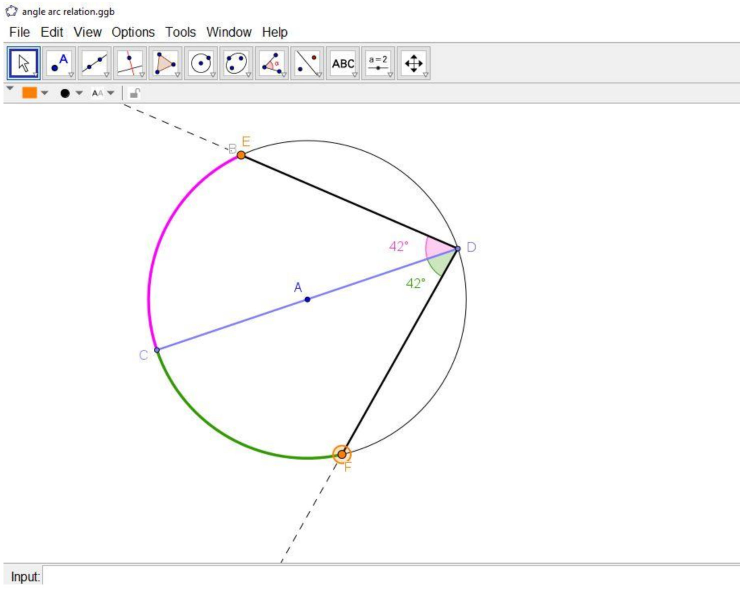

**Figure 14**
*Ratio of Central Angle and Inscribed Angle Standing on the Same arc*




*“I now understand why this theorem is true since I can create my own proof beyond just relying on the textbook statement,”* exclaimed one student, Yamin. Applications that address real-life problems formed the core content of my teaching approach during week three. The December 10th activity required students to collaborate through GeoGebra software while demonstrating the alternate segment theorem. The student population became more involved in class work, especially those who had previously shown weak abstract reasoning abilities.

GeoGebra revolutionized how students learned and understood circle theorems. The previously abstract ideas were now concrete and real, as is evident in Picture 10, where one student concluded*, "△OCD is isosceles because OC and OD are radii."* This graphic proof was more intuitive than formal symbol manipulation. It fostered a better sense of insight, particularly for those students who had not managed formal argument. However, a novel challenge emerged in high-performing students who began to over-rely on the software, circumventing the intellectual discipline of writing formal proofs. This prompted me to require double representation, replicating visual intuitions on study, in alignment with Ainsworth's (2015) theory of learning with multiple representations.

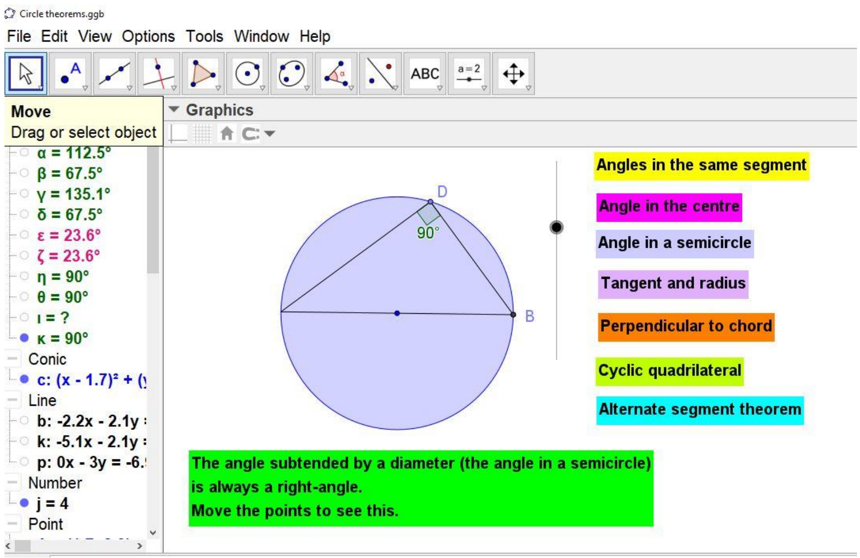
**Figure 15**
*Inscribed Angles Standing on the Equal arcs*




A student commented, *"It's like the diameter 'pushes' the angle open!"* Figure 15 captured a considerable cognitive jump between visual exploration and geometric thinking. Such episodes of embodied cognition also indicated GeoGebra's potential in recalibrating the internalization of mathematical truths by the students. I found later on, though, that without coaxial guidance towards formalization, a visual understanding proves to be temporary.

**Figure 16**

*Angle at the Circumference of Semi-Circle*




Some of the students also gave useful feedback regarding wanting more applets for other theorems. The student asked me to say, *"Could you have similar tools for the next theorems as well? I want to learn more, similar to today, using GeoGebra."* Pramisha, on day 3, 27 November 2024. The enthusiasm and curiosity of exploring more with technology made the method effective and, at the same time, drove me to prepare more for further classes. As a teacher-researcher, I was impressed by the high level of class participation. Students were attentive, participated, and were deeply interested in the learning process. Bright colors and an interactive interface of GeoGebra drew their attention and turned what could have been a difficult lesson into an exciting exploration. I've observed students discussing their findings with each other, helping, and even debating the results of their manipulations on the applets. These were some of the key participants whose reflections I sought after the session, on how such an approach had deepened their understanding. One key participant, Bishal, reflected, *"The animations of GeoGebra made the proofs so much easier to understand. I wish we had learned it this way a lot earlier."* I used to monitor their engagement and participation, underlined how inclusive and effective the session was through observation checklist and reflection. Even those students who were normally struggling managed to reveal notable improvement. When I asked them personally, they answered that they finally understood what had always been a bit obscure for them. This was a point in my life that made a radical change in my perception of the use of ICT tools while teaching.

The post-test on December 12 provided researchers with results to compare students' knowledge between the start and conclusion of the intervention. Major participants showed increased conceptual understanding in the post-test results rather than just performing rote memorization. The student went from memorizing theorems before discovery, yet now feels he understands their basis, remarked a student. In the course of ongoing research, more complicated theorems, such as "The angle subtended by a diameter in a semicircle is a right angle," were dealt with under GeoGebra-based activities on Days 5 and 6. Students explained that visual proofs allowed them to move beyond memorization so that they could actually understand why theorems worked rather than memorize statements. By Day 12, students like Nisha Khadka were remarking that GeoGebra was clarifying mathematics topics, once again confirming that conceptual understanding was highly supported using this technological approach. As a teacher and researcher, I was surprised to observe how engaging the lesson was for them all. Every single one of them was very focused and deeply involved in activities within the lesson. The interactivity and colorfulness of GeoGebra attracted their attention and made them see what could have been a routine lesson as something very exciting to discover.

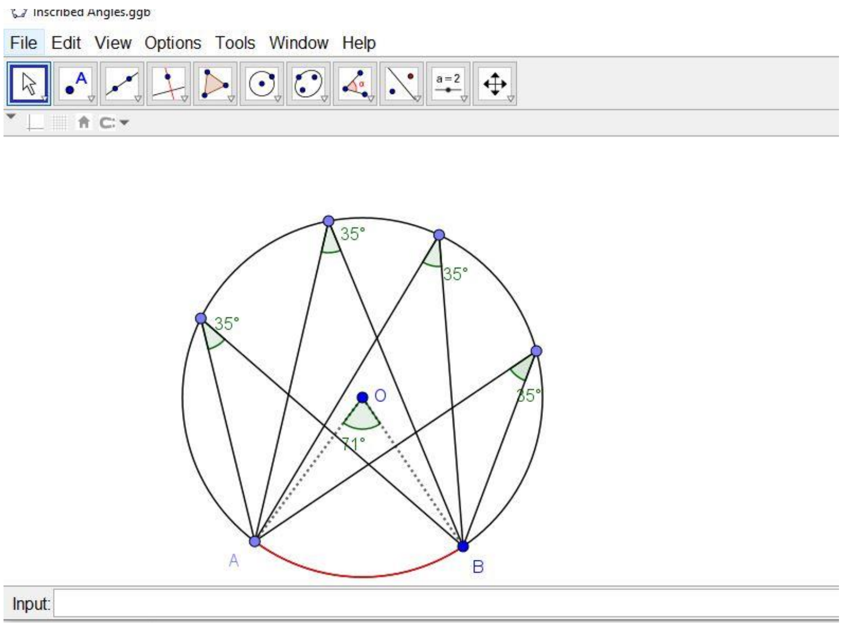
Having examined my 15-day action research, quite a noticeable difference was seen in the learning disposition and conceptual knowledge of the students. GeoGebra, being very dynamic, afforded the mode of active learning where students saw, modified, and dynamically explored geometric relationships. Students can learn better and faster if they are provided with instant visual feedback, which can break the stereotypes they have in their minds.

The session was also a moment of personal realization for me as a teacher and a researcher, seeing the enthusiasm and understanding on my students' faces, and not being able to help but think about how these tools, like GeoGebra, could have made a difference in my own school days' learning. Again, it made me even more ready to use ICT tools to make teaching-learning better. Also, this session taught me about the importance of listening to and valuing suggestions from my students. In fact, upon request for GeoGebra-based lessons more often, it stands to prove how it has created an impression and increased interest in math. I definitely believe it will not only help in terms of better grades in these exams, but leave an impression that would last throughout their memory on these concepts.

**Developing Problem-Solving Ability and Mathematical Confidence**

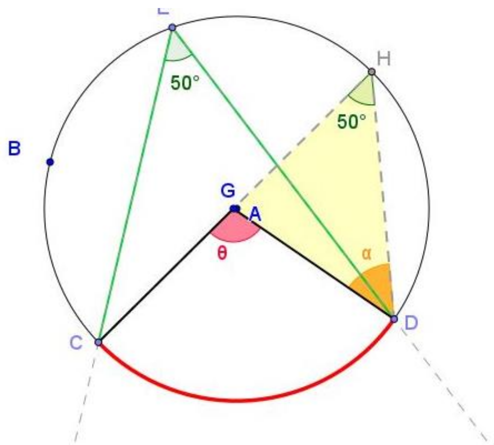
Students reported they felt more confident at this point about approaching unseen circle questions. Interactive learning helped them to read hard problems this made their problem-solving more efficient and boosted confidence in their mathematical skills. There were suggestions made on using guided discovery through GeoGebra. Every student was visually able to manipulate the central and inscribed angles to find their effects when the arc was changed. On November 27, I asked, *"What will the inscribed angle do if we change the arc?"* Then, as they dragged the points to show further patterns by their own effort rather than just memorizing rules.

**Figure 17**
*Representation of Inscribed Angles Standing on the Same arc*




In the second week, the focus had turned to problem-solving in a structured way. I set a challenge to a group of students to find out the relationships that exist between some angles provided to them by a GeoGebra simulation. Then they were to prove a theorem without direct instruction on 3 December. On December 5, the breakthrough occurred when Bishal, a mathematics student who initially did not show much confidence but has improved greatly, said, *"If the inscribed angle is always half of the central angle, then if the central angle is 100°, the inscribed angle must be 50°!"*

**Figure 18**
*Inscribed and Central Angle Relationship*




It was a good breakthrough to go from passively receiving information to actively reasoning and justifying solutions. In addition, some students who seemed initially shy were now actively arguing and countering each other's reasoning. In that last week, I brought up problems concerning real-life models. On December 10, student groups discussed practical problems using circle theorems, for instance, finding an optimal position to put a surveillance camera covering a specific sector of an encompassing circle. The next day, on December 12, I gave a post-test similar to that on November 25. Here, again, students did better than previously and were able to justify their solutions to questions. When asked how they feel about the progress, Anjali, one of the initially struggling learners, confidently said: *"I used to think geometry was really tough, but now I can actually solve problems without getting stuck."* Integrating GeoGebra and offering engaging problem-solving activity help students to build mathematical confidence. The movement from memorization of theorems to discovery and applying them has nurtured an active, deeper problem-solving mindset in students, not to mention that most students in class.

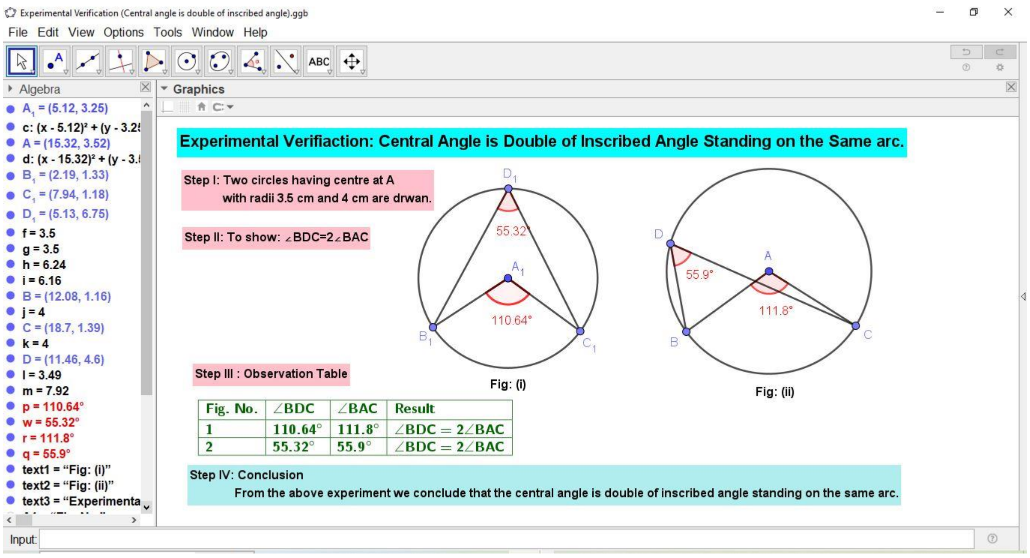
The normally quiet girl, Bipina, who rarely raises her hand in class, shouted, *"As I moved all of them, and it's always doubling! Which is amazing."* The feedback from one of the key participants was equally encouraging to me. One student reflected*, "This way of learning makes so much sense, sir."* Other students asked me, "*Sir, could you please use GeoGebra for all geometry lessons as well?"* Next student suggested to me, "*Sir, could you please prepare the same applets for other theorems as well, ok!*" I heard the sentence "*It is much better than just listening to lectures, sir."* These reflections confirmed how technology could help make learning both accessible and enjoyable.

From the second day of my action research the continuity was given to strengthen the students' mathematical problem-solving ability and self-confidence. GeoGebra interactivity facilitated the students in trying out hypotheses and verifying mathematical statements, producing a feeling of discovery. With GeoGebra, the students explored different cases of a cyclic quadrilateral and tested their properties positively. One of the students, Pari, indicated that GeoGebra removed misconceptions they previously held in grasping geometrical properties, making them more confident in solving math problems. At the end of the study, student Suman indicated that integrating visualization and problem-solving made their confidence in using circle theorems in real-life situations outside textbooks run high.

GeoGebra is always a safe zone where trial and error can take place. Because trial and error are part of it, students could grasp and change ideas. Where they were free to make mistakes, fix them, and keep trying. This was in strong contrast to traditional approaches, where everyone feared attempting solutions. It delighted me to find, as a teacher and researcher, how well the class merged the theoretical and practical views of the theorem. The freedom to explore the concept in the GeoGebra applet at their own pace deepened their understanding. The students who felt apprehensive about using the tool had become confident and enthusiastic towards the end of the session. Perhaps one of the most gratifying moments was student interaction in the exploration and discussion of findings. These are not mere learners but participants who begin asking questions, experimenting, and verifying the concept on their own. Therefore, this collaborative learning environment gives way to shared discovery that enriches a session for all participants involved.

**Figure 19**

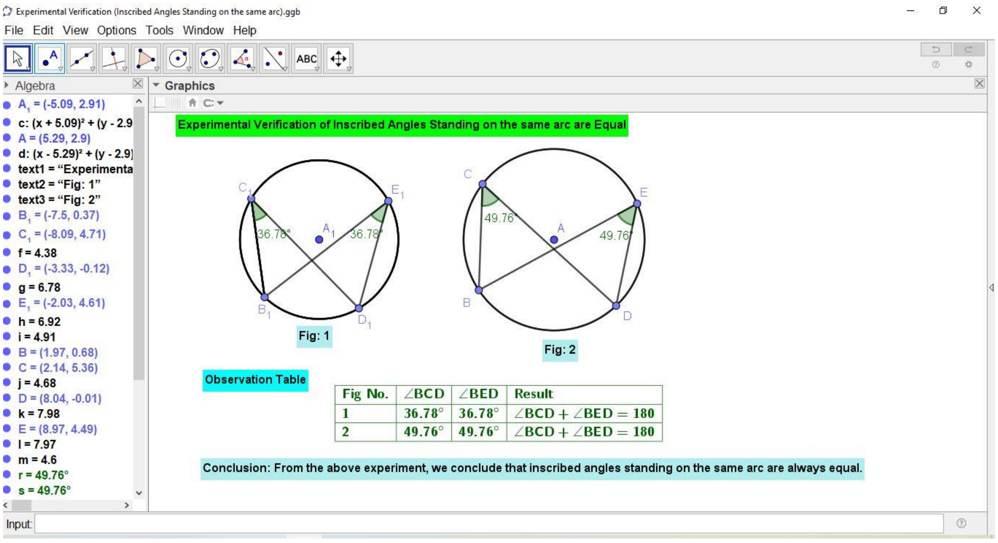
*Experimental Verification of Central and Inscribed angles*




Students boldly predicted the behavior of ∠BCD and ∠BED before working with the diagram illustrating Polya's (1945) stages of problem-solving. Such freedom to explore built confidence and inquiry. But not all students read the data correctly; some believed all 36.78° angles were equal simply because they looked so in vision. I found that I needed to ask targeted questions*: "Does this work for any position of a chord?",* pushing students from surface-level observation to analytical thinking. I immediately asked the question and received the answer *"No, sir! BC is a chord; when BC passes through the Centre of the circle, then it becomes a diameter.* Yamin also added, *"Sir, will be equal to 90 degrees when BC becomes a diameter."* I said, absolutely correct! You are very smart!

**Figure 20**

*Experimental Verification of Inscribed Angles*




GeoGebra makes the problem-solving process more democratic by lowering the barrier to entry. But to develop genuine mathematical confidence, it must be accompanied by exercises that require justification, not manipulation. My energy was self-evident: confidence is built not through always being right, but through the freedom to change one's mind. The way my students showed enthusiasm, curiosity, and smartness was the very reason this strategy seems to work. I am confident that this will lead them not only to excel well in their exams but also leave lasting impressions on their learning geometry for times to come. I am inspired by this process to continue trying the insertion of GeoGebra within my teachings, so that acquiring math becomes a pleasant and interactive moment for all.

**Overcoming Learning Barriers and Self-Actualization**

In the previous school year, the slow learners experienced a learning improvement in mathematics understanding. The learners acquired self-knowledge from their capability to recognize areas to improve, as a result of which they invested additional time in mathematics for personal growth. So, I started my action research journey on November 25, 2024. The students who really faced difficulties with circle theorems have a deeper, very much more complex problem than a lack of understanding; it is a learning barrier built over the years. Some students experience math anxiety, others have never been exposed to anything dynamically visualized, while others just don't believe they can make it. As the days passed by, however, I was most happy to see complete improvement-they overcame their challenges and were now self-actualized, realized their own potential in mathematical thinking. Some students had previously found geometry difficult to learn because of ideas that were hard to visualize and picture. GeoGebra bridged this learning gap because, in their responses, like those of Smriti Banstola, who was unable to initially picture geometric relationships, the dynamic model by GeoGebra reduced such ideas to ease of learning.

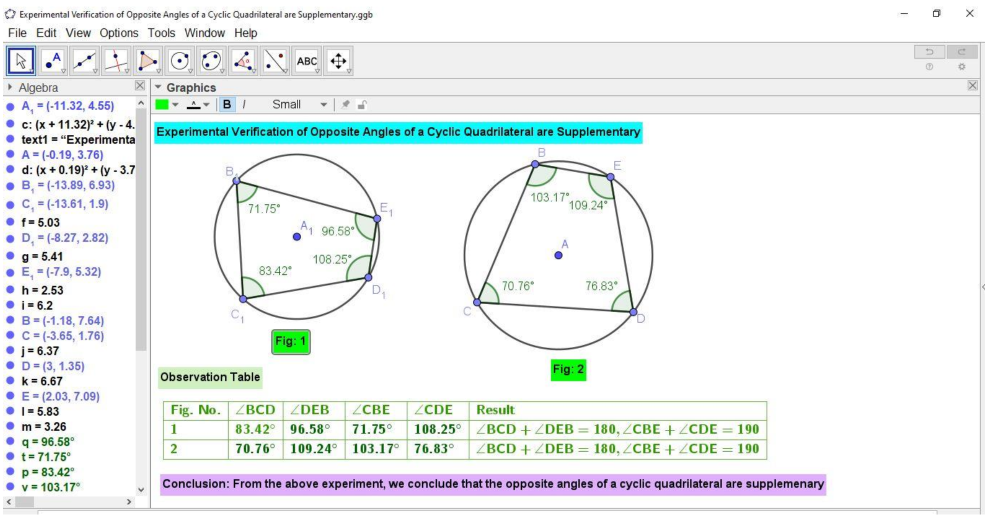
On Day 1, when students were pre-tested, I observed more than their scores on the test; I viewed their faces. While Amin and Suman finished fast but left half the questions unanswered, Bipina looked a little nervous, panicking, erasing answers many times. After the test, I smoothly asked, *"How did that feel?"* My student replied, *"Sir, I always get confused about where to start when I see a problem like this."* - Bipina, Nov 25. This was further evidence of what I suspected: the barrier was not so much ignorance, but a lack of strategy and confidence. Instead of just explaining the solutions, I introduced structured breakdowns of the problem through GeoGebra. When we explored visually how an inscribed angle varies according to arc, Sushmita experienced that click. *"Wait, so if I move this point, the angle always stays half? That means... I don't have to memorize it; I can just check!"* - Sneha, Nov 26. This realization proved to be a very significant turning point: understanding, not memorization, and therefore, the first layer of the learning barrier was removed.

GeoGebra was a life-changer for learners with various learning needs. Kinesthetic learners, in particular, thrived in the hands-on activity of matching radii in applets, where motion facilitated structure. Slow learners, who were likely to be puzzled by symbolic texts, were provided with clarity through dynamic images. One of the most emotional moments was when an average student, Bishal, utilized sliders to verify independently the property that opposite angles of a cyclic quadrilateral sum to 180°, as demonstrated in GeoGebra applets. He cried, *"I can feel the angle adding up! "* For a fleeting moment, I felt happy for a moment that I had known and understood the math. These moments make Tomlinson's (2001) claim for the need for different ways of teaching worth noting. Some students even got the help they needed by listening to others talk about what they saw or realized. Pair share discussions became a very important practice, helping students think about what they saw and tell others about it.

My day five of the action plan started on 29 November, using GeoGebra to show how to prove and test a theorem, by way of a theoretical proof and an experimental test with the same program. I have made a short recall of the definition of a cyclic quadrilateral, and then we started the lesson. With the aid of GeoGebra, I have proved the theorem without any problem with the GeoGebra applet that I already had set in my laptop before starting the class. As I was able to move, changing the shape of the quadrilateral again, there was no change in the sum of the opposite angles. Students really liked and understood the animated applet as well as the theorem very clearly, that the sum of opposite angles of a quadrilateral is always equal to $180^0$. I prepared four applets related to these theorems. Students love the animation and colorful visualization very much. GeoGebra interactivity encouraged students to learn the theorem. Many of them were amazed by the way the software was calculating the angles instantly when the vertices of the cyclic quadrilateral were dragged. They were able to explore many cases in real time. Students could easily see that the sum of opposite angles is equal to $180^0$ by rotating any vertex in any direction. Some students requested that they wanted to use them by themselves as well, and I allowed them. Some students who initially found the proof difficult to understand had their concepts cleared with the experimental approach. I could see a big positive change in their participation, which was reinforced through the visualization that strengthened their conceptual understanding.

