

Implementation of GeoGebra in Mathematics Learning of Triangle Materials in Elementary Schools

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Abstract: This qualitative case study evaluates the integration of the GeoGebra dynamic mathematics software for Information and Communication Technology (ICT)-based instruction on fundamental triangle concepts at SDIT Praya in Central Lombok, Indonesia. Utilizing a qualitative research design, the study selected a key primary mathematics teacher as the principal informant to gain deep contextual insights. The researchers systematically collected data through comprehensive online interviews and analyzed them using the Miles and Huberman interactive framework, comprising rigorous data reduction, data display, and verified conclusion drawing. The empirical findings reveal that GeoGebra serves as an effective visualization tool that vividly illustrates abstract geometric properties, significantly improves elementary students' conceptual understanding of triangles, and fosters heightened classroom engagement and learning motivation. Furthermore, these results provide empirical support for Paivio's Dual Coding Theory by demonstrating how combining visual and verbal representations optimizes cognitive processing in dynamic geometry environments. However, the study also highlights critical implementation challenges, including technological constraints and variable digital literacy among educators. Consequently, the research concludes that targeted teacher professional development and robust technological infrastructure are vital prerequisites for sustaining ICT-integrated instruction, establishing a strong foundation for future technology-enhanced mathematics education.

Keywords: Elementary school, GeoGebra application, ICT, mathematics learning



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DOI: <http://10.30736/atl.v10i1.2689>

Received 29 December 2025, Accepted 25 September 2026, Published 28 September 2026

A. Introduction

In today's digital age, it is essential for elementary schools to implement engaging learning methods that capture students' attention, especially since they are still in the concrete operational stage of development (N. Lestari and Wirasty, 2019). They need learning experiences that are enjoyable, visual, and easier to understand (Buchori et al., 2023). When learning is presented in a monotonous manner, students tend to lose focus quickly, so teachers are required to design creative learning activities that can motivate students (Bedada and Machaba, 2022; Muslim et al., 2023). In this context, the selection of teaching media and strategies is an important factor that can affect student engagement and understanding of the material (Haleem et al., 2022; Listyaningrum et al., 2025). One

way to create more engaging learning is through the use of information and communication technology, which offers more realistic visualization capabilities, interactivity, and is tailored to the developmental needs of elementary school students (Miasari et al., 2022)

Mathematics, a subject that aims to develop logical thinking and problem-solving skills, often challenges many elementary school students (Gurmu et al., 2024). The abstract nature of mathematics makes concepts such as spatial figures, comparisons, and relationships between elements often difficult to understand if they are only conveyed through conventional methods such as lectures or the use of blackboards alone. For example, students often struggle to distinguish among types of triangles and understand the relationships between side lengths and angle measures (Dahal et al., 2022). A lack of variety in teaching methods can cause students to become bored quickly, have difficulty concentrating, and even develop a negative attitude toward mathematics (Chen, 2023), which may reduce their learning motivation and negatively affect their academic performance (Munyaruhengeri et al., 2023). This situation highlights the need for teaching media that can connect abstract concepts with concrete representations so that they are easier for elementary school children to understand (Agustina, 2024; Ji et al., 2024).

Advances in information and communication technology (ICT) in today's globalized world have created new opportunities to illustrate abstract mathematical ideas, such as triangles, through dynamic and interactive representations that are more comprehensible for elementary school students (Ramadhan et al., 2025). Therefore, incorporating ICT into educational activities has emerged as a crucial approach to improving both the learning process and its outcomes (Ardiansyah et al., 2021; I. Lestari and Pratama, 2020). Technology serves not only as a supporting tool, but also as an interactive medium that can create a more engaging, creative, and meaningful learning environment (Purwoto et al., 2022; Tang et al., 2023; Ziatdinov and Valles, 2022).