**Figure 21**

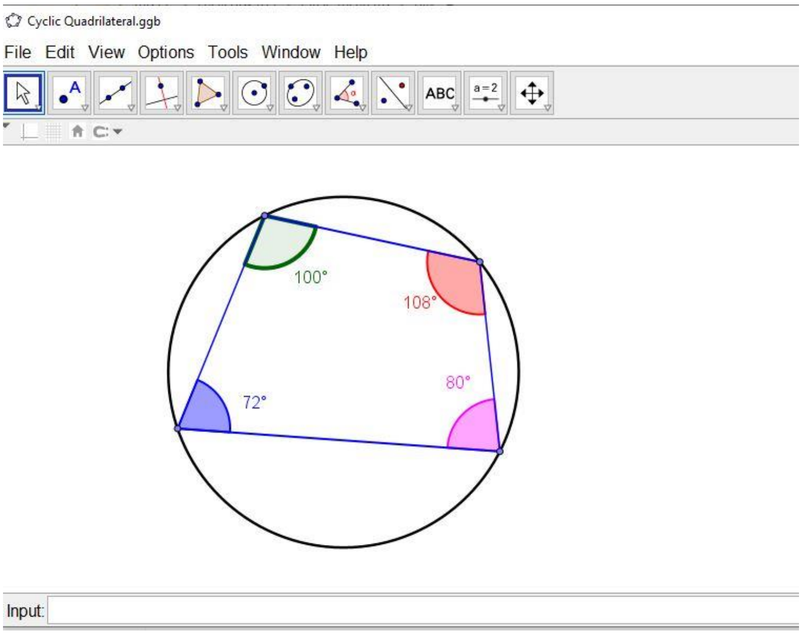
*Representation of Opposite Angles of a Cyclic Quadrilateral*



GeoGebra removed all the previous obstacles to learning, but not all of them. For those students who had low digital literacy or low access to devices, new obstacles emerged. To ensure equity, I adopted peer mentoring and similar groupings where more capable students mentored others, consolidating learning while fostering empathy. Some students found it difficult to link the moving picture with the actual proof. They seemed unwilling to express themselves when discussing, which may be because of a gap between seeing and reasoning, but some of the students said that *GeoGebra made the theorem "real" and understandable*, whereas in other situations, it was just the opposite.

In the second week, I found out that most of the students did not dare attempt proof-based problems by themselves. I have decided to replace mistakes by experiment - or better still - from "errors." Associated with this is the GeoGebra simulation that I assigned to my students on December 3, where they were supposed to manipulate a cyclic quadrilateral and observe its angle properties. Most of them weren't keen at first: Suman hesitated before clicking on the applet, saying, *"Sir, what if I do something wrong and the answer doesn't come out?* -Jisman, Dec 3" I said: *"Then that means you've found something interesting. Let's see what happens!"* Slowly, when they started messing with different cases, they learned that it was actually more insightful to mess up. By December 5, Bishal, who, on Day 1 of that simulation, had left several problems unanswered, had now become one of the first people to raise his hand when I asked about explanations. *"Sir, I think I get it now. If the opposite angles in a cyclic quadrilateral always add to 180°, that means even if I change the shape, the rule does not change!"* Suman, (December 5). That moment of discovery is a major turning point-students were no longer afraid of testing, failing, and trying again.

**Figure 22**
*Opposite Angles of a Cyclic Quadrilateral Representation*




In Week 3, something intriguing happened: those same students who had exhibited timid behavior were now laying the foundation for class discussions. On December 10, I threw them an open-ended challenge: to prove a theorem using GeoGebra and then give an explanation without using any digital aids. Sushmita and Niraj partnered and confidently proved the alternate segment theorem and taught it to the class. *"I don't just wait for you to show the solution; I feel I can now solve a lot of things on my own."* Nisha, (December, 10). On December 12, when we were having the last assessment, students were no longer only recalling theorems; rather, they were explaining and justifying them and teaching one another. The change was not just in grades; rather, it was in their attitude toward learning mathematics.

Looking back on those 15 days, I realized that for the better part, learning across barriers was not about the absence of obstacles but about the empowerment of students with the capability to confront them. All that was turning into exploration was, at first, hesitant exploration. With it came diminishing anxiety, coupled with realizing their own capacity to build a logical argument. I think that Self-actualization in mathematics does not mean getting all answers correct. It is when students arrive at the point of saying: "*I don't just memorize, I understand, I don't just follow steps, I explore."* And this is when learning suddenly means something. Day 10 had a session planned specifically to eliminate myths by allowing students to experiment with different chord and tangent setups. Students who at the beginning of the program had self-doubt about being capable of learning math, like the student, Joy, understood that GeoGebra revised their perception of math from difficult to possible. Students on the last day indicated self-confidence, understanding that they could now comprehend and apply mathematical concepts independently.

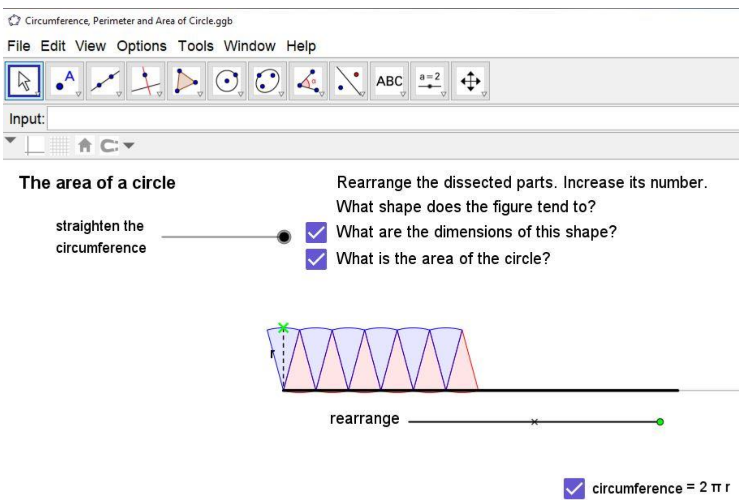
I noticed that several students wanted more time with GeoGebra on their own so that they could explore deeply and build confidence. The first is the visual learning of mathematics and interaction within mathematics. At the same time, the gap between visualization and abstract thinking is obvious, and to fill this gap, more practice is required. Second, GeoGebra helped in filling the gap between the abstractness of mathematical concepts and their practical grasp. Students of all levels of learning were able to participate in the lesson, and from this, an inclusive learning environment was established. The lesson involving GeoGebra had once again proved that ICT firms can provide a bridge to make learning mathematical concepts fun, less difficult, and participatory, and as a solution to overcoming obstacles to learning, and individual affirmation.

**Enhanced Peer Interaction and Cooperative Learning**

GeoGebra equally provided a learning room that collaborating while they played with each other, exchanging concepts, and they taught each other theoretical and experimental proofs of circle theorems; a team in which they supported and learned from this class. One of the most dramatic shifts during my 15-day action research (November 25 – December 12, 2024) was a shift from solo learning to active peer collaboration. Initially, students hesitated to exchange mathematical concepts with others, relying instead on me to explain things. As lessons went on and activities that used GeoGebra made students work with each other, the students started to help each other out, and had deeper work with how to prove theorems about circles. This is the part that talks about how students learning from each other and working together helped them learn more about math and made them remember what they learned.

**Figure 23**

*GeoGebra Applet Representing Area of Circle*

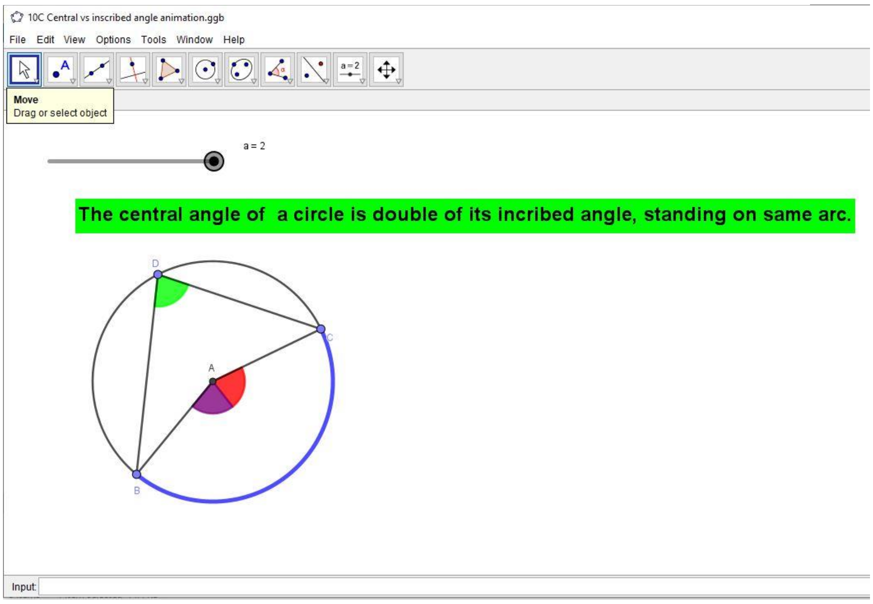


GeoGebra enabled learners to shift away from memorization and understand mathematics through experience. Students' spontaneous derivation of the area formula $A = \pi r^2$ by dissecting a circle in an applet enabled students to appreciate mathematics as a rational, systematic process. Supporting evidence of Hohenwarter and Jones (2007) verifies such findings: procedural and conceptual knowledge develop together when appropriately used digital tools. Even with improved post-test scores by a promising 22%, there remained a challenge in applying graphical insights to static study-based tests. This disconnect implied a need for hybrid assessment models, those that value both dynamic comprehension and static expression. My observation was on the fact that the strength of GeoGebra lies in how it makes math very interesting and real. I observed this when I was told that it also makes math real. But it must never be used as an end; it is a bridge. Applications in real life, like connecting circumference to rotations of the tire, help students take intangible learning and apply it in tangible ways. My greatest insight was seeing that the value of GeoGebra is not necessarily in visual clarity, but in supporting mathematical conversation between students, between representations, and even within students.

Collaborative work with GeoGebra facilitated active mathematical debate. In the applet, small groups debated why 90° throughout configurations remained. These debates were based on Bandura and Walters (1977) social learning theory: students learnt by watching, copying, and arguing with them. But I did see that there was unequal participation; some dominated the mouse, and the rest sat out, dull and inert. By establishing rotating roles: "*dragger,*" "*recorder*," "*explainer*." I leveled the playing field. One student commented, *"We disagreed at first, then agreed when we observed the angle change together."* This shared negotiation of meaning revealed the power of collaborative discovery. I realized that technology-mediated collaboration is most effective when it demands consensus. Not just group completion, but group construction of knowledge. Peer learning flourished when every member had a responsibility and was engaged.

On Day 1 (25 November), I noted that students were used to working alone; most listened carefully but did not discuss. When I asked them, *"Do you normally discuss math problems with your friends?"*, their answers showed a lack of confidence in discussion with peers: *“Sir, if I don't get it, I just wait for you to tell me."* – Bishal, on November 25. *Sometimes we do, but not the time all the time. However, the answer is not always the good one.* – Yamin, on November 25. To encourage collaboration, I designed a plan for a pair task with GeoGebra. Instead of delivering theorems in an unproblematic way, I provided students with an interactive problem: Task given (November 27).

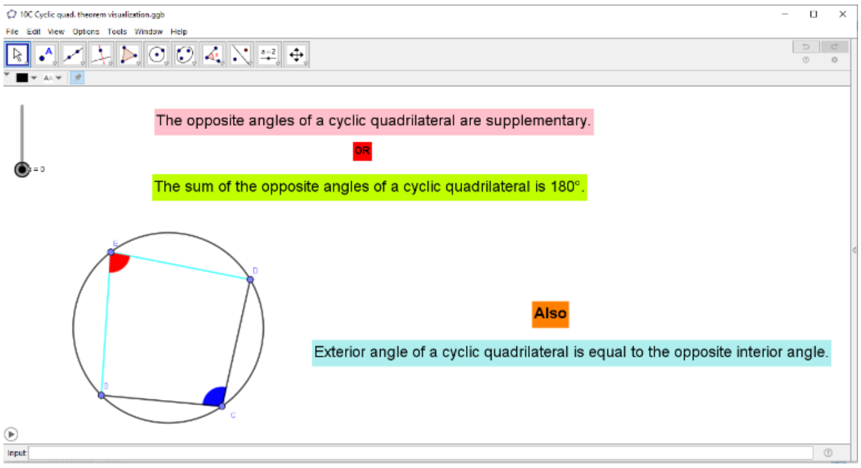
**Figure 24**
*Link Between Central and Inscribed Angles*

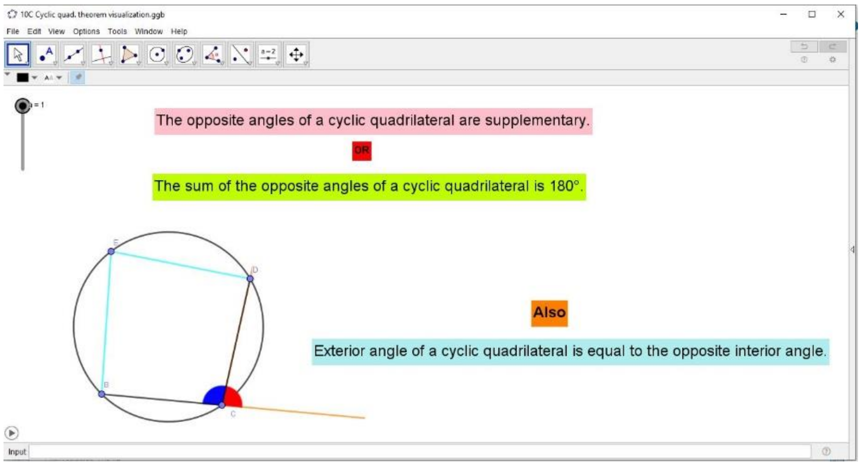



Work in pairs to drag points on the GeoGebra applet and observe how the central angle changes with the length of the arc. Then, share your observation with your partner before we go through it as a whole class. Initially, the students were working in silence, unsure how to put their observations into words. But eventually, tiny discussions were audible: *"Ah! Look, when I shift it, the center angle becomes double!"* – Nisha, Nov 27. *"Yes! That means… the central angle is always twice the inscribed angle!"* a voice of Garima, on Nov 27. By the time the class was over, the students discussed the rules on how to prove the theorems theoretically and experimentally without using GeoGebra from the examination point of view. They were growing peer talk about the problem that they learned in their class just before (December 2 – December 6, 2024). By Week 2, I had set up learning activities that required students to rely on one another rather than on me. On December 3, I introduced a peer-teaching activity task that different groups would be given a different theorem. Their job was to learn it using GeoGebra and teach it to another group. Some students resisted initially: *"Sir, what if we teach it incorrectly?"* – Prajit, on December 3. But as they tested GeoGebra and discussed among their pairs, they grew in confidence. Jisman and Ayush, in their group to prove the Cyclic Quadrilateral Theorem, were the pioneers to explain: *"See, we used all kinds of* *shapes, and it always turns out that the opposite angles add up to 180°. So, it is always true!"* – Jisman, on Dec 3. The rest of the groups soon caught up and went over their theorems with me, only listening. I said, more students talk, instead of just waiting for the teacher to teach, good students can help other students without being asked, and that makes your learning even better.

A sense of responsibility developed, as students knew they had to explain concepts. This interaction deepened conceptual understanding when students were taught, and they ensured they grasped the concept. I have given a readymade applet representing that the opposite angles of a cyclic quadrilateral are equal to $180^0$ and asked Ayush to explain the applet on how the figure changes before using the slider and after using the slider, and how to prove the sum is equal to $180^0$? Then Ayush tried to explain, *"Sir, the red mark and blue mark, if added, give $180^0$."* Again, I asked how? There is no given size, so how do you claim? Again, he replied, *"Sir, we can measure the size and get the total."* Next, I explained to him that I am not satisfied. There is a use of a slider, use it and tell me. Then he tried his best but was unable to explore the logic. Then I request Suman to do the same. Then he explained that *"Sir, before using the slider, we can see two opposite angles in different colors marked in red and blue in opposite positions, but after using the slider, the red mark angles become an exterior angle, and the sum of red mark angles and blue mark angles form $180^0$ as they lie in the same straight line."* I said Wow! Great Suman! You explained beautifully. Then I look at Ayush's face and ask again, what about now did you understand what I mean to ask? And he replied, *"Yes, sir! I understood very well.* I thank both of them for their active participation and asked other students as well whether they understood the theorem or not. Everyone replied, *"Yes, sir, we understood."* I was really surprised. I never explained this theorem in this style before, but when students explore the concept, they really surprised me that students are always creative. Another point I notice is that students easily learn with the help of their friends, and collaboration is necessary for better understanding.

**Figure 25**
*Exploring a Cyclic Quadrilateral with a Slider*

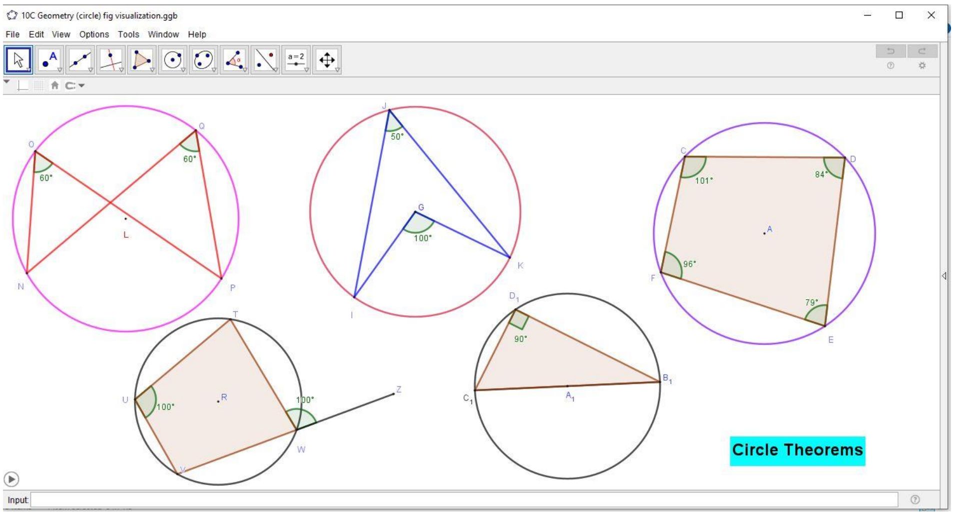



Building a Cooperative Learning Culture (December 9 – December 12, 2024). By week 3, students had fully understood collaborative learning. Instead of being provided with explicit solutions, I posed a challenge: *"If the inscribed angle in a semicircle is always 90°, how do you prove it without GeoGebra?"* Instead of asking me, students immediately started gathering in groups to talk. Sajan and Yamin quarreled over why, with Garima stepping in to explain. *"Look, if we create a triangle inside a semicircle, the diameter acts as a straight line. That's why it is always a right angle!"* – Garima on December 10. For the first time, students questioned, discussed, and refined each other's logic without my interrupting. This was true cooperative learning, not just the exchange of answers, but real discussion.

On December 12, during the final exam, I spotted students working on problems before class. Bishal, who had been hesitant to share before, was now lecturing his classmates on the Alternate Segment Theorem. *"I used to think math was all memorization. Now, if I'm stuck, I know that I am capable of asking friends and we will figure it out."* – Bishal, on December 12. Upon examining the 15 days, I noticed that peer interaction modified the process of learning in three significant ways: The students evolved into co-contributors rather than just being passive receivers. Students supposed to be weaker were boosted in confidence by putting concepts into their own words. A learning culture of co-operation emerged, in which students learned from one another instead of continually looking to the teacher. I have displayed all the theorems on one screen and asked three students, Bishal, Bipina, and Garima, to explain the theorems one by one. Bishal took the place of the laptop and tried to drag the applets, and Garima and Bipina started to explain the theorems. First, I request that Garima explain the first two figures. She replied that *"The first figure represents inscribed angles formed by the same arc, and their measurements are equal. The second theorem represents the relation between the central angle and the inscribed angle,"* I asked, what is the relation between them? She again replied, *"Sir, the central angle is greater than the inscribed angle."* I asked by how much? She replied, *"Sir double."* I said yes! Correct. Then I asked Bipina to explain the next two theorems. She started explaining, *"Sir third figure is about cyclic quadrilaterals, and in cyclic quadrilaterals, their opposite angles' sum is equal to* $180^0$*."* I said Wonderful! Then next. She replied, *"The fourth figure is also about a cyclic quadrilateral. Here, the exterior angle and opposite interior angle seem equal."* Then I requested Bishal to drag the points, and let's see the changes in their size. Again, Bipina replied, *"No change, sir."* I requested Bishal to explain the last theorem. *"He replied, Sir Dimeter divides the circle into two halves and makes a semicircle, and if we join two end points of the diameter to any one point of the circumference, the measurement of the angle is* $90^0$*,"* I replied awesome! All students of class were observing the activities that three students doing and I asked them as well. Are you learning theorems? Students replied *"yes sir"* I again asked can you connect the idea? Do you remember these theorems for your SEE? Everyone replied, *"Yes, sir, we can; these theorems are so easy."*

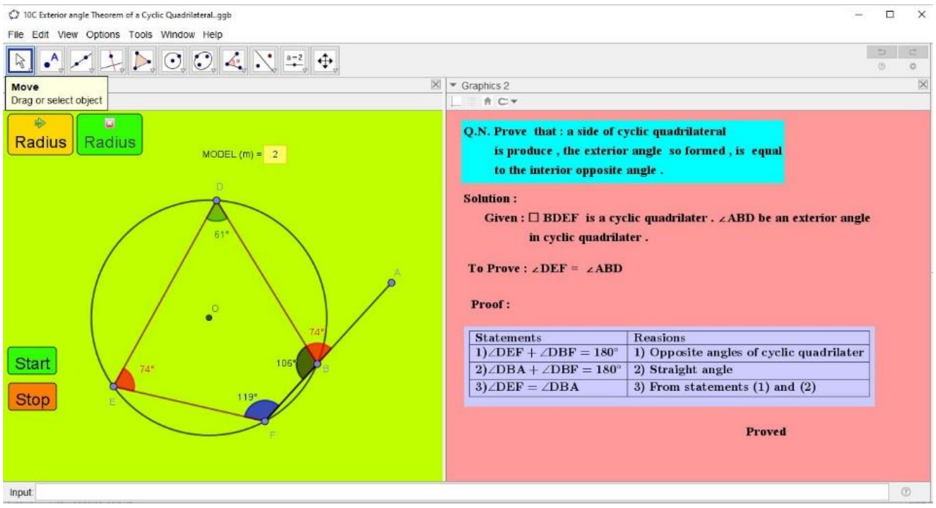
**Figure 26**
*Five Fundamental Circle Theorems*




From the above student's engagement and performance during 15 days of action research, I became assured that GeoGebra really enabled collaborative learning and peer-to-peer sharing. Students worked in groups throughout the action research on doing circle theorems and problems. Students proved *"Experimental verification of the exterior angle of a cyclic quadrilateral is equal to its opposite interior angle"* on Day 9 in groups, where students employed GeoGebra in producing and exploring segment relationships.

**Figure 27**

*GeoGebra Verification of Cyclic Quadrilateral Angle Theorem*




Group discussions were lively throughout the class; there were interested and enthusiastic attempts to try the theorem out on GeoGebra. Students also shared how, through GeoGebra, they *"sir I saw a live proof of the theorem since, after drawing various diameters, the subtended angles resulted in just one value."* – a voice of one of the average students. This streamlined the complex ideas to easily present to them the practical evidence they needed for the theoretical. One ongoing issue was the struggle of some groups to work with the GeoGebra interface. In spite of this, in each group, the stronger students naturally took on facilitator roles, making sure everyone contributed.

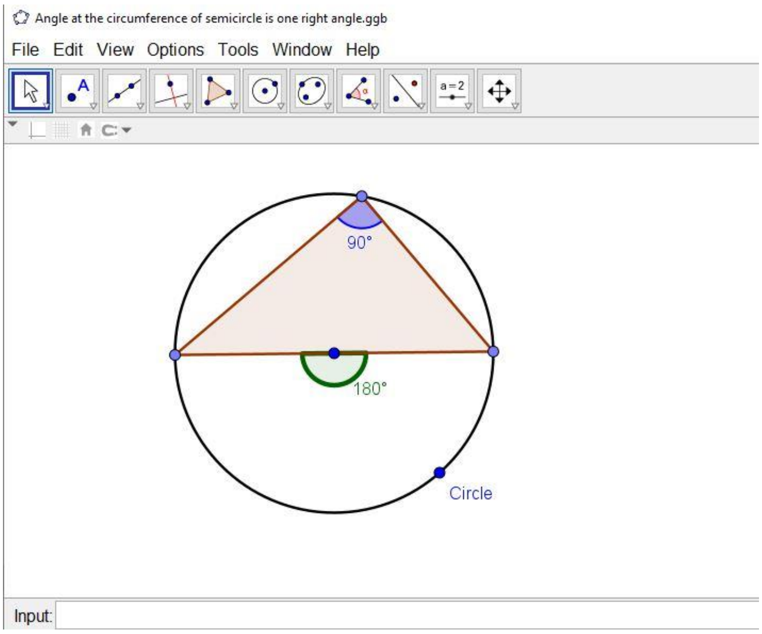
Two Students, Sneha and Srishti shared their experience after the class that they enjoyed the interactive sessions, where they were not only being lectured by their teacher but also learning from their peers. The interactive class environment enabled the students to ask questions, discuss, and support one another, which opened up a broader perspective of mathematical concepts. From the comments, interactive learning using GeoGebra facilitated sentiments of collaboration and collective academic enhancement. Hence, I also learned that a single teaching applet can describe whole theorems in a very effective way, and I learned the power of GeoGebra and its effectiveness in teaching Geometry is crucial. I also noticed that GeoGebra really makes students learn from peers and supports collaborative learning.

**Effectiveness of GeoGebra in Mathematics Education**

The effectiveness of GeoGebra in mathematics learning was fulfilled throughout the 15-day action research in facilitating students' concept comprehension, interest, and problem-solving abilities in circle theorem learning. In this research, in the initial days (Day 1–Day 5), students understood the inscribed angle theorem through GeoGebra usage. It was possible for students to use dynamic point manipulation to demonstrate that an inscribed angle subtended by the same arc is always constant. On Day 3, one said, *"I thought so that it was a theorem to memorize, but after dragging the points around and seeing that it keeps the angle, it finally fell within my realm of understanding why it is true!"*

**Figure 28**

*Verification of Angle in a Semicircle*




Teacher: *"Let's observe another GeoGebra applet that tells us the circumference angle of a semicircle is equal to a right angle. What do you observe first when reading the applet?*

*A semicircle is shown, with two angles: one of 90° and one of 180°. Where exactly can you find a right angle?"*

Bipina: *"Sir! That is a very good observation you shared. The 180° angle is showing the central angle, and 90°represents the inscribed angle at the semicircle."*

Teacher: That's great! Who can mark off where the 90° line lies in this shape?

Yamin: *"I'm wondering if this is the correct meeting point at the circumference. I can see that it looks like a correct angle!"*

Shiwant: *"Yes! You get a right angle when you join two lines: from the center to one part of the circumference and from the center to the other. Why can't the angle ever be anything else but 90°?"*

Ashmi: *"I guess it's because the diameter goes all the way around, which is 180°, and the circumference is at 90°."*

Teacher: *"That means, half of 180 degrees is exactly 90 degrees. As a result, the angle next to the browser must be a right angle. Wherever you measure the angle, the diameter subtended to the circumference is 90°. See if you can do this by shifting the pencil tip on the bend close to the middle."*

Shiwant (with the applet): "*Oh! No matter where I put the point, the angle always stays at 90°. That's amazing! It's all clear to me now. The diagram was really* *informative to me about solving it. Am I allowed to use it to solve problems? Can diameters give us fixed angles every time?"*

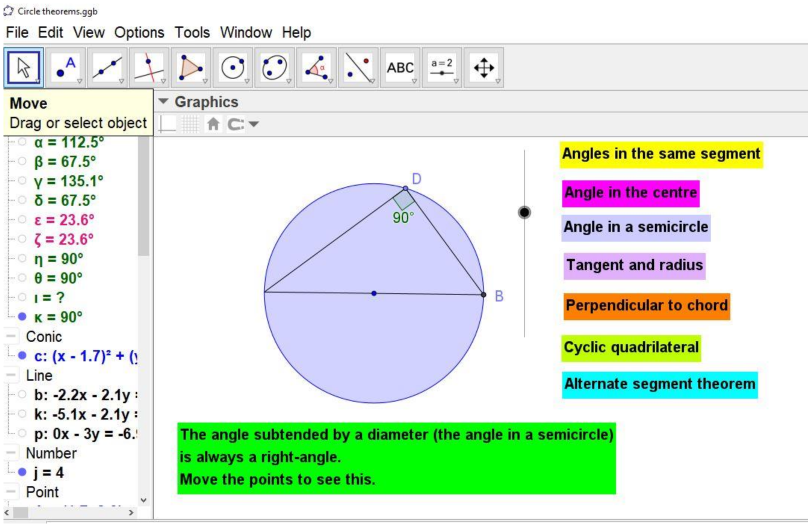
Teacher: *"Yes! The theorem is very useful when solving geometry problems. I think you all noticed that GeoGebra makes it so powerful to visualize theorems.*

Memorization to visual judgement, this shift from memorization to visual reasoning underlined the importance of GeoGebra in connecting ideas without thinking to things we can feel, see, and do. It also made the process of student learning more intuitive and meaningful. After some time in the study (Day 6-Day 10), the students learned the theorem which states that angles on the same segment of the circle are equal. The dynamicity of GeoGebra allowed the students to play with the different positions of points on a segment and actually ground their understanding of the universality of that theorem. During a class discussion on Day 8, Pramisha excitedly stated: *"I learned these theorems, but the problem is how to apply them to all cases! Being able to move the points and still observe the angles being equal made it feel more like a discovery and less like simply learning a rule".* Such experience of interactive learning shows that GeoGebra supports exploratory learning where students are not just passive learners of information but learn to actively construct their knowledge.

In addition, an immediate test of the results has been further shown to increase the confidence and motivation of students, which is also an affirmation of the constructivist theory in mathematics education. The last phase (Day 11-Day 15) was then of students going from exploration to creating formal proofs based on their observations and problem-solving to justify arguments. The theorem on cyclic quadrilaterals was then introduced, and students used GeoGebra to confirm that opposite angles are supplementary before attempting formal proofs. One student commented on Day 12: *"Earlier, proofs were very tough as I just memorized steps".* But now that I've seen it on GeoGebra, I can tell precisely why each step is true." This showed that GeoGebra not only strengthened procedural fluency but also improved students' logical reasoning abilities, where mathematical arguments become more intuitive. While some of the students had been battling with the manipulation of these tools as seen in the feedback on Day Five, they were quite fine in the end, which shows that indeed, scaffolding support is essential in technology integration in the classroom. Overall, the findings attest that GeoGebra is a highly effective tool for supporting engagement, conceptual learning, and mathematical reasoning when teaching geometry.

**Figure 29**

*Dynamic GeoGebra Applet Representing all Theorems in one Screen*




The overall efficiency of GeoGebra in education for mathematics was verified through nearly all student reflections. During all of the action research, GeoGebra always provided clear, interactive, and fun descriptions of math ideas. Students like Bishal emphasized that the bright colors and dynamic aspects of the tool made it easier to visualize the central and inscribed angles, arcs, and other geometric properties. A few students, Sajan and Kushal, recommended the use of GeoGebra in every school, appreciating its capability to transform the education of mathematics. By the close of the last days, even when students had objected initially, Arjun acknowledged the feat of its usefulness in a fast and effective way to teach and learn theorems with GeoGebra. These observations altogether emphasize that GeoGebra not only strengthens comprehension but also redefines the conventional learning process into an interactive and efficient mode of education. Hence, the research strongly recommends the utilization of applying integration of ICT tools such as GeoGebra to educate mathematics. The students not only enhanced their knowledge of Circle Theorems but also enhanced a positive attitude toward technology as an aid for learning. The research proves that electronic tools can cover learning gaps and improve conventional ways of teaching.

**Emphasizing Impact and Transformation**

This action research was grounded in the interpretivist paradigm, interested in understanding the meaning-making processes of individuals in natural learning settings. It was developed from the Social Constructivist Theory of Learning (Vygotsky, 1978), emphasizing that learning is socially mediated, an activity enabled by interaction with MKOs (more knowledgeable others) and cultural tools like GeoGebra. In this study, GeoGebra was a social and cognitive tool that enabled students to discover, visualize, and construct geometric concepts collectively. Constructivist and transformative learning theories (Mezirow, 2015) also played a part in shaping the study. These theories allow for the learner's control and foster profound changes in thinking through contemplation, talk, and finding new things. Students questioning claims and learning by working together fit with these theories. Through theorizing the process of making sense of participants' learning experience through data interpretation, emergent themes such as peer scaffolding, increased motivation, visualized engagement, and diverse learning needs were identified.

When I asked one of the students, Bishal, who started GeoGebra as soon as I started to demonstrate it, he said, "It' so interesting to learn the concepts of Geometry through GeoGebra, sir!" I was amazed by the response of this student because he was very excited to solve the problems using GeoGebra. I immediately asked him, *"Do you enjoy solving problems using study, pen, and pencil or GeoGebra?"* As soon as my question was finished, he said, *"GeoGebra, Sir! Definitely, GeoGebra!"* It helped me understand that the student was more motivated in learning mathematics than ever. That's why perhaps students were found engaged in learning activities. When I went near a struggling student, Garima, and observed her activities, I found she was trying to learn GeoGebra from her peers in the group. But it was not a cup of tea for her like the student Yamin. Unlike Yamin, she learned a few skills from her peers and applied and repeated them several times. I realized that there were some slow learners in the classroom who needed support from MKOs. After I had completed my demonstration of GeoGebra, I moved around the classroom and observed the 32 participants. I observed some responses and the levels of engagement of students. Others were mucking about with the tools backwards throughout the demonstration, being very confident and inquisitive. Others began tentatively following the demo, but some indicated uncertainty and could not even understand simple GeoGebra commands. However, all students were active, participating in discussions, trying out the package, and helping each other. Out of the 32 students, I closely monitored 6 key participants to learn more about their experiences and progress during the intervention.

## Pre-Test and Post-Test Analysis Results

In an attempt to determine the impact of GeoGebra on students' conceptualization of circle theorems, a pre-test had been conducted before the intervention, while a post-test had been given following the 15-day application.

**Figure 30**

*Pre-Test on the First Day of Action Research*

### Meaning making from the Pre-Test and Post-Test

From the pre-test, it was found that the majority of the students had fragmented knowledge of circle theorems. Many students could not visualize certain important concepts, e.g., the difference between inscribed and central angles. The average score was extremely low, which clearly showed that the instructions needed to be enhanced. The post-test data revealed that students performed at a high level in the experiments. The majority of the students performed with an enhanced conceptual understanding, showing high precision in problem-solving using theorems. The interactive and graphical nature of GeoGebra has improved conceptual gap filling based on the enhanced results obtained in post-tests and the testimonies of students. The pre-test and post-test scores of students revealed very clearly that there was a statistically significant improvement in understanding circle theorems through the 15-day GeoGebra intervention based on the software. I have taken a pre-test and post-test with a full mark of 10. From a mean score of 3.17 (SD = 1.69), the mean score rose to 5.98 (SD = 1.41), giving an average gain of 2.95 points. To gain further insights into the nature of this improvement, performance in the pre-test served as the criterion for classifying students into weak, average, and strong. The weak learners (n = 15), mean score increased from 1.93 to 5.13, and so gave a progress of 3.20, while for average learners (n = 10), the score rose from 3.70 up to 6.70, thus giving a gain of 3.00; while the strong ones (n = 4) progressed by 1.88 from 6.50 to 8.38.

The more considerable improvements made by the lower and average learners denote that GeoGebra played an important role in the development of conceptual understanding for the very first weak students and was very effective in that aspect. The pattern suggests that GeoGebra helped to remove the difference in the students' achievement and created a more equal learning process. The students were very often using the dragging and dynamic features, which enabled them to see the angle-arc relationships, and this helped them move from rote memorization to conceptual reasoning. Many students were actively conducting experiments, testing their own concepts, and correcting their misconceptions at that moment, behaviors being clearly linked to their success in the post-test. Lower-achieving students exhibited an increase in self-assurance and participation in the class to the extent that they would not only ask questions but also share their ideas more freely than before. Interactive collaboration through GeoGebra tasks allowed for peer explanations, which consequently helped in the development of conceptual clarity. My facilitator role, leading students to explore rather than providing them with answers, turned out to be crucial in the process of students arriving at the right math statements through dynamic visualizations. Nevertheless, there were some limitations: not only did students with poor digital skills or irregular attendance have relatively less gain, but also interruptions caused by technology sometimes reduced the flow of learning.

As a practitioner-researcher reflecting on the process, I realized that GeoGebra had a very positive impact on weaker learners by making the abstraction barrier much lower and providing them with a real-time visual confirmation of geometric relationships. The average ones became more correct in their reasoning and construction of diagrams, while the strong ones got more refined in their understanding, even though their scores on tests increased only slightly. It was the experience that made me more aware of the necessity of task design and teacher support; the software was not enough by itself; it was through careful integration that the difference was made.

The results have a number of important implications. From a teaching and learning perspective, regular integration of GeoGebra would be advantageous for the less spatially gifted students, while through tiered tasks, the more proficient ones could be further challenged. Assessment-wise, a combination of the two, i.e., quantitative and qualitative insights, would give us a more comprehensive view of the students' conceptual growth. Equity and access issues also came up; for ICT-based lessons, the students’ digital readiness and reliable devices are the prerequisites for their success. From the curricular point of view, the findings suggest the necessity of teacher training in GeoGebra-based pedagogy as well as the incorporation of dynamic geometry environments into secondary mathematics programs.

**Comparative Insights**

The results derived from both quantitative and qualitative studies reconfirm that GeoGebra has a remarkable impact on students’ comprehension of circle theorems, most of all, weak and average learners. The major factors behind the improvement included dynamic visualization, exploratory learning, peer discussion, and intentional teacher facilitation. The findings imply the effectiveness of ICT integration in the mathematics classroom and call for its wider adoption, supported by teacher training, digital readiness, and ongoing research. The boost in the average score indicated that the integration of GeoGebra in the classroom led to a much better understanding and increased participation. Learners who actively used GeoGebra were able to grow their skills in solving mathematical problems and made their reasoning and explanations in mathematics more powerful.

**Student Voices: Reflections and Feedback**

Students reflected during the study, highlighting strengths and weaknesses of GeoGebra use in learning circle theorems. Some of the most compelling insights from their feedback include:

***Positive Experiences***

Most of the students said that they loved GeoGebra integration in learning Circle theorems. I have recorded some of the students’ voices as

*"GeoGebra made it clearer to me the relationship between arcs and angles. Animations made me visualize better."*

*"I appreciated the fact that we could experiment with different figures and observe the theorems in action at the time."*

*“Technology in mathematics made learning enjoyable and engaging as opposed to traditional learning.”*

***Understanding Circle Theorems:***

*“Before the project, Geometry had always felt so blank. With GeoGebra, I can now see what those proofs were trying to teach. It was when I slipped the*

*points that I immediately got how the relation between inscribed angles and arcs became crystal clear when moving through points."*

*"Learning the theorems on my own using visual tools was so great. I now know I can do problems on my own."*

***On GeoGebra Role***

*"I really enjoyed it a lot. GeoGebra made learning fun and lively. I am curious about how the shapes change when we move them. It was like we learnt the theorems ourselves instead of just memorizing them."*

*"In writing the proof, once or twice GeoGebra helped me get out of my difficulty after going through difficult times with conventional writing and explanation. For both theoretical proof and experimental verification, I think, I will further use the applets for all theorems."*

***Challenges Faced***

*"At first, GeoGebra was hard to follow for me step-by-step, but once I got the hang of it, it turned out to be my favorite part of the lesson."*

*"The visual understanding came in rather easily, but linking the visual to the written proof required a little more depth on my part. I really think I need more practice doing that."*

***On Their Overall Experience:***

*"For the first time, geometry didn't seem just a few solved equations or learned-by-heart theorems, something like solving puzzles."*

*"I wish we could do this for other areas of math also. Using GeoGebra made everything so understandable in a much easier way."*

***Improvements Suggested:***

*"It would be nice if we did work in pairs more regularly during the usage of GeoGebra. Sometimes discussion with peers is quite useful."*

*"I believe some more exercises to practice afterwards on GeoGebra, then we would even understand more, and how we could use it to relate questions in an SEE exam as well."*

***Impact of the Project:***

*"I had never imagined that geometry could be so interesting. I will definitely go ahead and use GeoGebra for practice on my own now."*

*"This project really helped me realize that math isn't all about formulae but, in general, how it works out. It was a great experience."*

***Words of Appreciation:***

*"Thanks for teaching us in this way. Never have I felt so confident with math like I do now."*

*"We liked lessons very much, and I just hope that other students will get the possibility to learn geometry the same way sometime!*

**Challenges Encountered**

Not only students, but I also enjoyed teaching with GeoGebra. Even though we have faced some challenges. I asked students individually in-depth about their problems and difficulties. A few students have shared their problems as follows:

*"It was not easy for me to practice using GeoGebra at first because I was unfamiliar with the tool. But then later everything fell into place."*

*"Alternating technical faults hampered our rehearsals, especially in input. We were a bit longer than expected in getting the grip of the tool."*

*"As confused as I was becoming with some of the theorems, they came in handy when I needed to work out the explanation of their explanation for my classmates."*

**Voices of the Participants Students**

A total of 32 students told us their single best thing about the class. 28 wrote that GeoGebra allowed them to learn the concept of the circle theorem, in particular, the relationship between angles and arcs. 24 students said that they felt happy and had been more actively engaged with Geometry than ever before. 26 students preferred GeoGebra over traditional tools in the geometry classroom. Only 6 students liked to draw by hand for practice**.** Group discussions became increasingly more elaborate, with students participating in peer instruction without teacher initiation. As one group of students said during a session of feedback, *"We can see how the theorems work, not just hear about them. It's like the shapes are alive."* This kind of statement illustrates embodied cognition, where learners derive math concepts by abstracting them via interactive digital activities (Nemirovsky & Ferrara, 2009). By observing how learners learn, how they react in the past 15 days of the action research, I have seen some of the things that were common in their learning. First, I noticed that the way they visualized things made a huge impact on their learning. Many of the students who, when they first saw the shape, discovered that they could not visualize it, and made it into a mechanical thing. Well, these students, by manipulating these moving models through GeoGebra, were now able to visualize them more easily. And this instant visual manipulation had made all the difference, and learning was richer and real to them. Second, I saw how the social way of learning allowed students learned a lot on their own as they inquired. My class was like a team effort where students helped and taught each other, and this fits very well with what social constructivism stands for. There was a lot of working with each other, and there was a newness to using GeoGebra for most students. This was a motivating factor for students, especially those who had been very poor students in the past in the area of circle theorems.

Moreover, I realized how important scaffolding was for struggling students like Garima. With the assistance of more able peers, she could build confidence and develop the basic skills step by step, resonating with the value of guided support in learning. Finally, I learned that students follow different learning paths, especially in technology-enhanced learning environments. Each student responded to the activities and tools in a different manner, which emphasized the need for differentiated instruction to cater to their individual needs. The experience prompted me to speculate that technology not only facilitates learning but also opens up new possibilities for students to connect, interact, and learn at their own pace.

**Conclusion of Interpretation**

The voices of the six key players and the wider society indicated that through the combination of digital technology and sound pedagogical design, mathematics education can be a life-altering process for all students. After I completed my demonstration of GeoGebra, I visited all the participants one by one and observed their activities very closely. I found some students had already started doing the activities when I was demonstrating GeoGebra. Some others just started to do the task, while a few students were struggling to learn the basic ideas of GeoGebra. However, they were actively engaged in their learning activities. Moreover, students were working in groups and sharing their understanding with each other. I also observed that a smart student was helping a struggling student to learn GeoGebra. It's like more-knowledgeable-other (MKO) was helping weak students in a group, which is Vygotsky's scaffolding, in which a learner actively learns from MKOs such as peers, teachers, friends, parents, etc. (Vygotsky, 1978).

## Chapter Summary

This chapter explores how the action research investigation was executed, as well as how an action-oriented practitioner-researcher utilized ICT tools with

GeoGebra specifically to enhance students' learning of circle theorems. The study consisted of four structured phases: planning, action, observation, and reflection/modification. In planning and designing the instructional methodology, lesson planning, and checking adherence to curriculum outcomes were done. The assessment phase recorded student participation and concept development regarding circle theorems through their technological interaction. The modification phase conducted a reflective assessment of instructional strategy through student response data gathered from extensive assessment techniques. Through the six themes covered, student engagement, conceptual comprehension, problem-solving, inclusivity, peer interaction, and overall effectiveness, I observed students shift from passive recipients to active knowledge holders. As one of the students eloquently phrased it, *"Math is not only controlling now; it's a story we can redefine."* This experience reminded me again that where technology, pedagogy, and conversation meet, mathematics turns into a living mathematics, something each student can see, feel, and believe. Overall, 32 students took part in the research project, and six were randomly selected for further in-depth study. Follow-up reviews of the collected data suggested varied levels of participation by students involved in the research project. Students 'interaction with the tools, as well as their understanding of ideas, reinforces how technology can enhance learning and provide opportunities to break down barriers to learning. The study used an interactive teaching strategy, which had the student produce evidence of a solution to his or her problem and/or to the student's question in a group setting. The students' reaction to using the applets was encouraging; they accepted many other ways of learning. The results observed from this study may help the discussion on how to integrate technology into the lesson of mathematics with specific ideas for educators and policymakers. The research has made important contributions to the field of computer-based learning methods with an emphasis on the impact of GeoGebra on the active learner, when active learning occurs, and how learner involvement is affected inside the classroom as a result of the use of ICT-integrated applets like GeoGebra. The research has provided important breakthroughs to debate on the use of technology in the teaching of mathematics, coupled with solid recommendations for teachers, researchers, and education policy makers.

# CHAPTER V
# MY TRANSFORMATIVE JOURNEY: LEARNING AND REFLECTING ON MY RESEARCH JOURNEY

In this chapter, I wrote about my own growth outside school and in school after the 15-day action research on helping Grade 10 students learning about the circle theorems with GeoGebra. This chapter records the pros and cons of my hands-on experience with technology wedded lessons and the ideas that I learned from teaching, from learning, and from the dynamic of a learner centered classroom. In this chapter, I have discussed the problems that I faced, the ways I tried that did not fail, and how students' interest and understanding of the lesson were affected by how they counted in my adaptation. Through this story, I described how were reformed as a teacher, how I taught, and how I saw the power of GeoGebra in the teaching of mathematics, and where both the ups and downs in value and the pulling point from using this journey.

## My Experience in Teaching Circle Theorems with GeoGebra

Action research was conducted over fifteen days, and I was able to integrate GeoGebra into my mathematics teaching, particularly on how I taught grade ten students about circle-related theorems. This has been a learning process for me as a teacher and nothing less than awe-inspiring. Before GeoGebra, I introduced the circle and circle theorems the traditional way, chalkboard, textbook diagrams, and verbal descriptions. I drew pictures by hand, outlined theorems step-by-step, and depended upon students to visualize and understand them from static drawings. What I found was that far too often, students appeared to be memorizing concepts instead of truly engaging the principles upon which they were based. There was always some kind of conflict present whenever they tried to visualize properties such as the relationship of inscribed angles and central angles, or why opposite angles of a cyclic quadrilateral must be supplementary.

In my lessons, I upgraded my teaching and learning through the use of GeoGebra. If it had been before, I would have been scared to see how students would act when technology is used in the mathematics class. Their excitement and keen participation amazed me. I learnt many more things in all these 15 days, and observed that students were more active and creative. Concepts such as chord, diameter, semicircle, segments, sector, central angle, arc, inscribed angles, intersecting and concentric circles, cyclic quadrilaterals, and con-cyclic points came up on the screen. GeoGebra allowed us to construct, investigate, and verify circle properties interactively. For instance, when exploring *"inscribed angles standing on the same arc are equal"* or *"the central angle is double the inscribed angle on the same arc,"* students could simply see how the alterations in the figures affected the relationships. That kind of interactivity was just not present in my earlier classes. What amazed me most was how easily students began to investigate, question, and even dispute assumptions. They were no longer just listeners, but they started exploring mathematical facts. During classroom activities, lessons, and interviews, both oral and written, students elucidated that they could better grasp the concepts using dynamic graphics. One student, Bipina, said that GeoGebra helped her to *"see how it moved and why,"* which they could not do before with fixed pictures. I recorded most of their voices, in the form of audio, video, and written, which were valuable sources of information regarding their learning process.