In geometry learning, technology is particularly important because it lets students observe shapes, relationships, and transformations dynamically, making geometric concepts easier to understand. Technology is highly relevant. Mathematics is often viewed as a difficult subject because it includes abstract concepts that require logical and analytical thinking skills (Simanjuntak et al., 2021). For most students, these abstractions are often confusing (Nurabadi et al., 2022) especially when teachers rely solely on conventional methods such as lectures or blackboards (Siregar, 2025). This highlights the need for innovative learning media that connect abstract concepts with real representations to facilitate students' understanding (Haikal et al., 2025; Rahman et al., 2021).

One popular ICT-based tool widely used in mathematics learning, particularly to help students understand triangle concepts through dynamic visualization, is GeoGebra (Ziatdinov and Valles, 2022). This dynamic mathematics software integrates geometry, algebra, calculus, and statistics in one interactive platform (Weinhandl et al., 2020). GeoGebra allows teachers and students to visualize mathematical concepts through

dynamic, interactive, and easily manipulated graphics (Jabnabillah and Fahlevi, 2023; Juandi et al., 2021). Through exploration with GeoGebra, students can discover the interrelationships between concepts, test hypotheses, and build mathematical understanding independently (Juandi et al., 2021; Reflianto et al., 2022; Santos-Trigo et al., 2021). This aligns with the Merdeka Curriculum, which emphasizes reasoning-based learning, creativity, and active student participation (Hamzah and Hidayat, 2022).

Using GeoGebra has been shown to provide several benefits, including facilitating understanding of abstract concepts, increasing learning motivation, encouraging critical thinking skills, and making learning more enjoyable (Awaji et al., 2025). In addition, GeoGebra can also support collaborative and individual learning, as students can learn independently or discuss in groups (Haikal et al., 2025). Thus, this application has great potential to improve the quality of mathematics learning in schools.

Previous research, particularly on spatial and geometric materials, has widely studied and shown positive contributions for both teachers and students. A study by Mokotjo (2023) shows that GeoGebra training can increase teachers' interest, knowledge, and ability to design ICT-based learning media. However, this study was limited to training activities and did not assess its actual application in the classroom. Furthermore, research by Jabnabillah & Fahlevi (2023) found that GeoGebra-based interactive media can strengthen students' higher-order thinking skills, problem-solving, and learning motivation. However, implementation is often hampered by device limitations and differences in teachers' ability to operate the application.

In contrast, research by Awaji et al. (2025) confirms that GeoGebra can facilitate the understanding of geometric concepts through dynamic visualizations that make it easier for students to explore abstract ideas. However, this research does not discuss in depth the obstacles to using GeoGebra in resource-limited schools. Overall, these findings show that although GeoGebra improves the quality of mathematics learning, its successful implementation is still strongly influenced by teacher readiness, device availability, and the actual conditions in each school.

Most previous studies have focused on developing learning media or improving student learning outcomes. At the same time, empirical research on the contextual implementation of GeoGebra in real classroom settings at the elementary school level remains limited. In addition, most of these studies were conducted at the secondary education level. In contrast, the application of GeoGebra in elementary schools with limited ICT facilities and infrastructure has rarely been studied. This gap indicates a need to explore how elementary school teachers implement ICT-based mathematics learning through the GeoGebra application in settings with limited technological facilities.

This research presents a unique perspective by delivering empirical insights into the contextual use of GeoGebra for teaching triangle concepts in elementary education. Unlike earlier studies that mainly focused on media creation or the evaluation of learning outcomes, this research highlights the difficulties educators encounter. It explores how teachers' preparedness affects the success of GeoGebra-based mathematics instruction.

This study aims to describe the implementation of GeoGebra in teaching triangle material at the elementary school level and identify the challenges teachers face during the learning process. Unlike previous studies that emphasized benefits or development, this paper highlights real challenges in the field. Thus, this study complements the existing literature with a more comprehensive perspective, especially in Indonesian schools with limited facilities. GeoGebra has been shown to facilitate the visualization of abstract mathematical concepts, such as triangles, in line with Paivio's Dual Coding Theory. However, implementation in schools often faces challenges, ranging from limited devices and differences in digital literacy skills to unstable networks. This study shows that with proper planning and teacher training, these obstacles can be overcome, thereby improving student understanding even when learning conditions are not always ideal.