Personally, I learned a lot about my own teaching practice. I realized how limited my own practice had been by relying only on whiteboard sketches. I also realized how more procedure-centered my instruction used to be, rather than being concept-centered. GeoGebra forced me to be more inquiry-based and student-centered. GeoGebra caused me to craft lessons where students could discover properties for themselves, rather than instructing them as to what they should think. Another major concern for me was how strong visualization is in math education. GeoGebra allowed my students to link the abstract and the concrete. They were able to instantly test theorems, see things change in real-time, and understand more intuitively why some mathematical properties are true. It also minimized misconceptions. Once students were able to play with the figures themselves, they were less likely to get major ideas wrong.

GeoGebra did not merely introduce interactivity to the class, but also made the environment more learning-friendly. Even fewer active students felt motivated to involve themselves more. They enjoyed working with the software and were eager to repeat the process at home and again. The teaching was fixed since GeoGebra eliminated distractions and pushed the ball back to the students. Through this experience, I am convinced now that GeoGebra or similar ICT tools should be part of the arsenal of every math teacher. It promotes deep learning, promotes concept understanding, and supports learner-centered instruction. Integrating GeoGebra added brightness, fineness, and greatness to my class. It also gave me clear ideas on how I learn the stuff and how to teach in the best way to learn. It also brought clarity to my own understanding of the matter and the best ways to teach, for conceptual learning. Even though my focus within this action research was on circle theorems in geometry, I can see endless potential in applying GeoGebra to other areas of mathematics, such as algebra, coordinate geometry, and transformation. It has opened up a broader teaching avenue for me. During these fifteen days of the action plan, I learned many useful professional life lessons. GeoGebra has changed how I observe my life with students and how I experience myself as a teacher. I am now more willing than ever before to try out technology-based learning strategies and to tell other math teachers to try them as well.

**Experiencing Problem Identification**

Looking back at my research journey, I remembered the first day of stepping into action research. I was both nervous and excited, nervous because I was entering an unfamiliar role as a teacher-researcher, and excited because I was finally getting a chance to explore something I had always wondered: Can digital tools like GeoGebra really make a difference in students' understanding of geometry? Not only me, but my students also got curious about what our mathematics teacher is going to teach about, as most of the students had never heard of GeoGebra before. That’s why this is also a new experience for them as well. After taking the permission of the school administration and principal, I informed them that I teach them circle theorems using GeoGebra. Many of them were very excited, like me. I can say that students are always curious to learn new things. I have discussed here some of my problems that arose during my over two-week action research.

**Visualizing My Research Agenda**

It has been a journey, in reflection, that encouraged me to the depth of the content and methodology involved in mathematics teaching through the use of technology such as GeoGebra. My research agenda initially sought to explore the use of ICT to enhance understanding among students of circle theorems. In this study, however, when the research was still in its very initial stages, the broadening view on the general implications of introducing technology into the mathematics curriculum set me thinking on a possible research agenda with further exploration of the use of a wider variety of ICT tools while teaching mathematics at school and as a long-term impact on their engagement, motivation, and attainment. In addition, my research agenda is solely focused on exploring the ways through which technology can be utilized by the learners for learning customization, acquiring critical thinking and problem-solving skills, and bridging the gaps in their learning outcomes. I have aimed at experimenting with these in other mathematics and education areas in the coming years. This way, I was able to comprehend better the existence of technology and learning tools in diverse settings, the role of technology in our learning, and how to enhance the effectiveness of such settings.

I recalled my demo day distinctly and how I shaded a circle using chords, tangents, and angles on GeoGebra. As soon as the dynamic shape was manipulated, illustrating how arcs and angles were connected, Bishal, one of our students, lit up and whispered, *"Ohhh… now I get it!* " He eagerly wanted to work ahead, even before I finished the instructions. Another student, Bipina, said, *"Sir, like the picture is explaining the story by itself."* These little reactions taught me that interactive visualization helped students internalize concepts earlier, abstract, and difficult to visualize. Geometry is a visual topic, as it contains diagrams, but we prefer to teach it in static textbook diagrams. GeoGebra filled that gap." I then observed that students such as Bishal, who had been quiet during normal lessons, were now collaborating in actively building knowledge through just "seeing" how proving theorems occur.

**Social Learning Drives Engagement**

While one of the group activities for Theorem 3 (a right angle in a semicircle), I saw Roshan explain to Garima verbally the construction steps with a gentle tone, "*You just drag this point… look, the angle is still 90 degrees."* Garima noted slowly in agreement, and he explained it to her very well, step by step. Then, in reflection, she said, *"He taught me like a teacher! "* I was witnessing the effectiveness of peer learning in practice. Not only one pair, but every student taught each other in pairs, in meaningful ways. My role had shifted from instructor to facilitator. This interaction reminded me of Vygotsky's (1978) theory of the More Knowledgeable Other (MKO), where learners build meaning with the support of someone who is marginally more knowledgeable. Garima's growth, guided by Suman, showed me that learning runs deep in community and not in isolation. GeoGebra supported shared meanings that called for collaborative investigation.

**Technology as an Inspirer**

When I asked Yamin, who had shown low interest in previous lessons, what he felt about using GeoGebra, he smiled and stated, *"Sir, I feel that I'm doing something real, not merely listening and copying. It's fun!"* Another student, Pramisha, replied the same, *"It's like playing a game, but we are learning."* I felt that the novelty and interactivity of GeoGebra had a motivational impact. Once passive learners, they were now engaged and curious. Constructivist tools like simulations and visual models, according to Jonassen (2010), increase motivation because they allow learners to be masters of their own inquiry. Students who previously avoided the front row now wanted to move forward, click, drag, and argue. It changed the overall atmosphere of the classroom into one of discovery.

**Scaffolding is Essential**

One slow learner, Garima, was attempting the same activity: matching the points on the circle. She frowned and muttered, *"It's not working..."* But instead of giving up, she slowly copied from her friend Sudeep's screen. After repeating this three times, she sighed with relief and said, *"I got it!"* This was a wonderful example of the value of support. Some students were instant learners, but many others needed time, patience, and demonstrations followed by their own attempt to copy. Vygotsky's scaffolding says that if supported by peers or teachers within their Zone of Proximal Development, the pupils have a better opportunity to learn. I realized that just giving assignments was not enough; rather, I needed to create scaffolds for students, either from their peers or via some kind of guided steps provided through GeoGebra.

**Differentiated Learning Paths**

During individual task completion, I observed Bishal finish his work pretty quickly and start to venture outside the lines of the assignment. Whereas Dipika took her own time, laying eyes on the instructions every now and then, Sandesh kept trying out wrong moves on purpose to *"see what happens."* Each student was doing their own thing, exploring GeoGebra in a way that made sense for them. A little difference like this makes it obvious that students do not learn in one fixed way, especially when the opportunity for technology is present. In the words of Hiebert and Lefevre (2013), students are procedural and conceptual in style, and differentiated tasks meet both styles well. Having seen that, I started allowing students to take more ownership of their pace and process rather than syncing everyone up. The more flexible that ensued, the more inclusive the class became.

Looking back at my research experience, I can richly remember how nervous but excited I was on my first day of my research life in the second semester. Having come from a strict school environment where ICT tools were not in use, I had only made occasional use of them in class. Nevertheless, I had observed that students were more engaged when I used digital tools than when I used the whiteboard alone. Some students, despite my efforts, remained isolated, neither taking down notes nor even attending to them. It was this problem that led me to explore ICT-integrated pedagogy in the form of GeoGebra as an intervention. For action research, I had a 15-day schedule to educate theorems of circles to students of Class 10 to improve their concept building with dynamic visualizations. Initially, I found it difficult to integrate my research, classroom dynamics and make sure ICT integration was additive, not significant. But as I progressed, I could observe changes not just in students' interest, but also in the way I thought to educate mathematics through technology.

Even before I entered my fourth semester, I already had a clearer vision of how ICT tools, particularly GeoGebra, could transform the learning process of students. My research was no longer just demonstrating the fact that technology helps anymore, but rather it became finding out how conceptual and procedural knowledge could be balanced through visual and interactive learning. Studies such as those by Ertmer and Ottenbreit-Leftwich (2010) justified the findings of my study that ICT tools significantly improve students' understanding of geometry. In retrospect, I noticed that my initial skepticism had been replaced with confidence and that my teaching practice had changed from the traditional approach to a student-centered, inquiry-based practice. The challenges I encountered, the pushback from other students, the problems of the computer, and having to keep on changing all showed me that education research is not a one-time affair but a process of unending learning. Nevertheless, this whole thing was the greatest reminder of my belief that good teaching is not only about knowing the material but also about being fishy and creative to serve the students’ interests.

## Experiencing Research Proposal Development

When the work on my research proposal neared completion, I reflected on my substantial development from a state of confusion. At first, coming up with a systematic research plan and proving it with the new applet GeoGebra was very tough. The focus of the research work is to find out if GeoGebra can help students learning in circle theorems. For this, I have worked a lot personally to create different applets separately for different theorems. In the beginning, I struggled to prepare my research questions, aligning my research approach and ensuring that my research was scholarly as well as achievable or not. I benefited a great deal from my peers' and mentors' suggestions in my proposal. With full determination, I managed to stand for my stand on action research, explain why my work was worth doing, and make a good plan for using lessons learned, data collection, and analysis. While completing my first draft attempts, I understood that to go through with the research proposal was not about the fulfillment of the academic requirement but about getting certainty and clarity in my way of doing the research.

I have felt a sense of accomplishment at the time I finished my proposal. What had at first seemed to be an overwhelming task now evolved into a well-directed study with a clear goal. The reading of available literature, as Hohenwarter et al. (2007), supported my belief that the integration of GeoGebra would bring a positive influence on the students' conceptual knowledge of circle theorems. More importantly, the finalization process also made me more attuned to the issues that I would face in carrying out my study, e.g., technical limitations, flexibility of the students, and time considerations. Despite these concerns, I was willing to go ahead, considering that this research had the possibility of enriching not just my own teaching practice but the broader field of mathematics education. Finishing my proposal was not a conclusion but a beginning of a more targeted and informed research experience, one that would continue to build my knowledge of ICT-integrated instruction.

**Research Title Selection**

Reflecting on my experience of selecting the research title, I can still remember how frustrating and enlightening the experience was at the same time. I had a rough idea of what to research in the first place, that is, the application of ICT tools in mathematics education, but coming up with a precise and feasible title was a laborious process that involved much contemplation and guidance. My course instructor, Asst. Prof. Indra Mani Shrestha was continuously helping me to progress with my research work in the appropriate direction. The proper guidance from Indra Mani Shrestha helped me to improve my studies, carry out my research in an organized way, and master my studies. Guidance from my supervisor helped me to learn how to give a suitable research title that captured what I was doing with my research project. After refinement, I settled for the following research title: “Use of

GeoGebra in Enhancing Students' Conceptual Understanding of Circle Theorems: An Action Research Study." The title shows both my desire for the use of technology in schools as well as my goal of improving students' understanding of mathematical theorems through a deeper level of thinking. From the activity, it became clear that a good research title should be brief, relevant, and consistent with the aim of the study.

When I tried to write the title, I was pleased with the work that lay before me. I was well aware of what I needed to do. I then wrote the questions I had planned to ask about the nature and how of my research. Findings from the literature, e.g., Bayaga et al. (2019), which showed that GeoGebra helps in the teaching of Euclidean geometry, I have found another reassuring sign that my research will indeed add insight to an area in need of such. Research question construction was another challenge, imparting lessons on how to be specific, measurable, and relevant to my action research.

**Research Question Development**

Development of the research questions was a pivotal stage with regard to the study I was undertaking, and I easily remembered the hurdles that I faced in ensuring clarity and alignment with research goals. Originally, I did encounter an issue regarding framing questions that were specific, measurable, and related to my action research, such that I wanted to find the effect GeoGebra would have on students' conceptualization of circle theorems, but I had to make this inquiry well-defined research questions. After conducting discussions with my course facilitator and reviewing studies like Mensah (2023), which pointed out how mathematical tasks played in learning by students, I was able to narrow my research question to students' engagement, conceptual understanding, and problem-solving skills. This gave a more real feel of how to learn when it comes to doing research, for good questions help in the collection of data and lead to an important and specific understanding. While recollecting, I see that the development of this study question was not technical, but a very important way of strengthening the base of this study. The central question guiding my investigation at the inception of my study was "How does the use of GeoGebra enhance grade 10 students' conceptual understanding of theorems related to circle?" The use of GeoGebra increases the ability of Grade 10 students to understand circle theorems by letting them see, move, and test changing geometric relations in a quick time, which is very hard with stationary illustrations in books. During the 15 days in my action research, I taught lessons where students studied with

GeoGebra each of the most common circle theorems in the school work. Students could make circles, draw angles, and see how changing one part of the figure would have an effect on other relationships, giving them instant visual clues, and supporting their proof. Students proved ideas, conjectures, and checked relationships on directed ventures and team work, and with much more depth than simple recall. The students improved on the conceptual understanding and post assessments, as well as observations during lessons. Students were able to confidently explain and apply the theorems throughout the lessons. The statement agrees with the research query that GeoGebra helps students to actively conceptualize concepts and to better understand circle geometry in a structured and scaffolded learning environment.

**Research Paradigm in My Study**

In my research, I adopt the interpretive paradigm. It highlighted the importance and experiences of individuals within a research setting. This is not only about testing the effectiveness of GeoGebra but also about how students perceive the tool, experience, and engage themselves with GeoGebra. This paradigm helped me to develop an understanding of how students have interacted with GeoGebra, their perceptions about learning mathematics, and the challenges encountered. Furthermore, my research was configured within an action research approach. Since action research is a cyclical process, it gave me the scope to keep on reflecting on my teaching practices throughout, accordingly adjust those considering the students' responses, and thus improve the learning environment as a whole. This method also fits with my objective, not only to assess the impact of GeoGebra but also to improve my teaching methods in the process.

The study discussed the circle's concepts of chord, diameter, semicircle, segments, sector, central angle, arc, inscribed, concentric circles, intersecting circles, con-cyclic points, and cyclic quadrilateral. In addition, concepts and verifications as inscribed angles of a circle standing on the same arc are equal, the central angle of a circle is double of the inscribed angle standing on the same arc, the inscribed angles standing on the same arc of a circle are equal and the opposite angles of a cyclic quadrilateral are supplementary were explore using the GeoGebra during the experimental classes. The purpose of the experimental classes was to see how GeoGebra could be integrated into mathematics classrooms, especially while introducing the concepts of the circle for learning and assessments. Based on the research question, what role does GeoGebra play in helping students to understand

and visualize the concepts of the circle? Similarly, we put our effort into understanding students' conceptual understanding of the concepts of circles through intensive teaching in two episodes of fifteen classes.

In Euclidean geometry, a circle is a basic shape. It is the set of all points in a plane that are at a given distance from a given point, the center; alternatively, it is the curve traced out by a point that moves in such a way that its distance from a given point remains constant. On the contrary, drawing the various concepts of the circles on the whiteboard limits the students' conceptual understanding, but GeoGebra helps to visualize the changes made and their exact figures of the circles and associated concepts. These engagements offer the students meaningful and conceptual learning of the concepts of the circle. Further, various individuals have concluded that there should be a variety of approaches to mathematics learning and instruction, including the use of teaching tools proven to increase students' interest in mathematics. As far as I am concerned, this is certainly one of the best few discoveries in my life. Math teachers should have access to this software to offer students a broader perspective on mathematics and to help them develop their critical and creative thinking skills. GeoGebra is one of the mathematical software programs on this list. As a result, expanding the use of ICT applications in mathematics classes could assist teachers and students in contextualizing mathematical concepts.

While doing my research, I observed students participating actively in experimental classrooms. Similarly, I found that GeoGebra was a very user-friendly software. The findings of the study, namely, GeoGebra promotes meaningful learning, GeoGebra encourages conceptual learning, GeoGebra promotes learner-centered teaching, and GeoGebra motivates students to learn mathematics, concluded that using GeoGebra in the classroom can improve students' conceptual and procedural understanding of the concepts of the circle. Similarly, students' engagements in class and their replies after that revealed that GeoGebra can assist students in visualizing the abstract geometrical concepts of circles quickly, correctly, and effectively. Likewise, GeoGebra helps improve students' understanding of the circle concept. Integration of GeoGebra allows students to become active learners in the classroom. It helps teachers make student-centered mathematics classrooms. It also helps to minimize unnecessary distractions in the classroom. All these benefits of using GeoGebra in the mathematics classroom make the mathematics classroom effective and meaningful. So, as a teacher-researcher, I suggest that all mathematics teachers use GeoGebra in their classrooms. In this study, I have explored the use of GeoGebra in teaching geometry circles. There are many other mathematical contents where GeoGebra can be used effectively. Many algebraic concepts and transformations can be made visible and easy for students. So, I recommend that mathematics teachers explore the possible use of GeoGebra in teaching other concepts in the school mathematics and beyond.

**Looking Back to My Theoretical References**

Theoretically, the framework for this study has been informed, essentially, by the theories of constructivist learning, that is, by Piaget and Vygotsky, and technological affordances in education. From Piaget's theory of cognitive development and Vygotsky's sociocultural theory emerge the emphases on active participation of students in learning and social interactions. Based on these theories, GeoGebra has been implemented in a way that supports visual learning, facilitates the engagement and interaction of the students. Not only did Piaget agree with my view, but he also stressed in his theory the problem-solving and hands-on learning approach as the best ones for students. Vygotsky's contribution to the theory of social interaction and collaboration was actually a great help in my understanding that students learn from each other and through technology interactions. These referents have enabled me to contemplate the potential of GeoGebra, supported by new forms of developing cognition and collaborative learning beyond those aimed at mathematics.

During my action research, I justified in real life that Vygotsky’s sociocultural theory worked, by the way students learned circle theorems. We saw that learning took place when students worked with each other and with a computer program, not when they did it alone and by themselves. GeoGebra acted as a tool that linked students to learning. Students used the program to see and move around shapes and lines. It was quick for them to get feedback from the program. Allowing students to connect to the program was the way the program mediated the learning of circle theorems. Mediated learning was what Vygotsky had written about (Vygotsky, 1978). Classroom activities were, by design, built around pair and small-group work, where students could discuss what they saw, argue for meaning, and build together explanations of circle theorems in social space before internalizing them. I was less the instructor and more the more capable other providing scaffolding through scaffolding questions, Geogebra demonstrations, and timely help when students ran into a lack of understanding, thus working within the students' ZPD. Evidence from observations, interviews, and journals showed that the students who found understanding hard at first could, through working with their peers and using GeoGebra with guidance, understand the relation between central angles, inscribed angles, and arcs. Therefore, in authentic classroom settings, the learning of mathematics following the intervention was consistent with and a realization of Vygotsky's sociocultural principles of engaging in meaningful activity through mediated interaction, peer collaboration, and the use of tools.

## Field Experiences

Entering the classroom as a researcher, not as a teacher only, was a life-changing experience. I was a math teacher for years, but researching in my own classroom meant that I had to think more reflectively and analytically. My 15-day action research on circle theorems using GeoGebra was an opportunity to observe the learning habits of students very closely. Students were used to the approach of not learning from the machines; however, some other students were eager to get their hands on the same interactive nature that GeoGebra brings to classes. However, managing the classroom became more difficult because I had to find a way to combine the visible learning without denying the vibrant learning experience that technology was bringing forth to all the students. Despite these challenges, I could gradually see students developing a stronger understanding of geometric relationships. GeoGebra allowed them to visualize theorems and translate abstract notions into concrete forms. In retrospection, I realized how necessary it was to interweave ICT meaningfully rather than at the surface as a facilitator tool.

**Figure 31**

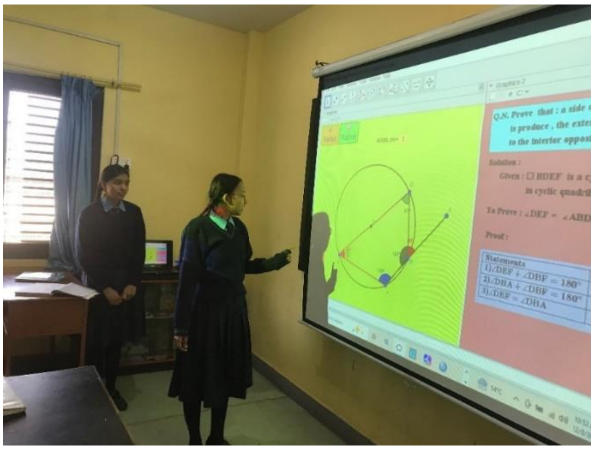
*Reflective Insights from Action Research*

Within the time frame of the research period, I noticed a definite change in the level of students in terms of interest and understanding. Even some of the shy students became lively and self-motivated in exploring GeoGebra software. My role was only to provide them with information about the lessons learned and the important issues from these lessons for the SEE examinations.  Studies like Bayaga et al. (2019) have shown that GeoGebra enhances students' conceptual knowledge of geometry, and my experience was consistent with these findings. However, I also encountered limitations, such as technical problems and variations in students' levels of digital literacy. These problems highlighted the need for proper training and gradual incorporation of ICT tools in classrooms. Looking back, my field experience was not just data gathering; it was a professional growth learning experience, confirming my belief that technology, if used properly, can revolutionize the teaching and learning of mathematics.

## Theme Generation Process

After doing fieldwork, I arranged and studied the huge amount of data that I had collected during the 15-day action research period. It included students' voice recordings, classroom videos, and study comments written by students, students' discussion notes, and pictures of their work with GeoGebra integrated lessons. The first challenge that I faced was to put all these different kinds of data into an arranged pattern that was easy to look at. The discussion and one-to-one interviews helped to record the students′ voices, whereas their raw, unprocessed ways of learning were the most precious data for my study. I paid close attention to each tape recording and made notes of salient comments, moments of rattled states, ‘Aha’ experiences, and how GeoGebra affected them in their understanding of circle theorems. The procedure was laborious, often extending deep into the night, but I was stubborn enough to get good information out of what they went through.

**Figure 32**
*Circle Theorems in the Classroom*



Once I finished transcribing, I moved on to coding data systematically. I constructed a tabular organization to sort students' answers into patterns of repeated ideas from their reflections. Comparable ideas were grouped, establishing common themes according to their learning experiences. For instance, many students repeatedly emphasized how GeoGebra helped them visualize circle theorems dynamically, in a way that the abstract became concrete. Others described their initial frustration, but then reported eagerness with the interactive nature of the lessons. Through marrying these student voices to my classroom observations, I could create the top-level themes that summarized the essential findings of my study. I was careful in selecting the strongest and most representative voices, those that captured the difficulties and the moments of epiphany experienced by students. This painstaking process enabled my findings to be strongly based on authentic student reflections and not just my own.

Having the themes well set, I went ahead to compose Chapter 4 of my dissertation, in which I described the main discourse of my action research. This chapter ended up being a significant platform for answering fundamental questions: Why do we require GeoGebra in mathematics education? What did the students learn from it? How did their knowledge evolve over the 15 days? What did they report concerning their learning process? What difficulties did they face? Most importantly, what actually happened throughout the whole research process? I carefully connected students' voices to the themes so that their experience and responses guided my research story. A few students admitted that they first of all considered GeoGebra scary, but ultimately liked how it allowed them to play around with the properties of geometry. Others felt more confident in being capable of problem-solving, realizing they could manipulate numbers and explore relationships interactively rather than having to memorize them. Theme generation not only confirmed the validity of my research but also assisted me in gaining a greater understanding of how technology can solidify learning ideas in mathematics.

## Chapters Development

Organizing the chapters in my research was a challenging but rewarding process. At first, I had been struggling with organizing my research study to be able to present what I had in mind to do, the methodology, and the findings. It was also difficult to compose the literature review as I had to incorporate existing research, such as (Hidayat et al., 2024; Romero Albaladejo & Garcia Lopez, 2024) to find the basis behind my work on how GeoGebra affects how well students learn about circle theorems. Comparing my work with these others made me show why my work really matters and also pointed out holes that my work tried to fill. Further, writing the methodology chapter required great attention to detail to clarify my research design, data collection methodologies, and analysis plans. By doing that, I improved my ability to write about academic topics, learn how to clearly convey my ideas while making arrangements and following different parts of my study.