B. Method

This research uses a qualitative methodology with a case study framework to investigate the implementation of technology-based mathematics education through the GeoGebra application at an Islamic elementary institution, SDIT Praya, in Lombok, Indonesia. A qualitative approach was chosen because it allows researchers to understand the processes, experiences, and dynamics that arise naturally in the learning environment. Meanwhile, case studies are used to examine a phenomenon in depth in a real context, so that researchers can obtain a detailed picture of teachers' practices in using GeoGebra, the responses shown by students, and various obstacles encountered during the learning process. Creswell and Creswell (Creswell, John W.; Creswell, 2018) state that case studies are used to comprehensively describe and analyze an event, process, or activity in a real environment, resulting in a deep understanding. This approach helps researchers examine in detail how GeoGebra is applied in learning, including student responses and obstacles that arise during the process.

The study involved one Grade IV mathematics teacher at SDIT Anak Soleh Praya, Central Lombok, Indonesia. The participant was selected through purposive sampling because the teacher had direct experience implementing ICT-based mathematics instruction using the GeoGebra application and taught triangle material in the Grade IV curriculum. This participant was considered appropriate because of their practical experience in integrating GeoGebra into classroom instruction, enabling the researcher to obtain in-depth information on lesson planning, classroom implementation, learning barriers, and evaluation practices. This study examined the implementation of GeoGebra in mathematics learning, focusing on lesson planning, classroom implementation, learning barriers, and evaluation.

This research was conducted at SDIT Anak Soleh Praya, Central Lombok, Indonesia, during the odd semester of the 2025/2026 academic year. Data were collected through a semi-structured online interview conducted via Google Meet with the selected Grade IV mathematics teacher (see Figure 1). The interview aimed to obtain in-depth information regarding lesson planning, the implementation of GeoGebra in teaching triangle material, learning barriers, and evaluation practices. The research instrument

consisted of a systematically developed semi-structured interview guide to ensure the relevance and accuracy of the data collected.

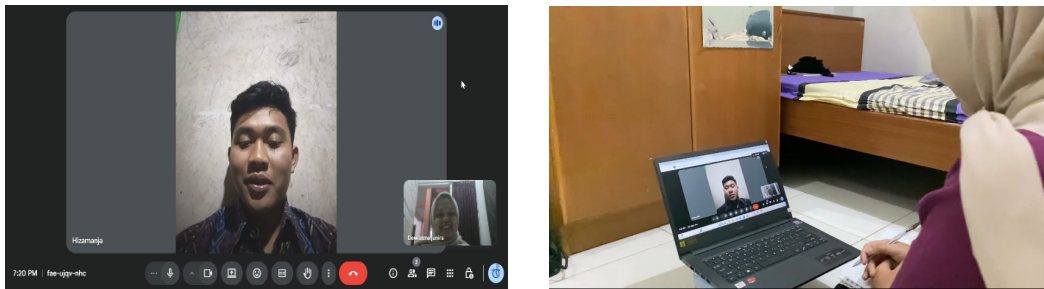


Figure 1. Online Interview Documentation via Google Meet

The data sources in this study include primary and secondary data, and the researchers triangulated the data by comparing interview results with supporting documents and relevant literature to ensure consistency in the findings. Primary data were obtained through in-depth interviews with mathematics teachers, who provided direct information about the planning process, implementation, and obstacles that arose during the use of GeoGebra in learning. This study also used lesson plans prepared and used by teachers as supporting material to understand the learning flow applied. Meanwhile, the researchers obtained secondary data from various literature sources, including scientific articles, books, and previous studies on the use of technology in elementary school mathematics learning. To ensure data validity, this study used data triangulation by comparing interview results with lesson plan documents and relevant literature.