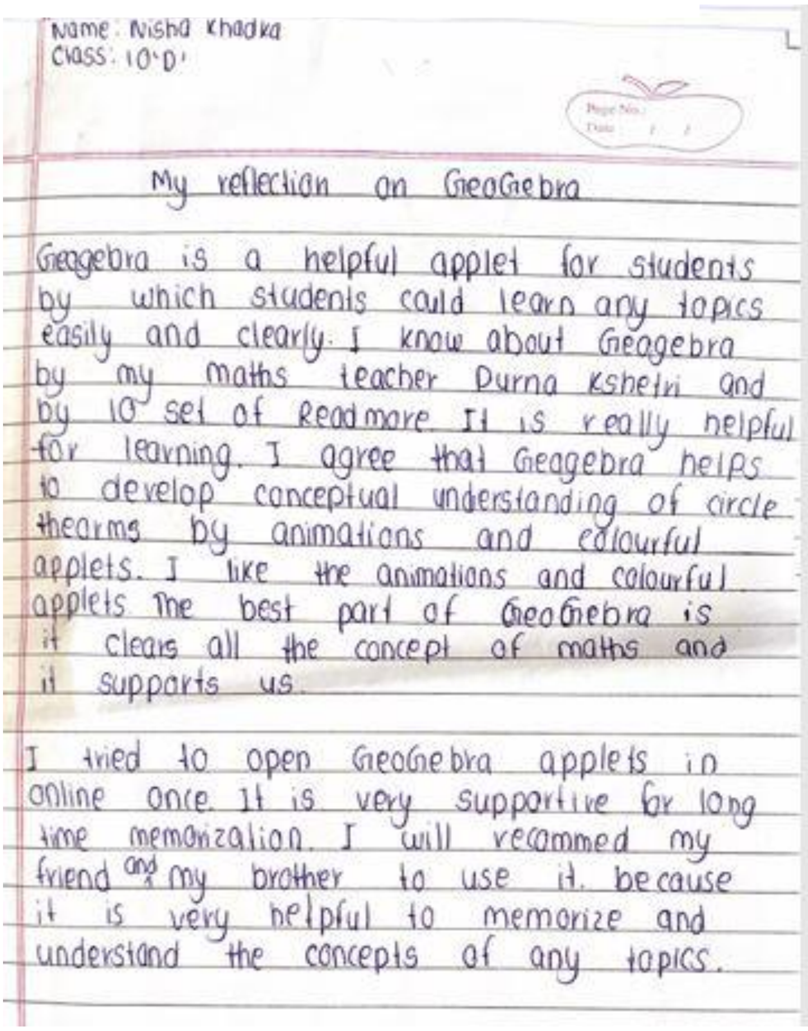
As I progressed, I realized that chapter creation was not a linear process, but rather an iterative one, with constant revisions and refinement. The discussion, along with the data analysis section, proved effective since I had to compare the collected information with my research questions and existing literature. The research by Kugblenu (2022) showed that students achieved better conceptual learning when they used GeoGebra to answer research questions that focused on utilizing the program to teach geometry within the educational environment. I also had to consider limitations such as technological constraints and variations in digital proficiency among students. The composition of the conclusions and recommendations chapter was a reflective process. Since it allowed me to synthesize key findings and make suggestions on how to improve future research on ICT-embedded teaching of mathematics. Like a mirror, writing on these chapters made my research harder, but also showed me how to write as a scholar. I was more willing to share what I had learned and how my research added to the work in this field.

## Students' Transformation

My research exposed a significant shift in students' understanding of circle theorems when I used GeoGebra applets as a teaching tool. The use of GeoGebra pronounced a new development of student observation of geometric relations, as students had depended previously on embedding rather than conceptual learning. For example, when prompted to state why the same arc subtends equal angles, students were able to recall the statement of the theorem without having the ability to prove it. Their study was very much passive, reproducing solutions on the board without their own inquiry about underlying principles. Even a single student admitted, *"Sir, I just try to remember the steps, but I do not actually see why the theorem works."* This conceptual deficit was then expressed in their problem-solving strategy, as they were having difficulty using theorems in new contexts. In addition, the conventional pedagogy, that is, static diagrams and written proofs, limited the possibility of them working with different representations of geometric concepts. The response of students to using GeoGebra to study for 15 days in the action research study proved its effectiveness towards conceptual understanding, especially on circle theorems. Most of the students, like Nisha and Sandesh, praised this applet for its animated extensions and interactive features that made complex mathematical ideas quite understandable. They noted that they were able to learn for longer with GeoGebra's visual and dynamic approach since it involved more than one sense and learning through repetition. The students also appreciated that the software simplified abstract concepts, hence mathematics became less intimidating and friendlier.

**Figure 33**

*Student's Reflection on GeoGebra*



Name: Nisha Khadka
Class: 10'D'

My reflection on GeoGebra

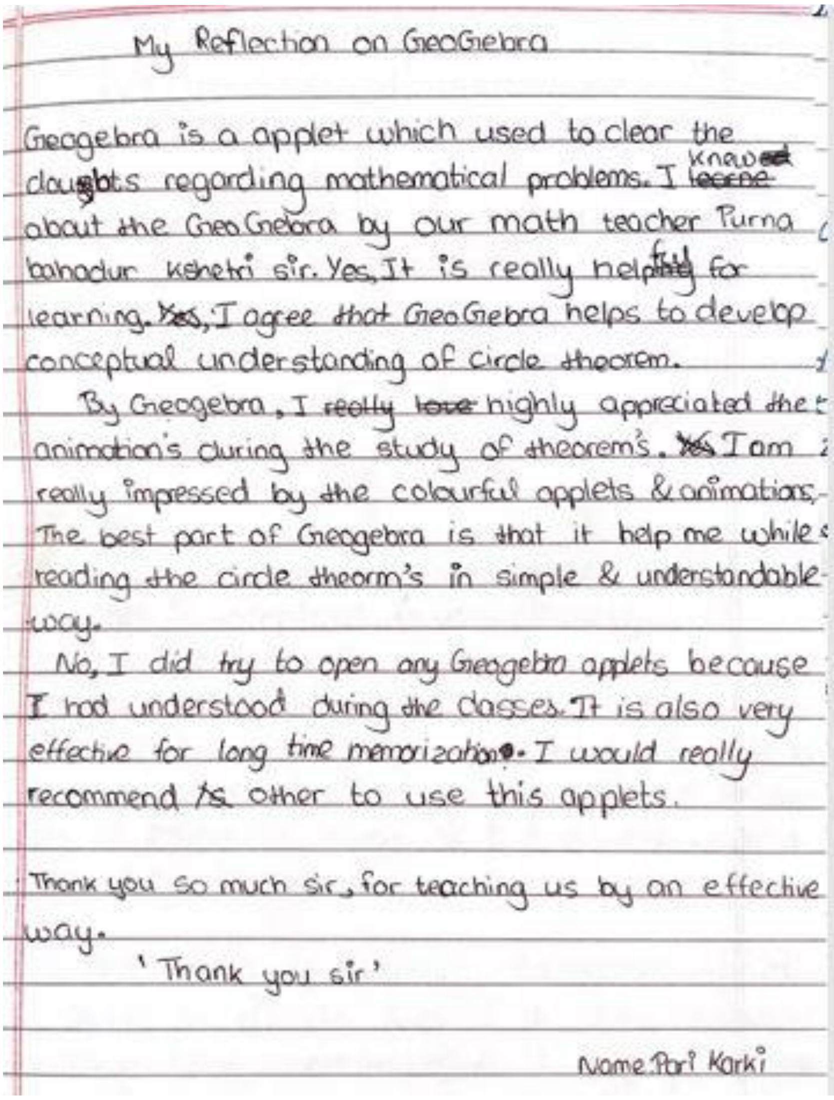
Geogebra is a helpful applet for students by which students could learn any topics easily and clearly. I know about Geogebra by my maths teacher Purna Kshetri and by 10 set of Read more. It is really helpful for learning. I agree that Geogebra helps to develop conceptual understanding of circle thearms by animations and colourful applets. I like the animations and colourful applets The best part of GeoGebra is it clears all the concept of maths and it supports us.

I tried to open GeoGebra applets in online once. It is very supportive for long time memorization. I will recommed my friend and my brother to use it. because it is very helpful to memorize and understand the concepts of any topics.

The other dominant theme in the reflections was how GeoGebra was used to support independent and collaborative learning. Another student, Smile Ranabhat, talked about how they made them edit topics and to show problems on the web. This gave them a way of being interactive and having control. This is only because of the use of GeoGebra. Student, such as Smile Ranabhat, initially refused on recommending the tool because they are the first users of such tools, but there were others, like that student who is anonymous at first, when pressed, allowed us to find out that the reasons they wanted people to use the tool were their belief that there was promise for memorization when used over a longer period of time and their opinion that the tool made the concepts very clear to understand. The varied feedback re-emphasizes how important it is to be aware of and allow for consistency when making use of innovative teaching tools.

**Figure 34**

*Student's Perception about GeoGebra*



My Reflection on GeoGebra

Geogebra is a applet which used to clear the doubts regarding mathematical problems. I ~~learne~~ Knowed about the GeoGebra by our math teacher Purna bahadur Kshetri sir. Yes, It is really helpful for learning. ~~Yes~~, I agree that GeoGebra helps to develop conceptual understanding of circle theorem.

By Geogebra, I ~~really~~ ~~love~~ highly appreciated the animation's during the study of theorem's. ~~Yes~~ I am really impressed by the colourful applets & animations. The best part of Geogebra is that it help me while reading the circle theorm's in simple & understandable way.

No, I did try to open any Geogebra applets because I had understood during the classes. It is also very effective for long time memorization. I would really recommend ~~to~~ other to use this applets.

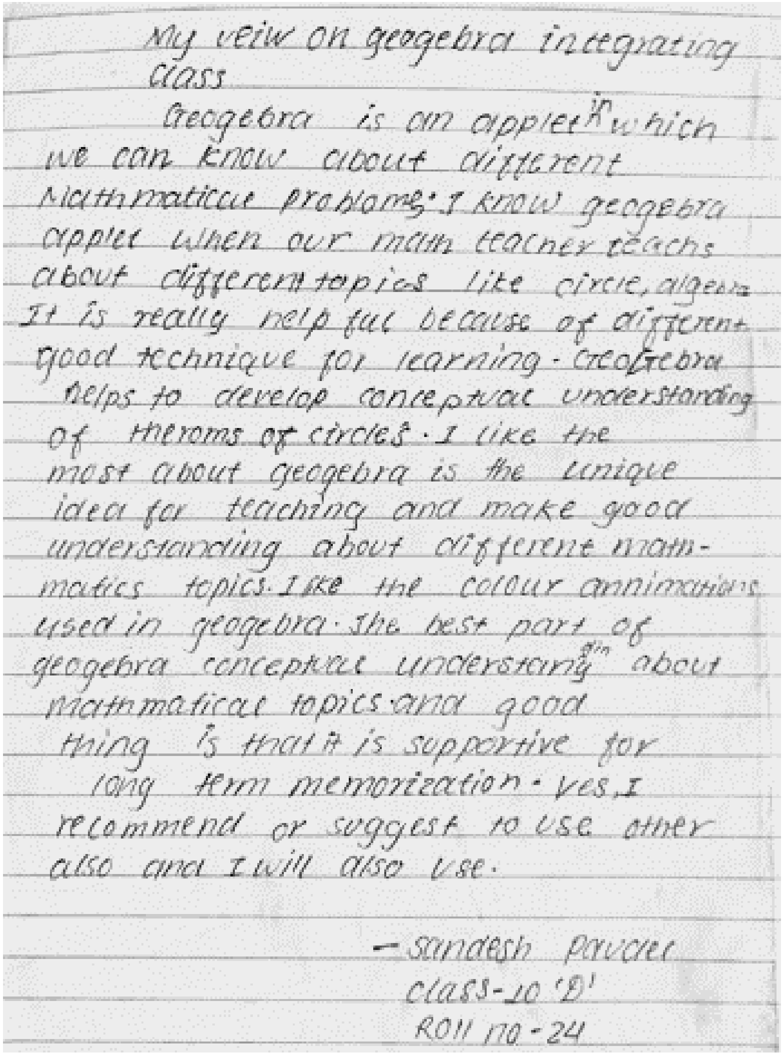
Thank you so much sir, for teaching us by an effective way.

'Thank you sir'

Name Pari Karki

Generally, students' feedback suggests that GeoGebra significantly enriched their learning experience during the 15-day course. The capability of the software in expressing mathematics visually and interactively found enormous appeal among many, as suggested by the enthusiasm and willingness to recommend the software to classmates. But the reflections show that the full benefits obtained from GeoGebra can only be realized through constant motivation and encouragement, particularly for beginners. The motivational effectiveness of the experiment reveals its potential as an enabling learning tool, making mathematics so exciting.

**Figure 35**
*Student's Personal Views on GeoGebra*



My veiw on geogebra integrating class

Geogebra is an applet in which we can know about different Mathmaticul problems. I know geogebra applet when our math teacher teachs about different topics like circle, algebra. It is really help ful because of different good technique for learning. Geogebra helps to develop conceptual understanding of theroms of circles. I like the most about geogebra is the unique idea for teaching and make good understanding about different mathmatics topics. I like the colour annimations used in geogebra. The best part of geogebra conceptual understanding about mathmatical topics and good thing is that it is supportive for long term memorization. Yes, I recommend or suggest to use other also and I will also use.

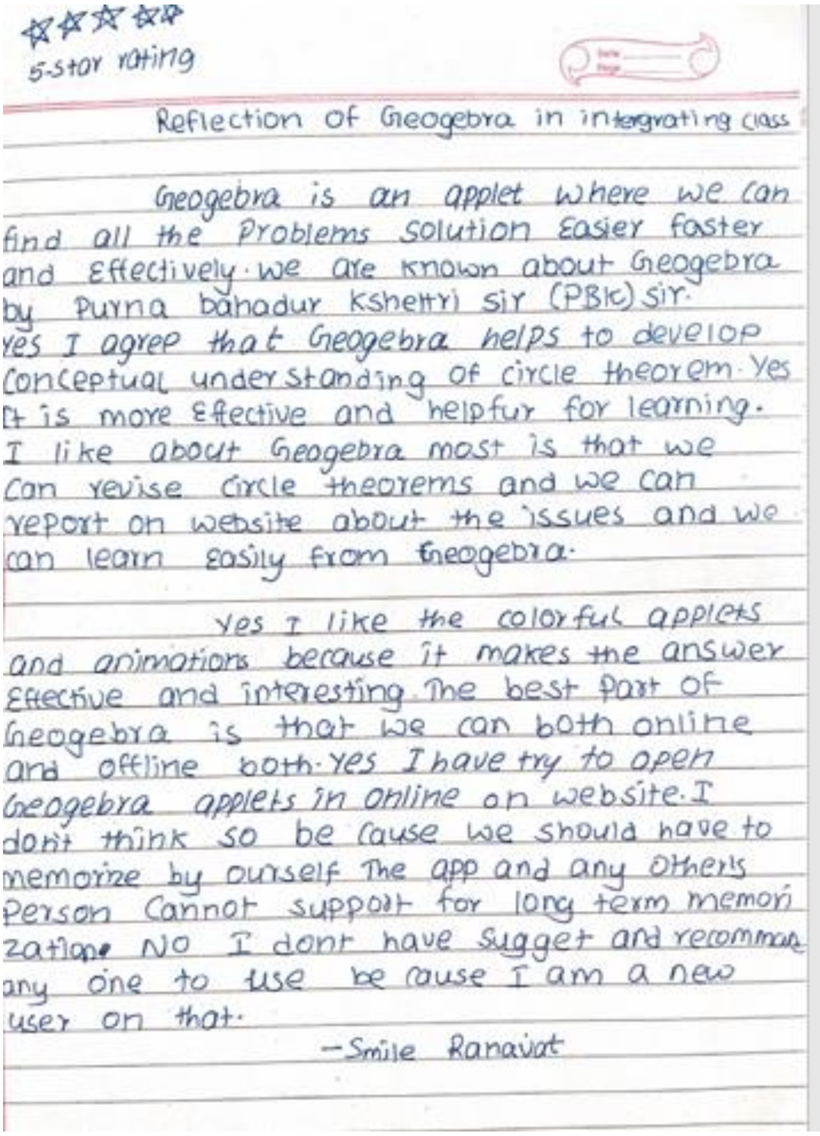
— Sandesh Pavael
Class-10 'D'
Roll no - 24

My use of GeoGebra in class has made a huge difference in how students do and learn circle theorems. They had fun graphics that students could edit and change how points moved, change figures, and watch how the arcs, lines, and angles change instantly. Students became more engaged and curious to learn more through their experimentation crawl. One student enthusiastically illustrated, *"When I'm translating the points, I can see how the angles stay equal. Now I understand why it works!"* This kind of active learning encouraged conceptual understanding even more, as students were not memorizing formulas but testing mathematical relationships for themselves.

GeoGebra also encouraged active learning in collaborative work. Students worked together in attempting different cases, discussing their findings, and verifying theorems by experiment. By doing so, their faith in justification and reasoning grew stronger. Instead of hesitating to explain an idea when asked, students started to explain their ideas more clearly in mathematical terms, as well as in visual evidence from GeoGebra simulations.

**Figure 36**

*GeoGebra in Mathematics Classroom*



5-star rating

Reflection of Geogebra in integrating class

Geogebra is an applet where we can find all the Problems solution Easier faster and Effectively. we are known about Geogebra by Purna bahadur Kshettri sir (PBK) sir.
yes I agree that Geogebra helps to develop Conceptual understanding of circle theorem. Yes It is more Effective and helpfur for learning.
I like about Geogebra most is that we can revise circle theorems and we can report on website about the issues and we can learn easily from Geogebra.

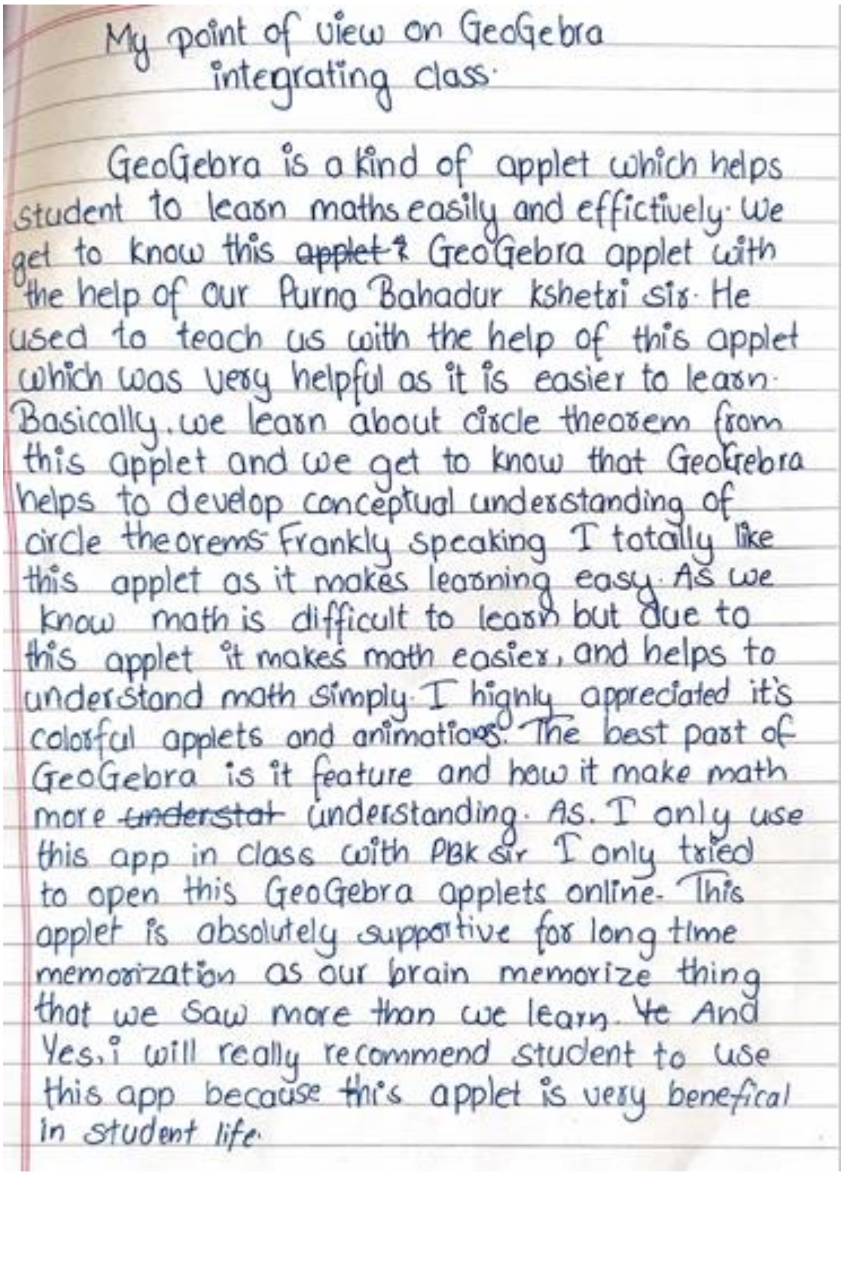
Yes I like the colorful applets and animations because it makes the answer Effective and interesting. The best part of Geogebra is that we can both online and offline both. Yes I have try to open Geogebra applets in online on website. I dont think so be cause we should have to memorize by ourself The app and any others person cannot support for long term memorization. No I dont have sugget and recomman any one to use be cause I am a new user on that.

—Smile Ranavat

By the end of the 15 days of research, the shift in students' learning was tangible. Students who once struggled to navigate geometric proofs were now able to construct their own explanations with ease. Now, they didn't see geometry anymore as a mere collection of indivisible pieces of data but a well-structured whole where phenomena line up according to relations that make sense. One of the students remarked, *"I used to think geometry was all about memorizing rules, but now I feel like I'm learning the rules for myself."* This shift from passive to active learning was the most satisfying aspect of my study. The study conducted by Kugblenu (2022) reviewed the application of GeoGebra in developing conceptual understanding, and class experiences validated these findings. The educational technology has offered these so that students would be devoid of that and provide interest in mathematics. Recollections of the experience bring me to understand that this learning of geometrical transformations brought new interpretations in mathematics education for students.

**Figure 37**

*Integration of GeoGebra in Mathematics Classroom*



My point of view on GeoGebra integrating class.

GeoGebra is a kind of applet which helps student to learn maths easily and effictively. We get to know this ~~applet~~ & GeoGebra applet with the help of our Purna Bahadur kshetri sir. He used to teach us with the help of this applet which was very helpful as it is easier to learn. Basically, we learn about circle theorem from this applet and we get to know that GeoGebra helps to develop conceptual understanding of circle theorems. Frankly speaking I totally like this applet as it makes learning easy. As we know math is difficult to learn but due to this applet it makes math easier, and helps to understand math simply. I highly appreciated it's colorful applets and animations. The best part of GeoGebra is it feature and how it make math more ~~understat~~ understanding. As. I only use this app in class with PBK sir I only tried to open this GeoGebra applets online. This applet is absolutely supportive for long time memorization as our brain memorize thing that we saw more than we learn. ~~Ye~~ And Yes, i will really recommend student to use this app because this applet is very benefical in student life.

## Personal Transformation

The 15–day action research period led me to understand that I grew deeply as both a professional teacher and a researcher. The initial impression indicated GeoGebra would be an easy supplement to my usual teaching practices to enhance classroom interaction and dynamism. What happened next was actually more than I could have ever imagined because I saw that when practicing action research at the same time with my daily routine as a high school mathematics teacher, for a M.Ed. student at Kathmandu University, I needed more than passion, discipline, patience, changeability, restraint, endurance, and flexibility. My early passion was soon met with the harsh realities of planning, doing, and thinking critically about every step of the research process. It was a heavy task for me to prepare an action research plan because I had to make sure that each step from the planning of a lesson to data collection was well structured and connected to my purpose of conducting the research. It was all but impossible to find the proper mix of doing research, school work, and meeting my teacher commitments, so that most of the days I was filled to bursting with work to meet all my obligations. Achieving that balance between conducting research, doing schoolwork, and fulfilling the norm of teachers was hard, and most days were overloaded.

During the 15-day research, I had challenges that made me tough. The biggest challenge was creating different GeoGebra applets for every lesson plan daily. Though I already knew how to operate GeoGebra, I put much time and struggle into transforming the lesson plans into more personalized, lesson-based, and interactive simulations. Some nights were spent late at night, debugging applets and familiarizing myself with how to put them in a manner that would be used in class. Additionally, having to process real-time data collection daily was tiring. I needed to document students' learning experiences through voice recording, capture photographs and videos, and collect written comments while continuing with my usual lessons. There were moments when I felt that I was multitasking so many tasks at once: preparing pre-test and post-test questions, conducting assessments, re-checking answer sheets, recording marks, and processing information. Conducting oral consultations and face-to-face meetings with key stakeholders even increased the burden of tasks, making it difficult to keep everything on track. There were certain days when I doubted if I could manage it all, but I kept feeling that my research was too important and persisted.

Despite these challenges, I gradually learned to adapt to the challenging nature of action research. Teaching circle theorems using GeoGebra daily not only transformed my students' learning but also transformed my perspective on teaching mathematics. I came to realize that technology in and of itself will not do for the successful integration of technology. One must also be supported by good planning, constant introspection, and commitment towards involving students. I documented each evening, after a day of learning and teaching, my reaction journal and emailed it to my course facilitator. This assisted me in having a grip of how my day was going, keeping in mind what I had to do once more, and what I had to modify on the subsequent day, if at all possible. As a result of the experience, I acquired enhanced time management, became familiar with unexpected events, and increased confidence in conducting research in classrooms. In hindsight, this was not just a learning improvement process for the students but also one of transformation as a teacher, researcher, and continuous learner. The challenges that I faced, nonetheless, actually increased my desire to incorporate technology in teaching mathematics, and I am now better able to advocate for GeoGebra-based learning in my professional life.

## My Paradigm Shifts

Going through the 15-day action research was not merely an intellectual exercise but a very personal process that triggered a paradigm shift on epic scales in my educational philosophy. My teaching before this exercise was embedded deeply in a positivist paradigm where knowledge was certain, teaching was didactic, and examinations were methods of measuring quantified recall. I rarely questioned my practice, believing that traditional lectures and textbook problem-solving were enough. But observing students working with ICT tools like GeoGebra and observing conceptual understanding in them, I moved more and more to a non-positivist stance where I believed that knowledge is constructed, not delivered. This did not occur overnight, but in stages of self-doubt, critical reflection, and authentic communication with my students.

### Researcher's Reflections and Learning

As a practitioner-researcher, this action research was eye-opening to an extent as it taught much about the process of integrating ICT into mathematics teaching. Major observations are:

#### *Role of Scaffolding*

The students needed initial guided instruction to maximally utilize the potential of GeoGebra. A step-by-step exposure to the software ensured a seamless shift towards learning with GeoGebra. By applying GeoGebra-based lessons in the instruction of circle theorems, I valued the role of scaffolding in facilitating students' learning, especially when introducing dynamic visualization tools. At first, many students found it challenging to adapt to controlling the software or geometric relations visualization dynamically. I provided them with step-by-step lessons, visual clues, and also helped them find proofs by teaching them how to use guided discovery. I eliminated support systems as their self-confidence increased. The experience validated my understanding of Vygotsky's Zone of Proximal Development by showing that correct scaffolding techniques at opportune moments help students cross the gap between what they already know and what they need to achieve. I learned to watch carefully while being patient to customize assistance both for individual students and for group progress.

**Figure 38**

*Teacher Facilitating Students in Class*

***Peer Collaboration Enables Learning***

The students of class 10 gained a lot from the peer discussions and the collaborative problem-solving. The group activities using GeoGebra were a sole way of making learning active and participation better. One of the most emphasized aspects of this research was that through peer collaboration, students' understanding and participation were greatly increased. The GeoGebra activities were designed for group completion, pressing students to negotiate the building, report their findings to each other, and conduct hypothesis testing on each other. Students in a controlled group setting would be explaining principles to their peers in their own words, making the abstract theorems more understandable. As an educator, I came to appreciate more student voices and understood the need to build a classroom community where collaborative learning is the norm. This also led me to become a better listener, picking up from students' understandings and elaborations, enriching my own teaching practices as well.

***Time Management***

Allocating sufficient time for discovery and practice via a pre-determined syllabus of lessons was problematic. Future arrangements must allow more time for technology familiarization. While all these very few activities continued, they were considered serious time crunches. Technical issues combined with various preparation levels of students and a bit slower discussion pace resulted in some classes exceeding their intended duration. Instant decisions on activity truncation or rescheduling had to be taken. All of these are truly helping me to build in buffer times, keep things as a priority target, and yet at the same time be flexible for the sake of quality learning. On a personal note, I became resilient and adaptive - better able to walk the crossroad between structure and responsiveness in classroom planning.

***Evaluation External Tests***

In addition to measurable improvement observed via pre- and post-testing, the classroom observations and reflection journals also provided an equal qualitative basis to the knowledge gained by the learners. Observations of students' pre-tests and post-tests, together with external assessment, showed that conceptual understanding was formed through the GeoGebra activities, but that students were left with little practice in writing formal proofs and giving rigorous answers to exam questions. This reflection pointed to the need to try to maintain a balance between new pedagogy and examination requirements. It made me conscious of the discrepancy between participative learning and summative testing, which later prompted me to include frequent test-style questions as well as participative activities. On a personal level, it prompted me to accomplish a balance towards instruction that helps in the grasp of concepts, as well as prepares students enough to excel in summative assessments.

***Professional and Pedagogical Transformation***

One of the deepest transformations I experienced in my life as a teacher. I came to understand that everything I had been doing for years - teaching content and assessing learners only - wasn't resulting in deep learning. Action research enabled me to embrace constructivist tenets of putting student agency, cooperative learning, and discovery first. I embarked on creating lessons where students discovered circle theorems using GeoGebra, presented discoveries in groupings, and explored their own learning. Assessment also became more formative and diagnostic. I employed observation, discussion, and students' own explanations as an indicator of understanding. What this transformation made me realize is how assessment is a part of the learning process and not the result.

#### ***Self-Discovery Through Critical Reflection***

The big change, I discovered, happens from the inside out. Reflective self-inquiry led me to challenge not only my practices, but also my assumptions about students' abilities and my own teacher identity. The experience led me to realize that students could create their own meanings, provided the right conditions and tools were made available to them. Moreover, I described myself as a contributor, as a reflective practitioner who was not limited to fixed patterns but could innovate, change, and grow forever. This internal change has been perhaps the most valuable component of the entire action research. As a student at Kathmandu University, exposure to a multitude of educational theories and frameworks made this reflection all the richer and gave me the vocabulary and vision to understand my own transformation.

### **Ontological, Epistemological, and Axiological Realizations**

Ontologically, I realized that there are different realities in the classroom. There is no one "truth" of math, but many different ways of knowing it and doing it when solving a problem. Having the ability to accept that each student can know in different ways released me from my former assumption of one-size-fits-all teaching. Epistemologically, I was convinced that knowledge is not fixed but is built in society through visual interaction and conversation. In my classroom, students shared ideas, debated among themselves, and co-constructed knowledge. Axiologically, I now appreciate that values are intrinsic in learning and teaching. Students' learning was shaped by their backgrounds, perspectives, and interactions, and I began respecting the value-infused nature of education. The classroom transformed into a democratic space consisting of students who took ownership of learning and made a noteworthy contribution to the collective knowledge.

### **Striving Towards Praxis-Oriented Professionalism**

After I finished the 15-day action research, I feel my professional identity has actually shifted in a way that I have become more and more a practice-oriented professional, in which I see and feel the continuous interchange between theory and practice. Previously, I taught based on how I wanted to dump the content, but by being systematic, I think the content of my lessons was not static but a work in progress. The GeoGebra forced me to think seriously about the reasons why students made mistakes and their motivation every day that changed what I did the next time I taught. This feedback loop moved me away from managing the class teaching and into the pedagogical way of giving students experiences that drive how student work guides my planning, which directly and immediately affects how I plan to organize my next step forward. This process of repetition pushed me to go beyond pure rule-based learning and become practice-based, where feedback from the students determined my choice of teaching. I embraced the constructivist and sociocultural foundation in the real world of the classroom. This has further cemented my belief that good teacher has to think on their feet, cater to the learner, and has s a responsibility to society by loving what is fair and just. Hence, the action research not only sharpened students' grasp of circle theorems but also turned me into a better facilitator and a reflective and research-driven teacher who, by intention stress effort to follow educational theory in classroom practice. I do not settle only for surface teaching. Instead, I intentionally seek out new ways of teaching and learning through discussion, group work, experiential learning, and technology integration. My idea of professional development is that it is something that will always grow as I keep learning in this area. I was able to put my skills and knowledge into the face value of others, and I learned that I should have an open mind, be curious, and be committed to growing professionally for my students as well as for me that this assignment taught me.

## Implications of the Study

The implications from this study run deep. Among educators, these findings again reinforce the importance of incorporating ICT tools in mathematics classes for the enhanced conceptual understanding and participation of the students. They could use GeoGebra or any other free software to view a concept and enable active learning. Policymakers will learn that more funding should have been directed at teaching and teachers' development. As would be expected from the findings, access to technology is not the key. This means that training for teachers using these tools needs to be established for the full potential to be reached in teaching. These findings also encourage research on the usage of ICT within mathematics education at the algebra, calculus, and statistics levels.

## Limitations

This research has brought to light various important aspects about GeoGebra in teaching circle theorems. However, this research also has several limitations: it was carried out in one school, with a fairly small sample, which could affect generalization; secondly, this study was conducted over a short period of 15 days, which is too short to determine long-term changes in the students' learning results. Another limitation is the dependence on self-reported data from students, which might be biased. Though the insights from the students through the feedback were rich, further studies with more diversified methods of data collection, such as classroom observations and standardized assessments, would give a broader understanding of GeoGebra's impact on student learning.

## Future Directions

In 15 days, I saw how GeoGebra should be used for more than just circle theorems and short-term activities. Personally, I will plan to use it on other branches of mathematics, including algebra, trigonometry, coordinate geometry, and calculus as well. As we know, GeoGebra can visualize and change in real time, and it can be used in most intuitive fields for conceptual understanding. It has provided me with brief lessons that if students were able to truly question and argue math ideas with the help of computers, learning would be better, it would stay in their minds, and it could last equally long as the time people normally take to learn these ideas. Future studies need to be conducted that will use data from the long-term or follow-up period to see if, during new learning situations, students are still capable of using the ideas that they learned through GeoGebra.

In future studies, the extension of the current study can be to explore how GeoGebra can be re-united with other forms of online learning tools, such as learning management systems, online classes, and tools for collaborating on work, to improve how the get-going spaces work, when it is used to teach math with more scope for actual integration. Alternative school forums like urban, rural, public, and private ones can reveal how GeoGebra-based instructions and apps are affected by the different settings for geographical, societal, and infrastructural reasons. Comparative research between ‘GeoGebra’ and ‘non-GeoGebra’ based instruction has the potential to strengthen research recommendations for curriculum development and policies.

These directions will contribute to the support of better mathematics teaching & learning and further efforts toward fair & innovative practices for teaching and learning of mathematics.

## Recommendations

Based on the results of this research study, certain recommendations can be formed to ensure optimum inclusion of ICT tools like GeoGebra in teaching mathematics. From what I have experienced, my recommendation is to make action research a normal part of classroom practice for ongoing professional development. It assisted me in putting planned research on how I was teaching into practice, thinking critically about it, and making informed choices based on student feedback and results. My recommendation is also to share planning with employees, along with the incorporation of new tools like GeoGebra, as inter-teacher peer support helps solve implementation problems and fosters collaborative learning. This cycle of research has not only enhanced my teaching practices but also strengthened my identity as a reflective practitioner and educational researcher.

### Recommendations on Teaching

The teachers and tutors must make interactive mathematics software, such as GeoGebra, available during their geometry classes, and particularly in those topic areas that are augmented by visual-spatial perception, such as circle theorems. Proper integration does require planning, GeoGebra facility availability, and attendant training. Besides, lesson plans should include collaborative tasks, differentiated support, and room for reflection. Teachers must find a way to connect conceptual learning and formal examination tasks through exploratory learning mixed with examination-style exercises. This research has greatly influenced my teaching practice. I now see the mathematics classroom as a space of active inquiry, where technology, collaboration, and reflection intersect to maximize student learning.

#### *Use GeoGebra in Lesson Design*

The teachers must use GeoGebra as a tool to present and not as an add-on to the teaching process. This may even increase the visual potential and potency of the perception of the learners. Students can learn through colorful, attractive simulations of GeoGebra, not only for circle theorems but also for many other topics of algebra and geometry. I think GeoGebra will definitely help teachers to develop lessons.

#### *Provide Hands-On Training to Students*

It is through the optimum utilization of ICT integration that one might have realized the need for GeoGebra training, which must be delivered beforehand, so that all can feel comfortable with the operation of the software. Very simple instructions for students may encourage them to learn better in the future.

***Promote Collaborative Learning***

The peer-to-peer learning methods can enable students to learn from one another for the sake of better conceptual understanding of mathematical concepts. GeoGebra can be a tool to promote collaborative learning, as students can learn many mathematical concepts.

***Integrate a Blended Learning Model***

A combination of conventional teaching and electronic material creates a balanced and holistic learning process. GeoGebra could be one of the tools to integrate a blended learning model, as students can also learn many mathematical concepts from their homes, as well as without teachers' presence or friends.

***Create Interactive Tests***

Technology-based exercises must be included in tests to ascertain the ability of learners to apply their learning using GeoGebra. Not only teachers but also students will be able to develop many applets related to mathematical concepts in their lessons, and that will be beneficial for all the students.

**Recommendations for Research**

The long-term effect of GeoGebra implementation on the mathematical reasoning and problem-solving ability of students must be examined in future studies. My short study showed that students had shallow benefits in how they visualized and explained circle theorems. Their pictures and explanations about the way things fit into a space go better and are more detailed, but I wonder if this positive change will last after they make a change. Will students keep their skills of go thought images and thinking and solving problems after a few months? This has made me think about doing a follow-up or a long-term study in the future. It's not hard to see how GeoGebra could help students to learn, demonstrate, and solve problems better in geometry and similar mathematical areas. I believe examining it further could also provide us with some strong leads on how the use of means can cause better long-term learning.

***Generalize to More General Mathematical Topics***

This research study was limited to the theorems of circles in Grade 10 only. Other research would then investigate the application of GeoGebra in the other strands of mathematics, such as algebra, trigonometry, and statistics, to see if it is similarly effective across content strands. Research would then be comparable, and it would be ascertainable if the interactivity and visualization of GeoGebra are more advantageous for some mathematical topics than others.

***Include Larger and More Diverse Samples***

As the present study involved a small sample of 32 students from one private boarding school, it is suggested that future studies be carried out with larger and more representative samples from various schools and backgrounds. Larger participation would render the findings more generalizable and also promise the detection of the contextual variables like school infrastructure, teachers' professional development, and socio-economic status of students that moderate the effectiveness of ICT-based learning interventions.

***Increased Focus on Teacher Professional Development***

Future research is needed to explore the part played by pedagogy support and teacher training in effective classroom integration of GeoGebra. Studies of teachers' attitudes, beliefs, and technological competencies can provide valuable insights into planning professional development programs toward improved ICT tool use in mathematics teaching.

***Mixed-Method and Comparative Studies***

I appreciate the fact that follow-up studies are to be conducted in mixed-method and comparative study designs that supplement quantitative measures of student learning with qualitative interview and classroom observation data. Comparative studies between technology-enriched and traditional classrooms can perhaps enlighten us more on the role of GeoGebra in learning procedural and conceptual knowledge.

***Learn Collaborative and Inquiry-Based Learning***

To the best of my knowledge, future research can also talk about the possibility of GeoGebra in making inquiry-based and collaborative learning settings. The possibility that the students can actively engage with geometric objects using the tool provides opportunities for encouraging peer interaction, such as testing hypotheses, exploring, and discussing. Research on these teaching approaches would contribute to the literature on how technology can change the prevailing role of teachers in the classroom to that of the students taking charge of learning.

***GeoGebra and Non-GeoGebra Classrooms***

From my experience in undertaking this 15-day action research, I observed that there was a concrete effect of GeoGebra on the interest and understanding of circle theorems on the part of the students. To have more granular evidence of its overall effect, I recommend that future researchers pursue comparative studies between GeoGebra and non-GeoGebra classes. These comparative studies would tell us specifically the areas where technology-based education is superior to traditional teaching in conceptual understanding, reasoning, and problem-solving skills. Time spent on both learning environments' comparison as well as shows how much GeoGebra makes it easy for teachers and students to see, work together, and make meaning in math learning.  Decision makers and teachers would then have better details to make up their minds about how well the use of new ways of learning by computers can be when it comes to mathematics teaching in high school.

***Teachers' Professional Development to be Investigated***

During my research, I noticed that the level of knowledge and skills of teachers in working with GeoGebra played a great role in the adoption of the tool in the classroom. Exactly for this reason, I suggest that future research be done on the professional development of teachers on GeoGebra integration. It will be interesting to see how, through workshops, mentoring, and collaboration with peers, teachers will be in a position to develop GeoGebra lessons that are fun and their use will be productive. Understanding the attitudes, concerns, and intentions of ICT tool use, teachers will guide schools and curriculum developers on designing effective professional development programs via technology adoption and pedagogical goals.

***Expand Research to Other Areas of Mathematics***

This action research was on circle theorems in the geometry strand of the Grade 10 curriculum. The positive findings mean that GeoGebra can similarly be used for quality work in other mathematical disciplines. My recommendation is that more research on other topics like algebra, trigonometry, coordinate geometry, and statistics to observe the effect of GeoGebra should be undertaken. By doing so, it will be feasible for researchers to identify which among the dynamic and visual properties of GeoGebra support concept learning in mathematics across different subjects. It would also be applied in identifying what mathematics lends itself to computer-based learning and how GeoGebra can be utilized in a manner that supports content-specific goals.

***Student Attitudes Toward GeoGebra***

In class intervention, I see most of the students reacting positively towards GeoGebra activities, where they classify it as enjoyable, but most of them don't seem to have their own attitudes, interests, or learning styles play a big role in how students use that tool. Future research also needs to continue investigating students' perceptions and attitudes regarding GeoGebra learning. Establishing students' motivation, ease, and interests allows for the development of teaching strategies that are able to be aligned and more supportive of learner needs. Greater sensitivity can be called upon in lesson planning, pacing, and support strategies to construct an effective and inclusive learning environment by being sensitive to students' attitudes towards the application of ICT in the integration of teaching mathematics. The research would also enhance the pedagogical value of GeoGebra in classroom teaching of mathematics.

***Conclusion***

This chapter integrated the overall findings of the action research study and brought them to daily pedagogic recommendations for practice teachers and educational researchers. The study emphasized the emancipative role of GeoGebra to facilitate student concept attainment as well as learning aspiration concerning circle theorems. Novice learning resistance, as well as lack of class time, were mediated through facilitative forms as well as discussion with class peers. Over the next few years, effective integration of ICT tools into mathematics classrooms requires careful implementation, ongoing evaluation, and coordination among policymakers, teachers, and researchers. Observations of students' pre-tests and post-tests, together with external assessment, showed that conceptual understanding was formed through the GeoGebra activities, but that students were left with little practice in writing formal proofs and giving rigorous answers to exam questions. This reflection pointed to the need to try to maintain a balance between new pedagogy and examination requirements. It made me conscious of the discrepancy between participative learning and summative testing, which later prompted me to include frequent test-style questions as well as participative activities. On a personal level, it prompted me to accomplish a balance towards instruction that helps in the grasp of concepts as well as prepares students enough to excel in summative assessments.

**Summary of Chapter**

This chapter recapitulates the key ideas and findings from my action research on integrating GeoGebra into teaching circle theorems. After all the time and effort, I learned that doing 15-day action research was hard but also a rewarding experience. The first thing I struggled with was changing between my roles of a teacher of secondary level mathematics and an M.Ed. student of Kathmandu University, to a researcher. GeoGebra applet preparation, lesson planning, management of assessments, data gathering, and contemplation of a classroom day experience required huge dedication. Despite these challenges, I learnt a lot about the use of GeoGebra in teaching circle theorems in Geometry. I also learnt that students need to be involved in the learning of difficult geometric shapes. There is a chapter here about how I went through and how I did the research. I look at how I came up with the research question. I also look at the paradigm that I used and the theoretical frameworks that helped me do the research. Actually, the findings of my research indicated the positive influence that GeoGebra exerts on the conception of circle theorem development and on mathematics learning activity. This chapter also addressed implications of the research, limitations, and future directions for forthcoming research. The research discussed how ICT tools, in this case, GeoGebra, affected the field of teaching circle theorems of Geometry, which was conceptualized and developed further, and reinforced learners' conceptual understanding of difficult mathematical concepts.

Through the acquisition and observation of data in an organized way, I was able to make the overall conclusions from the learner experiences. The research discovered that students first perceived technology integration into the theorems as difficult, then later, with dynamic figures and colorful applets of GeoGebra, had enhanced their conceptual understanding of the circle theorems. The results revealed a shift from memorization by rote learning to brilliant discovery, where the students could change the shapes and theorems became evident. Furthermore, the research depicted that while GeoGebra accounted immensely for bringing about the student engagement and understanding, some of the students evidenced initial resistance toward technology. The theming and coding shed light on the students' learning transformation, justifying the effectiveness of GeoGebra as a pedagogic instrument. Overall, the research not only improved my individual professional growth but also enabled me to develop a model for future teaching practices. According to the findings, the introduction of GeoGebra enhances learning of concepts as well as makes it easier to access abstractions. In the immediate future, I will further strengthen my teaching practices and incorporate more technological teaching methods to address the diverse needs of students. Future studies could be carried out for the long-term consequences of GeoGebra adoption and usage in different mathematics concepts. This research proved my first assumption was true, that when we used GeoGebra Applets properly according to our syllabus correctly, then that can fill the holes in math classes, and give a new way to learn and get excited about lessons for learners. This study supports my first idea that when used wisely, technology can fill in the gaps of math teaching and give students a way to learn in a more lively and active way.

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APPENDIX A

## Sample Action Plan

## Action Lesson Plan of Day – 5

**Objective of day – 5:**

Upon the completion of today's class, students will have the practical knowledge of establishing and confirming that "Opposite angles of a cyclic quadrilateral are supplementary. Students will have both theoretical knowledge of this theorem and practical understanding of it through the use of GeoGebra to do the experiments, and they will deepen their understanding of the theorem by looking at pictures.

**Schedule (45 minutes)**

| **Time** | **Activity** | **Description** |
|---|---|---|
| 0-5 mins | Introduction | Recap theorems on the relationship of a central and inscribed angle. Set purpose: In learning today, we will understand and prove that the opposite angles in a cyclic quadrilateral are supplementary. |
| 5-15 mins | Proof by the textbook | Provide the formal proof of the theorem. Start by defining a cyclic quadrilateral and then walk through the reasoning behind why the sum of the two inner angles is 180° step-by-step. Use a diagram to support the hypothesis of the inscribed circle around the quadrilateral to help students visualize the theorem using the GeoGebra applet. |
| 15-35 mins | GeoGebra Experiment | Guide students in GeoGebra to form cyclic quadrilaterals. Show them how to take the opposite angles, then ask them to find and look at the total sum of the opposite angles. They will check that these are supplementary. |
| 35-40 mins | Discussion and Q&A | Lead a group talk and have students talk about what they saw when they did the experiment. Ask them to look at the theoretical proof and the results they got |

| | | |
|---|---|---|
| | | with GeoGebra, and have them tell you what that was like. Let them ask questions or talk about how making the picture made their understanding better. |
| 40-45 mins | Reflection and Feedback | Students think back on what they learned. Ask safe questions, such as, "*How did GeoGebra help you learn about this theorem?*" and "*What was hard or fun today*?" Use a short-written question and answer form to see how they felt. |

**Data Collection on Day 5**

**Observational Notes**

- Prepare report of student participation and issues faced by them in the proof and GeoGebra activity.
- Record students' interaction with each other, especially noting moments of understanding or struggling to see the extra part of the opposite angles.

**Student Reflection Feedback**

- Gather feedback on how student learn from hands-on experience using GeoGebra about theorem.
- Observe student comments 'o areas of struggle with either understanding the proof or GeoGebra, which shows common themes or needs more help.

**Reflection Questions for Day 5**

a) What did you discover about the angles on a dead circle?

b) How did making use of GeoGebra applets help in checking that these angles add up to 180 degrees?

c) What problems or do you notice this week called today?

**Journal entry**

**Successes:** I will write about students' level of engagement, especially concerning how GeoGebra enhanced their ability to visualize and confirm the theorem. I will record positive reactions to seeing the theorem "in action" through the use of technology, with some details about what students may have reported finding.

**Challenges:** I will point out the difficulties that students faced regarding the theoretical parts of the proof or the technical operation of GeoGebra. I will keep a record of instances where I noticed students having a hard time making cyclic quadrilaterals or accurately measuring angles.

**Next steps:** I will compute my plans for lesson modifications that would make it easier for students to understand the work f and the significance of cyclic quadrilaterals' properties, as well as providing them with extra help in GeoGebra software.

APPENDIX B

## Observation Checklist

**1. Classroom Engagement**

**Indicators:**

- Student focus during presentations and demonstrations.
- Engagement in group talks and question time.
- Eagerness to raise questions or give input.
- Team work with others in pairs or groups.

**2. GeoGebra Interaction**

**Indicators:**

- Student ability to move in GeoGebra on their own
- Interaction students had with GeoGebra (halt exploration, changing views, zooming, the ability to change circle, triangle properties, move-point, use of rulers and compass, and construction tools with right click)
- Number of times students asked for help with GeoGebra features
- Students made new supplies and / or all the use of them to show a pattern.

**3. Conceptual Understanding**

**Indicators:**

- Correctly identifying the terms to circle for example, radius, diameter, and chord.
- Showing they understand what they see by giving explanations in their own words.
- Questions that made them think about words and their answers; and showing they understood what the day aims to achieve.
- Getting better in understanding and using circle theorems.

**4. Student Responses to Assessments Indicators:**

- To compare student's pre-test his/ her post-test score.
- How rightly and how in-depth student gave when answering to a short answer or conceptual type of question.
- Completion of problem-solving tasks, including drawing and labelling diagrams.

- Consistency in matching theoretical proofs with GeoGebra explorations.

**5. Challenges and Need for help**

**Indicators:**

- Particular features of GeoGebra with which students find it difficult.
- Common mistakes associated with the circle theorems.
- Trend of technical had difficulties with devices or software.
- How often and what sort of help do students ask for.

**1. Student Reflections**

**Indicators:**

- In feedback about GeoGebra (e.g., “It helped me visualize”, “It was tough to use”).
- Any reflections on how hard or easy it was to understand the circle theorems.
- Anything that could make the learning better.
- Any parts of circle that was different, new, on a different way, or special during the sites.

**7. Teacher Adjustments**

**Indicators:**

- Improvements in way of learning as directed by votes of the learner.
- Changes in GeoGebra learning units or problems that when corrected fixes the problems.
- Unique means to strengthen hard-to-get ideas.
- Approaches taken to make sure fair getting involved.

**Observation Checklist Table**

**Observation Checklist Indices**

***Engagement***

1 = Below Average: Almost never participates, is inattentive or disengaged.

2 = Average: Sometimes participates, Ward's moderate attention.

3 = Good: Participates actively, is attentive and engaged throughout.

**Understanding of Concepts**

1 = Below Average: Has difficulty in understanding the concept; needs constant help.

2 = Average: Has basic understanding; needs help at times.

3 = Good: Understands clearly and can use every time on his own

**Problem-Solving Skills**

1 = Below Average: Often cannot fix issues even when given tips.

2 = Average: Can fix simple issues; gives help on harder ones.

3 = Good: Even if complex, can fix problems with accuracy.

**Use of ICT Tools (e.g., GeoGebra)**

1 = Bellow Average: Finds it hard to use ICT tools; very little interaction.

2 = Average: Can use tools if helped a little; well, enough.

3 = Good: Can use without help and can also bring them into his work where needed.

**Collaboration with Peers**

1 = Below Average: Too rarely assists or creates problems in working with others.

2 = Average: Sometimes participates but does not initiate action.

3 = Good: Cooperates well with others and provides value to team.

**Questioning and Reasoning**

1 = Somewhat less than okay: Never asks questions or explains why.

2 = Average: Always asks just simple questions; comes up with somewhat right answers.

3 = Nice: Always asks sharp questions; always explains why answers are right.

**Presentation of Work**

1 = Below Average: Work is not finished, is not clear, or not well put together.

2 = Average: Work is ok, but has some small mistakes or is not neat.

3 = Good: Work is in order, clear, and has no mistakes.

**Checklist Table**

| **Date** | **Day** | **Domain** | **Observation Criteria** | **Observation Checklist** | | |
|---|---|---|---|---|---|---|
| | | | | **1** | **2** | **3** |
| 25 Nov | Monday | Classroom Engagement | Did students pay attention during the explanation? | ☐ | ☐ | ☐ |
| | | | Did students contribute to discussion or Question and Answer sessions? | ☐ | ☐ | ☐ |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | Were students posting the right questions or leaving comments? | ☐ | ☐ | ☐ |
| | | | Did students work well together during group work or pair work? | ☐ | ☐ | ☐ |
| | | GeoGebra Interaction | Were the pupils able to use GeoGebra on their own? | ☐ | ☐ | ☐ |
| | | | Did the pupils actively use the GeoGebra activities (e.g. moving circles, looking at properties)? | ☐ | ☐ | ☐ |
| | | | How many times did the pupils need help with GeoGebra? | ☐ | ☐ | ☐ |
| | | | Did the pupils find new patterns or properties with the help of GeoGebra? | ☐ | ☐ | ☐ |
| | | Conceptual Understanding | Could students give the right meaning for important words (e.g., radius, diameter, and chord)? | ☐ | ☐ | ☐ |
| | | | Could students say how patterns or relationships they saw in GeoGebra fit together? | ☐ | ☐ | ☐ |
| | | | Did student reviews show a grasp of circle theorems? | ☐ | ☐ | ☐ |
| | | | Was there any real progress in making use of circle theorems in activities? | ☐ | ☐ | ☐ |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | Assessment Responses | How well did students do on pre-test and post-test tasks? | ☐ | ☐ | ☐ |
| | | | Were students correct when working on problem solving tasks (e.g., drawing pictures, working together on solving a problem)? | ☐ | ☐ | ☐ |
| | | | Did students well link the theoretical proofs with the explorations in GeoGebra? | ☐ | ☐ | ☐ |
| | | Challenges and Support | What exact GeoGebra features did students find hard? | ☐ | ☐ | ☐ |
| | | | Did students keep making the same mistakes about circle theorems? | ☐ | ☐ | ☐ |
| | | | Was there any problem using the devices or the tools? | ☐ | ☐ | ☐ |
| | | | How frequently and in what way did students called for help? | ☐ | ☐ | ☐ |
| | | Student Reflections | What themes came out in the ones from students on GeoGebra? | ☐ | ☐ | ☐ |
| | | | What knowledge did students bring up about really knowing about circle theorems? | ☐ | ☐ | ☐ |
| | | | What writings do ones have for making the learning better? | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | Did students bring up new or cool ideas? | ☐ | ☐ | ☐ |
| | | Teacher Adjustments | What changes in teaching were made from student feedback? | ☐ | ☐ | ☐ |
| | | | Were GeoGebra stuff or lessons fixed for problems? | ☐ | ☐ | ☐ |
| | | | Was there any new way to help for hard stuff? | ☐ | ☐ | ☐ |
| | | | How did you make sure everyone joined in and took part? | ☐ | ☐ | ☐ |

# APPENDIX C

## Pre – Test and Post – Test Questionnaire

Total Marks: 10 Time: 20 minutes

Class: 10 Sec: D Total Students: 32

**1. Explain the following terms with respect to circles:**

a) Radius (1 mark)

Ans:…………………………………………………………………………………

b) Diameter (1 mark)

Ans:…………………………………………………………………………………

c) Chord (1 mark)

Ans:…………………………………………………………………………………

**2. Write "T" for true and "F" for False:**

a) All radii in a circle are of the same length. ________ (0.5 mark).

b) The diameter of a circle is double of its radius. ________ (0.5 mark)

**3. Multiple Choice Question (Give √ for correct answer).**

Which of the following is true? (1 mark)

i) A tangent to a circle intersects it exactly at two points.

ii) A chord is a line that passes through the centre of a circle.

iii) Radius is a line segment joining the centre of a circle and a point on the circle.

iv) A circle doesn't have any lines of symmetry.

**4. Fill in the Blanks:**

a) A tangent to a circle is perpendicular to the ………. at the point of contact. (0.5 mark)

b) The length of the longest chord of a circle is called the ……...  (0.5 mark)

**5. Short Answer Questions:**

a) If the radius of a circle is 5 cm, what is its diameter?  (1 mark)

Ans:………………………………………………………………………………

b) Draw a circle, label its centre O and mark two points A and B on the circumference. Now, draw the line AB and label it as a chord. (1 mark)

Ans:………………………………………………………………………………

**6. Conceptual Question:**

Explain briefly what you understand by "congruent circles" and give one example.

(1 mark)

Ans:…………………………………………………………………………….

**7. Problem Solving Question:**

In a circle, if two radii form an angle of 90° at the center, what type of triangle is formed between these two radii and the chord connecting their endpoints? Explain.

(1 mark)

Ans:………………………………………………………………………………

**Pre – Test and Post – Test Result Scores of Students**

**(Before and After-Action Plan)**

**Class: 10 (D)** **F.M.: 20**

**Subject: C. Mathematics** **Topic: Circle**

*Pre-test taken date: Monday, 25 November. 2024*

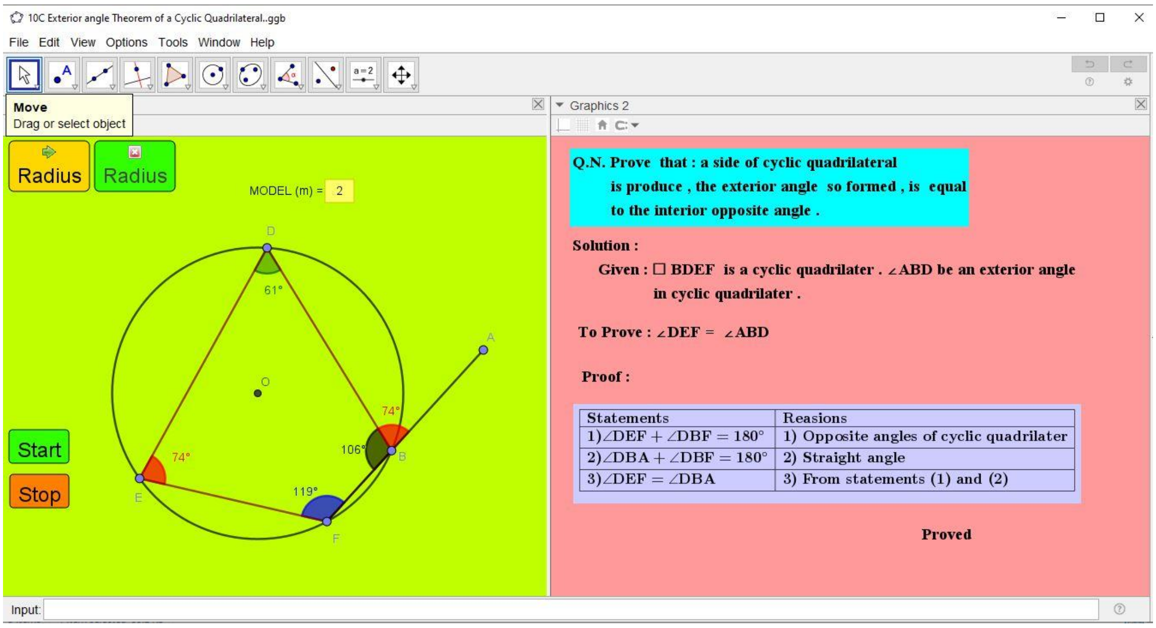
*Post-test taken date: Wednesday, December 11, 2024*

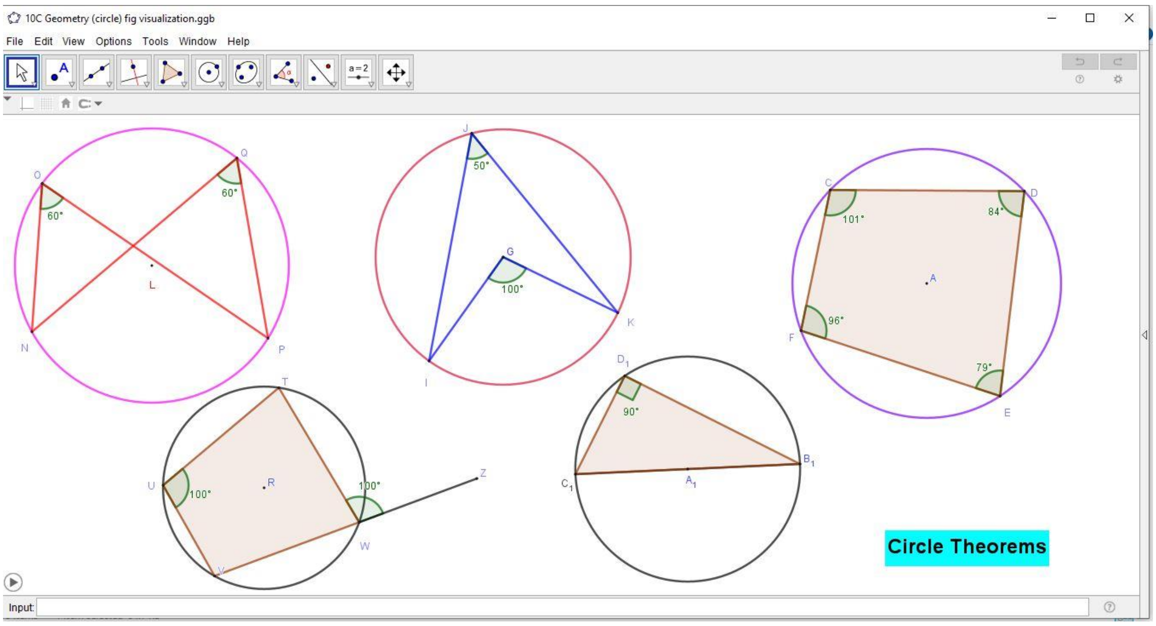
| Roll No. | Name of Students | Pre- Test Score | Post -Test Score |
|---|---|---|---|
| 1 | Aayusha Karki | 2.5 | 5 |
| 2 | Abhishek Tamang | 1.5 | 4.5 |
| 3 | Abishek Chhetri | 3.5 | 6 |
| 4 | Anish Karki Chhetri | 2 | 5.5 |
| 5 | Anisha Taramu | 2 | 6 |
| 6 | Arjun Chhetri | 2 | 5 |
| 7 | Ashmi Bhandari | 4.5 | 7 |
| 8 | Ayush Adhikari | 2 | 5 |
| 9 | Babu Pariyar | 1.5 | 5 |
| 10 | Bipina Poudel | 2.5 | 5.5 |
| 11 | Bishal Devkota | 0.5 | 4 |
| 12 | Garima Bishowkarma | 2.5 | 5 |
| 13 | Ishan Adhikari | 2 | 6 |
| 14 | Jisman Rana | Absent | 4 |
| 15 | Joy Ghimire | 3 | 6 |
| 16 | Kushal Karki | 3.5 | 6.5 |
| 17 | Nisha Khadka | 5.5 | 6.5 |
| 18 | Pari Karki | 3.5 | 7 |
| 19 | Prajit Thada Magar | 4 | 8 |
| 20 | Pramisha Karki | Absent | 6 |
| 21 | Prapti Chiluwal | 2.5 | 5 |
| 22 | Rabin Puri | 3 | 7 |
| 23 | Sajan Giri | 2 | 5.5 |

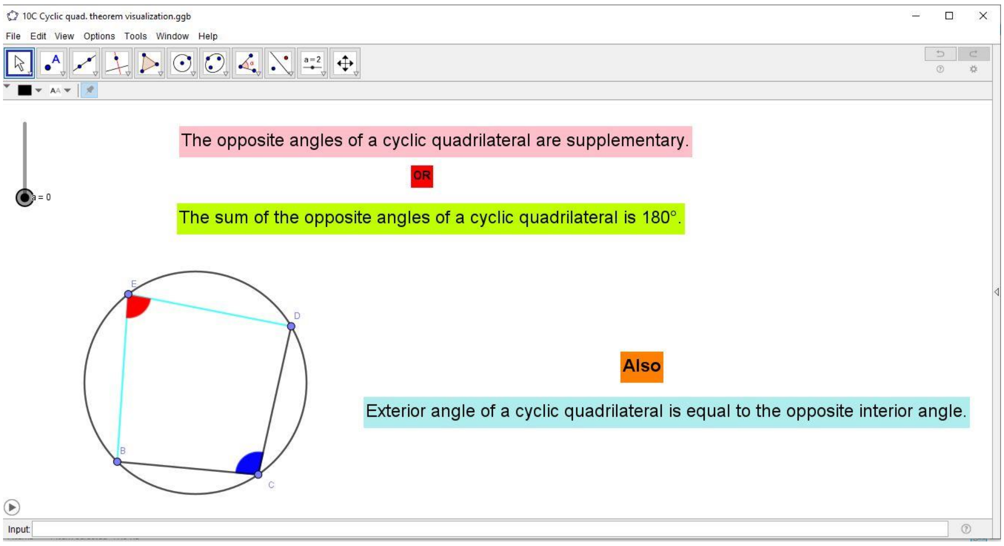
| | | | |
|---|---|---|---|
| 24 | Sandesh Poudel | 4 | 6 |
| 25 | Shiwant Karki | 2 | 5 |
| 26 | Shristi Sapkota | 4.5 | 7.5 |
| 27 | Smile Ranabhat | 3.5 | 6 |
| 28 | Smriti Banstola | Absent | 4 |
| 29 | Sneha Lungeli Magar | 6.5 | 8 |
| 30 | Suman Dhungana | 8 | 10 |
| 31 | Susan Khatri Chhetri | 1.5 | 5 |
| 32 | Yamin Thapa Magar | 6 | 9 |

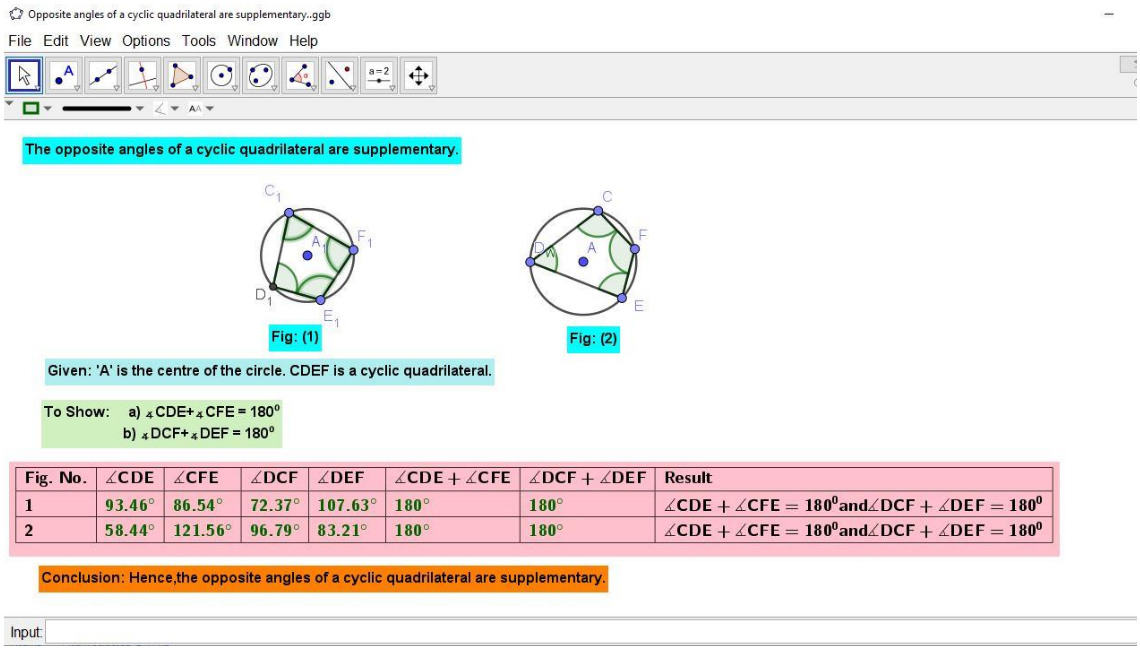
# APPENDIX D

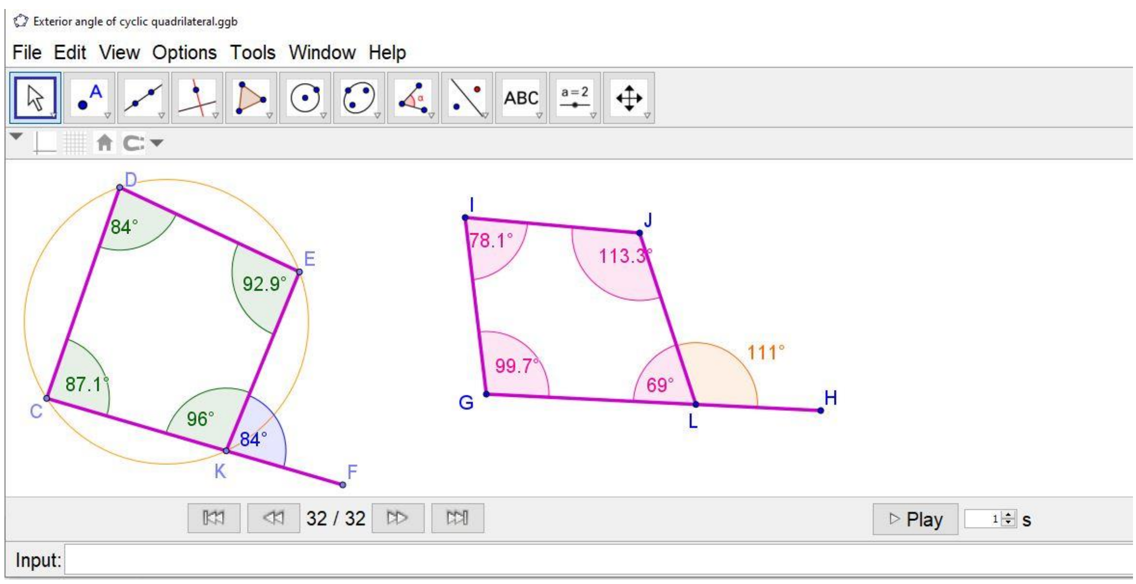
## GeoGebra Files

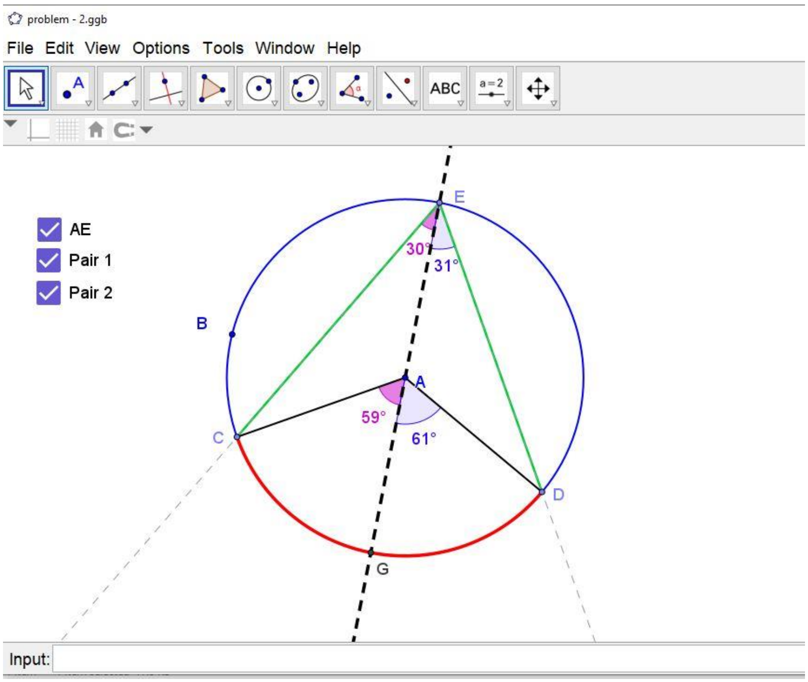


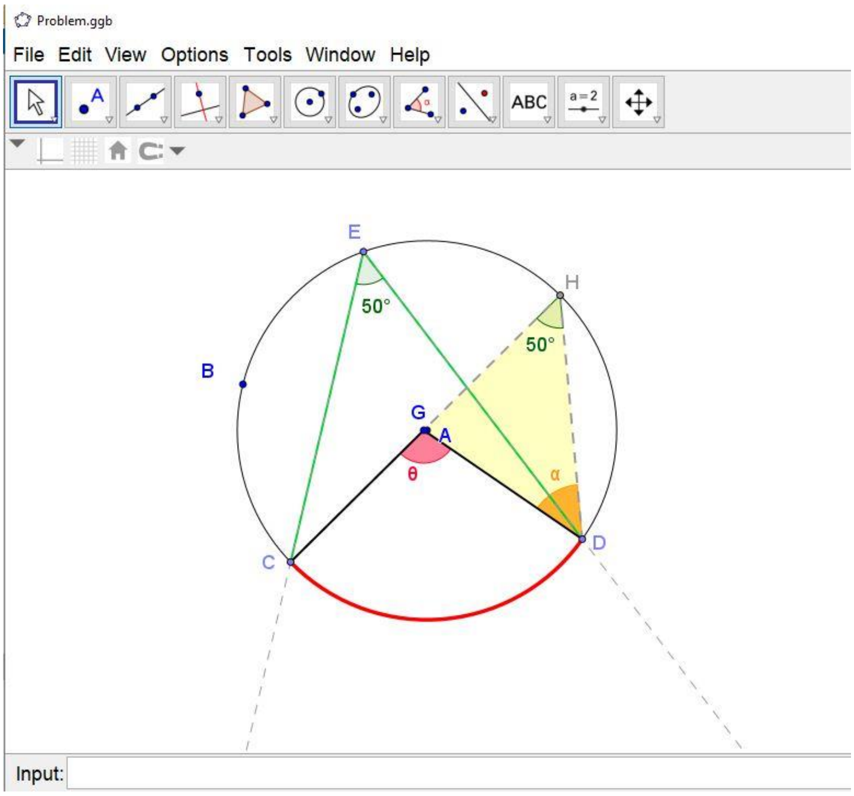




10C Cyclic quad. theorem visualization.ggb
File Edit View Options Tools Window Help
The opposite angles of a cyclic quadrilateral are supplementary.
OR
The sum of the opposite angles of a cyclic quadrilateral is 180°.
Also
Exterior angle of a cyclic quadrilateral is equal to the opposite interior angle.
Input:


Opposite angles of a cyclic quadrilateral are supplementary..ggb
File Edit View Options Tools Window Help
The opposite angles of a cyclic quadrilateral are supplementary.
Fig: (1)
Fig: (2)
Given: 'A' is the centre of the circle. CDEF is a cyclic quadrilateral.
To Show: a) ∡CDE+∡CFE = 180⁰
b) ∡DCF+∡DEF = 180⁰
Fig. No. | ∡CDE | ∡CFE | ∡DCF | ∡DEF | ∡CDE + ∡CFE | ∡DCF + ∡DEF | Result
1 | 93.46° | 86.54° | 72.37° | 107.63° | 180° | 180° | ∡CDE + ∡CFE = 180⁰and∡DCF + ∡DEF = 180⁰
2 | 58.44° | 121.56° | 96.79° | 83.21° | 180° | 180° | ∡CDE + ∡CFE = 180⁰and∡DCF + ∡DEF = 180⁰
Conclusion: Hence,the opposite angles of a cyclic quadrilateral are supplementary.
Input:


Exterior angle of cyclic quadrilateral.ggb
File Edit View Options Tools Window Help
D
E
C
K
F
84°
92.9°
87.1°
96°
84°
I
J
G
L
H
78.1°
113.3°
99.7°
69°
111°
32 / 32
Play
s
Input:


problem - 2.ggb
File Edit View Options Tools Window Help
ABC
a = 2
AE
Pair 1
Pair 2
E
30°
31°
B
A
59°
61°
C
D
G
Input:


Problem.ggb
File Edit View Options Tools Window Help
ABC
a = 2
E
H
50°
50°
B
G
A
θ
α
C
D
Input:

APPENDIX E

**Student's Reflections**

My veiw on geogebra integrating class

Geogebra is an applet in which we can know about different Mathmaticae problome. I know geogebra applet when our math teacher teachs about different topics like circle, algebra It is really help ful because of different good technique for learning. Geogebra helps to develop conceptual understanding of theroms of circles. I like the most about geogebra is the unique idea for teaching and make good understanding about different mathmatics topics. I like the colour annimations used in geogebra. The best part of geogebra conceptual understanding about mathmatical topics and good thing is that it is supportive for long term memorization. yes, I recommend or suggest to use other also and I will also use.

— Sandesh pavdel
class-10 'D'
Roll no - 24

☆☆☆☆☆
5-star rating

Date
Page

Reflection of Geogebra in intergrating class

Geogebra is an applet where we can find all the Problems solution Easier faster and Effectively. we are known about Geogebra by Purna bahadur Kshettri sir (PBK) sir.
Yes I agree that Geogebra helps to develop Conceptual understanding of circle theorem. Yes It is more Effective and helpfur for learning. I like about Geogebra most is that we can revise circle theorems and we can report on website about the issues and we can learn Easily from Geogebra.

Yes I like the colorful applets and animations because it makes the answer Effective and interesting. The best part of Geogebra is that we can both online and offline both. Yes I have try to open Geogebra applets in online on website. I don't think so be cause we should have to memorize by ourself The app and any other's Person Cannot support for long term memorization. No I dont have sugget and recomman any one to use be cause I am a new user on that.

—Smile Ranavat

My Reflection on GeoGebra

Geogebra is a applet which used to clear the doubts regarding mathematical problems. I ~~learne~~ knew about the GeoGebra by our math teacher Purna bahadur kshetri sir. Yes, It is really help~~ing~~ful for learning. ~~Yes~~, I agree that GeoGebra helps to develop conceptual understanding of circle theorem.

By Geogebra, I ~~really~~ ~~love~~ highly appreciated the animation's during the study of theorem's. ~~Yes~~ I am really impressed by the colourful applets & animations. The best part of Geogebra is that it help me while reading the circle theorm's in simple & understandable way.

No, I did try to open any Geogebra applets because I had understood during the classes. It is also very effective for long time memorization. I would really recommend ~~to~~ other to use this applets.

Thank you so much sir, for teaching us by an effective way.

'Thank you sir'

Name: Pari Karki

Name: Nisha khadka
Class: 10'D'

Page No.:
Date: / /

My reflection on GeoGebra

Geagebra is a helpful applet for students by which students could learn any topics easily and clearly. I know about Geagebra by my maths teacher Purna kshetri and by 10 set of Readmore. It is really helpful for learning. I agree that Geagebra helps to develop conceptual understanding of circle thearms by animations and colourful applets. I like the animations and colourful applets. The best part of GeoGebra is it clears all the concept of maths and it supports us.

I tried to open GeoGebra applets in online once. It is very supportive for long time memorization. I will recommed my friend and my brother to use it. because it is very helpful to memorize and understand the concepts of any topics.

DATE

My point of view on GeoGebra integrating class.

GeoGebra is a kind of applet which helps student to learn maths easily and effictively. We get to know this ~~applet~~ GeoGebra applet with the help of our Purna Bahadur kshetri sir. He used to teach us with the help of this applet which was very helpful as it is easier to learn. Basically, we learn about circle theorem from this applet and we get to know that GeoGebra helps to develop conceptual understanding of circle theorems. Frankly speaking I totally like this applet as it makes learning easy. As we know math is difficult to learn but due to this applet it makes math easier, and helps to understand math simply. I highly appreciated it's colorful applets and animations. The best part of GeoGebra is it feature and how it make math more ~~understat~~ understanding. As. I only use this app in class with PBK sir I only tried to open this GeoGebra applets online. This applet is absolutely supportive for long time memorization as our brain memorize thing that we saw more than we learn. ~~Ye~~ And Yes, i will really recommend student to use this app because this applet is very benefical in student life.

APPENDIX F

## Feedback And Reflection Session with Key Participants

On the 3rd day of my 15-day action research, I concentrated on the concept of the theorem "Inscribed angles standing on the same arc are equal." By the use of GeoGebra, I took my grade 10 students through a theoretical proof and a practical visualization of the concept. This will help them understand the concept more comprehensively with a mathematical approach while integrating interactive technology.

To find the students' views about the use of GeoGebra, I also asked them to write individual reflections on whether or not the tool was helpful to learn. Here is a summary of their responses:

**My Reflection and Observations**

It is clear from the feedback that GeoGebra increases students' mathematical knowledge, particularly about geometry. A lot of the students mentioned the visual and interactive nature that facilitated an approach to abstract theorems. A number mentioned that such a facility should be used in all schools to modernize their teaching with ICT.

From this exercise, I learned that the integration of GeoGebra enhanced not only conceptual clarity among students but also created an interest in and motivation toward learning mathematics. In the future, I will continue with GeoGebra and try to clarify the occasional confusion to make sure all students benefit from this interactive approach.

**Students' Reflections**

| S.N. | Name of students | Student’s Voice |
|---|---|---|
| **1** | Garima Bishowkarma | *“GeoGebra helped in making the theorem very clear. The things that I did not get in the regular classroom lessons became crystal clear.”* |
| **2** | Ashmi Bhandari | *“GeoGebra made me recognize and respect modern facilities in teaching, improvement of my skills and concepts, which were complex, with its view applets.”* |
| **3** | Pari Karki | *“GeoGebra helped me to solve the doubts about the theorems of the circles, and such tools might also bring them up to successfully building a career in mathematics.”* |
| **4** | Pramisha Karki | *“GeoGebra helps visualize learning - GeoGebra made me explore even tough, complex theorems much more approachable.”* |
| **5** | Prapti Chiluwal | *“Learning was fun and interactive with GeoGebra; colors and animation added to it.”* |
| **6** | Sneha Lungeli | *“I found it quite interesting and, in the future, wanted classes to be continued with it.”* |
| **7** | Srishti Sapkota | *“GeoGebra is really an effective modern teaching method and might bring a revolution in mathematics.”* |
| **8** | Prajit Thada Magar | *“I was fascinated initially; having been shown GeoGebra in operation, I thought that the next teaching cycle would certainly benefit from it.”* |
| **9** | Arjun Chhetri | *“After experiencing its use in class, I thought GeoGebra was really amazing to learn geometry.”* |
| **10** | Bishal Devkota | *“I liked how GeoGebra could visually represent angles and arcs with clarity and ease.”* |
| **11** | Anish K.C | *“GeoGebra was one of the best tools for theorem-proof and for learning mathematics in general.”* |
| **12** | Kushal Karki | *“GeoGebra should be used in every school because it is very useful while learning.”* |

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| **13** | Sandesh Poudel | *"I found GeoGebra very practical and efficient in understanding concepts."* |
| **14** | Ishan Adhikari | *"Though I was confused sometimes, I accepted the fact that GeoGebra made things easy to learn about theories."* |
| **15** | Joy Ghimire | *"GeoGebra changed his negative view towards mathematics and helped him to learn it easily."* |
| **16** | Smile Ranabhat | *"I liked the usefulness of GeoGebra and recommended further spreading it in Nepal."* |
| **17** | Suman Dhungana | *"I liked the graphical and animated features of GeoGebra, which enabled learning to be practical and detailed."* |
| **18** | Nisha Khadka | *"I felt GeoGebra was effective in making concepts clear and suggested making its use prevalent everywhere."* |
| **19** | Shiwant Karki | *"I found important topics included in GeoGebra and its usefulness in revision and understanding."* |
| **20** | Smriti Banstola | *"I like GeoGebra because it helps to connect the theorems easily, and I wish to learn all the lessons with the help of GeoGebra if possible."* |

**Student's Feedback and Feedback on after action plan Day 17 (December 12, 2024)**

| S.N. | Name of the Students | Student's Reflection |
|---|---|---|
| 1 | Nisha Khadka | *"In my understanding GeoGebra is a helpful applet for students by which students could learn any topics easily and clearly. I learned about GeoGebra by my Mathematics teacher Mr. Purna Bahadur Kshetri and from a book. It is really helpful for learning. I agree that it is really helpful for learning. I agree that Geogebra helps to develop conceptual understanding of the circle theorems by* |

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| | | *animations and colorful applets. The best part of GeoGebra is that it clears all the concepts of abstract Mathematics and it supports us. I tried to open Geogebra online once. It is very supportive for long term memorization. I recommend it for my friends, my brothers and sisters to use in future because it is very helpful for them."* |
| 2 | Bipina Poudel | *"I learned that Geogebra is an applet which helps in learning mathematics. We learned about GeoGebra through our mathematics teacher. It is really helpful for learning. I agree that GeoGebra helps to develop conceptual understanding of circle theorems. I like the colorful applets and animations. The best part of Geogebra is its attractive dynamic animations. I also tried to open GeoGebra applets once, it is easy to use and helps for long term memorization. I recommend every student and teacher to use this applet in their classroom. I highly appreciate and declare that it is a really genuine applet for learning."* |
| 3 | Rabin Puri | *"GeoGebra is an applet where we can revise all the mathematical chapters and resolve our issues. I know the GeoGebra app by Purna Bahadur Kshetri, sir. I agree that Geogebra really helpful to develop conceptual understanding of circle theorems. It is easier to learn the theorem with GeoGebra. I think it supports us for long-term memorization. It is really helpful for mathematical learning."* |
| 4 | Smile Ranabhat | *"GeoGebra is an applet where we can find the problem's solution more easily, faster, and effectively. We have learned about Geogebra by our teacher, Purna Bahadur Kshetri (PBK sir). I also agree that GeoGebra helps to develop conceptual* |

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| | | *understanding of circle theorems. It is more effective and helpful for learning. What I like most about GeoGebra is that we can revise circle theorems many times, we can report on the website about the issues, and we can learn easily from GeoGebra. I like colorful applets and animation because it makes the answer effective and interesting. The best part of GeoGebra is that we can use the app both online and offline. (5-star rating).”* |
| 5 | Babu Pariyar | *“GeoGebra is a very useful applet for learning. Our mathematics teacher, Mr. Purna Bahadur Kshetri, has introduced this app for the first time in the classroom. It really helps me in the exam for memorization of theorems in my second term. I agreed that GeoGebra helps to develop conceptual understanding of circle theorems. I like the animation and love colorful applets. It is a perfect applet for learning mathematics, so I recommend using this app all over Nepal in every school for both students and teachers.”* |
| 6 | Pari Karki | *“GeoGebra is an applet which is used to clear the doughty regarding mathematical problems. I learned about the GeoGebra by our math teacher Mr. Purna Bahadur Kshetri. It really helps us to develop conceptual understanding of circle theorems. I highly appreciate its animation and colorful applets. I like GeoGebra the most because it helps me to learn the concept in a very simple and understandable way. I had never used this app before and I would prefer to use it in future.”* |
| 7 | Suman Dhungana | *“As per my view GeoGebra is a software used to learn Mathematics. Since it is easy to operate and* |

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| | | *can be made attractive in many ways. It helps to solve doubts. It was first introduced to us by our mathematics teacher. Since I hadn't heard about it before and I had little expectations from it but after using GeoGebra, I found it is very useful beyond my expectation. We have learned five theorems of circles and three theorems of area of triangle and quadrilaterals using GeoGebra. It was fun reading through Geogebra and the attractive animations made it fun to read. Once ever sir made us go in front of class and explain what we had read. It was done on the last day of using GeoGebra to learn in class. Once there was animation on theorem when sir tried to explain front, I was the computer controller not understanding how to operate the animations started to move on their one with one click after that the class started to get interesting seeing that sir taught me how to operate that small incident helped me to remember the theorems and concept of the topic. I think using GeoGebra will make students more attentive."* |
| 8 | Sandesh Poudel | *"GeoGebra is an applet in which we can learn about different mathematics problems. I know the GeoGebra applet when our mathematics teacher teaches us about different theorems of the circle using GeoGebra. It is really helpful because of the different good techniques for learning. GeoGebra helps me to develop a conceptual understanding of circle theorems. What I like the most about GeoGebra is the unique idea for teaching and make good understanding of different mathematics topics. I like the colorful animations used in GeoGebra applets. The best part of GeoGebra is to make it* |

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| | | *clear about the topic and makes to learn easier. It is supportive for needy students as well and also help for long time memorization. I recommend and suggest to use other as well, and I will also use them in the future as well."* |
| 9 | Ashmi Bhandari | *"GeoGebra is an applet that is used for learning mathematical content like Algebra, Geometry, and Mensuration effectively and efficiently. I learned about the GeoGebra applet in my mathematics class while our respected Purna Bahadur Kshetri (PBK) sir was teaching. It was really helpful for learning. I absolutely agree that GeoGebra helps to develop conceptual understanding of circle theorems. I mostly like the animation of the applet. I highly appreciate the colorful applets and animations. The best part of GeoGebra is its feature as it helps me to clear all the doubts related to circle theorems. I didn't try to open any applets online or offline before, but it is very supportive for long-term memorization. I highly recommend my friends to use this applet. I am really thankful to my teacher, Purna sir, for letting me know about this applet."* |
| 10 | Anish K.C. | *"GeoGebra is one of the best applets ever I found. In this platform, we can learn mathematics and other subjects as well. When our math teacher teaches circle theorems using GeoGebra to us, I knew its best use in mathematics is very crucial. It is really helpful for students like me who are struggling to learn theorems like circles in a more clear way. I am really thankful for introducing GeoGebra in our class and making learning theorems so fun and interesting. I really appreciate the colorful and animated applets. I also like to* |

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| | | *recommend using this app in every mathematics class all over the globe.”* |
| 11 | Prajit Thada Magar | *“GeoGebra is an applet in which different types of files are uploaded with animation or 3D models related to the course book. I knew about it through my mathematics teacher Mr. Purna Bahadur Kshetri sir. It is really helpful for learning. I was a little bit quicker in learning after the use of GeoGebra. My learning has increased by 5 times as I feel because of GeoGebra. Animation and creativity are the things that I like about GeoGebra. The colorful applet and animation were fantastic. I would like to recommend using this applet for better learning and understanding mathematics.”* |
| 12 | Bishal Devkota | *“GeoGebra is really helpful for learning mathematics. I know about GeoGebra through our respected math teacher, Mr. Purna Bahadur Kshetri, sir. It is very helpful for us because it explains the theorems in detail and clearly. I agree that GeoGebra helps me to develop my conceptual understanding of circle theorems. I like the movable degree, circle, angle, arc, chord, and other parts in circle theorems through GeoGebra. That really surprised me, and having fun. I love the animation and colorful applets that really help to connect me to the theorems. I suggest to my brothers and sisters to use this application as I do.”* |
| 13 | Garima Bishowkarma | *“GeoGebra is an applet that I came to know about through my mathematics teacher. It was really helpful for us to learn mathematics in a very interesting way, with fun. GeoGebra helps us to develop conceptual understanding of theorems, and also, I believe I can memorize it for a long time as* |

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| | | *well. I really like the colorful applets and animations. I learned the theorems very clearly and effectively. It is supportive for weaker students as well. I highly recommend everyone to use it in their classroom for a better understanding of mathematics."* |

APPENDIX G

**Permission Letter**

Date: 24 November, 2024

To,

The Principal

Sainik Awasiya Mahavidyalaya

Phulbari, Pokhara -11

Subject: Request for Permission to Conduct Research in Class 10 (Section D)

Dear Sir,

I am writing this letter for formal permission to conduct a research study titled "USE OF GEOGEBRA IN ENHANCING STUDENTS' CONCEPTUAL UNDERSTANDING OF CIRCLE THEOREMS: AN ACTION RESEARCH STUDY." In Class 10 (Section D), I am the subject teacher of this class. In addition, I am also a student of M.Ed. Mathematics at Kathmandu University. Being a teacher at Sainik Mahavidyalaya, I am lucky to have the helpful surroundings that help me to have personal growth as well as to do academic research.

The main aim of my research is to improve students' knowledge of circle theorems through the use of ICT tools, especially the GeoGebra application. During a period of 15 days, I propose to use GeoGebra as part of my lessons for teaching circle theorems so that the students will learn hands-on and practice skills towards the attainment of the set learning outcomes. For purposes of data collection, I humbly seek your permission to:

*i) Recording of the speech and discussion of the learners in class during the lessons.*

*ii) Taking photographs of students interacting with the GeoGebra application during computer work.*

I promise that all data, such as recordings and photographs, collected will only be used for research purposes. It will stay anonymous and be shared only with my dissertation supervisor and used in my thesis. I will make sure not to further use or let anyone else see the data. Your approval would be a very big help in my trying to make a difference in the students who are in the school and in the teachers' work in our school. I promise I will not do anything that will hurt our school's good work or anyone's values.

Thanks for hearing what I asked for. Please let me know if there are any additional conditions or formalities I need to fulfill to proceed.

Sincerely yours,

……………………………

Purna Bahadur Kshetri,
G.T. Sainik Awasiya Mahavidyalaya, Pokhara
M.Ed. Scholar, 2023 batch

APPENDIX H

## Day-Wise Sample Reflections

**Day – 15 (Wednesday, December 11, 2024)**

On the 15th day, the last of my 15-day action research, I mainly concentrated on receiving good feedback and shared learning as to the extent to which the use of GeoGebra contributed to the teaching of circle theorems. The day consisted of delivering reflective feedback, having an in-depth interview, and writing down each step at the end, which states the result and focuses on all those who made this enriching process a reality through their gratitude.

We began the day with a short introduction, underlining that this session provided an avenue for all 32 of them to be frank in their experience. I had to mention that their reflection would go a long way in informing refinements for future teaching practices and evaluating the impact of the integration of ICT tools, notably GeoGebra, into the understanding of mathematical concepts.

**Collection of Feedback**

The feedback session started with the administering of anonymous questionnaires. While the students were filling these out, I could feel them go deep in reflection over their learning circle theorems. These questions dug into conceptual understanding, how GeoGebra supported them to visualize and enhance this, and how things might be improved. It feels, as I read through the responses, all positive about GeoGebra, to realize that a visualization and experimentation of geometric ideas go hand in hand. Indeed, students seemed to have appreciated most how it demystifies abstract theorems by allowing insight into concepts such as angles that are inscribed and how those relate to arcs.

The discussion of the group after the questionnaire was yet another enriching session. In the words of many students, these interactive lessons using GeoGebra really engage them and have helped in viewing the mathematical relationships in a much better way than ever before. In fact, some have shared that it is often difficult to translate this type of understanding, often gained visually, into written proofs. Some of the constructive feedback pinpoints certain areas of integration between ICT and traditional teaching where integration might further need balancing.

**In-depth Interviews**

The six selected students made very valuable contributions in their individual interviews. The stories of these students intensely brought out the different ways in which they experienced the action research project. One student related how GeoGebra overcame his fear of Geometry by allowing him to manipulate and observe the circle theorems in movement. Another student reflected on a moment of insight when, through the movements that occurred on the screen, he understood why opposite arcs are equal.

**Challenges Faced**

All the Challenges that students faced were shared, and we tried to resolve them. One of the students shared how, although she could always imagine in her mind the different logical flows line by line, with the traditional proof-writing format, she struggled to be sure of it. This made the need to bridge the conceptual and procedural gap in future teaching clear.

These insights have enriched my understanding of the students' learning needs and provided a clear direction for improvement.

**Closing and Gratitude**

The wrap-up session was an emotional wrap-up of this action research journey. During them students were writing down their thoughts, and it was clear that this project had really left its stamp. Appreciative words for engaging lessons and a now confident self to tackle geometry problems were simply satisfying to hear. I also made it a point to thank the whole school family from my heart for making the event happen. I thanked the 32 students for their active participation, candid feedback, and interest over those 15 days. First and foremost, I would like to extend my heartfelt gratitude to the six key participants who were open and intelligently contributed during the interviews. I am also deeply indebted to my colleagues, friends, and facilitators who helped me go through this torturous yet fascinating process. And last but not least, I express my deep gratitude to Kathmandu University for providing the opportunity for upgrading me on this transformation journey.

**Reflection as a Researcher and Teacher**

This action research has indeed become a deep learning curve for me as a researcher, a M.Ed. student, and a secondary mathematics teacher. The noticeable successes included an improvement in the understanding of circle theorems by students, which included their engagement in trying to visualize mathematical concepts with the use of GeoGebra. Yet, equally instructive were the challenges that pointed to the necessity to further strengthen procedural knowledge, besides attending to individual learning pace. For the next time, I suggest the combination of embedding the GeoGebra tool into scaffolder activities and guided practice. With this approach, modelers in the room should be able to see and speak about their mathematical thinking well.

As I sum up this work, I wish that good things are still to come in our way of trying to use tools to change how we teach math. It has made me stronger in my views of how good teaching should happen, and that student feedback becomes an important piece in coming up with good ways to teach. Once more, I want to thank all my really special students for making this time worthwhile and fruitful. We have just not learned about the circle theorems, but learnt what it takes to work as a team, be patient, and most of all, about having fun during the whole process of finding new ways to know mathematics.