According to Creswell (2018), qualitative data analysis occurs continuously from data collection to conclusion drawing. The interview transcripts were coded and grouped into four main themes: lesson planning, learning implementation, learning obstacles, and learning evaluation. The collected data were analyzed using Miles and Huberman's interactive analysis model, which includes three main stages: data reduction, data presentation, and conclusion drawing.

Data Reduction

In the initial stage, researchers processed the data by sorting it, focusing on relevant information, and simplifying the interview results. The data were selected based on their relevance to the research objectives and grouped into four main themes: lesson planning, the implementation of GeoGebra, learning obstacles, and learning evaluation. In this stage, the study focused on information related to lesson planning, the implementation of GeoGebra, and the obstacles faced by teachers.

Data Presentation

After reduction, the data were organized into coherent descriptions so patterns and findings could be clearly seen. This presentation made it easier for researchers to understand how GeoGebra was applied in the learning process more systematically.

Conclusion Drawing

The final stage involves formulating the meaning and core findings based on the data presented. The conclusions were validated by comparing the interpreted findings with the original interview transcripts and supporting documents to ensure that the results obtained were accurate, valid, and consistent. The conclusions were then reviewed by comparing them with the original data to ensure that the results obtained are accurate, valid, and consistent.

C. Results and Discussion

Results

Lesson planning

Based on the interview findings, the teacher prepared thoroughly before implementing GeoGebra-assisted mathematics instruction. According to the participant and the documentation in Figure 2, the planning process included preparing lesson plans, designing GeoGebra-based learning media, and preparing technological facilities such as laptops, projectors, and GeoGebra files containing various representations of triangles. The participant's account indicates that lesson planning involved not only administrative preparation, but also pedagogical and technological considerations intended to support students' understanding of geometry.

The participant explained: "I prepared a lesson plan and created media using the GeoGebra application to help students understand the types and properties of triangles more easily". The interview results indicated that teachers chose GeoGebra intentionally because its dynamic visualization capabilities let them present abstract mathematical ideas in a more tangible, interactive, and meaningful way. This finding implies that incorporating GeoGebra into lesson planning aimed not only to introduce digital technology into classroom teaching but also to enhance students' comprehension of geometric concepts through visual exploration. Consequently, the lesson planning showed the teacher's intention to align instructional goals, learning resources, and students' learning needs to create an engaging mathematics learning environment.

According to the participant, the teacher used several GeoGebra features, including the Slider, Polygon, Segment, and Angle tools, to demonstrate changes in triangle shapes, side lengths, and angle measurements dynamically. According to the participant, these features helped students observe geometric relationships through visual representations rather than relying solely on verbal explanations. The participant also reported that automatic labels displaying side lengths and angle measurements helped students identify the characteristics of different types of triangles. The participant stated, "These features help students see the differences in triangle shapes directly". This statement suggests that GeoGebra gave students opportunities to explore mathematical concepts through dynamic visualization. The participant's account suggests that the planned integration of GeoGebra was intended to enhance the presentation of learning materials and support students' understanding by representing abstract mathematical ideas visually and dynamically. Consequently, the participant's account suggests that the planned use of

GeoGebra was intended to create a more interactive and meaningful mathematics learning process.

LESSON PLAN	
EDUCATION SECRETARY	: SDIT ANAK SHOLEH PRAYA
SUBJECT	: MATHEMATICS
MATERIAL	: Triangle
PHASE/GRADE	: B/4
SEMESTER/T.P	: 2/ 2025
TIME ALLOCATION	: 8 meetings x 4 JP

A. IDENTIFICATION

1. Student Identification

- Initial Knowledge:**
Students have become familiar with simple flat buildings and their characteristics.
- Interests:**
Students are interested in learning that uses images, visual media, and observation activities.
- Background**
- Learning needs**
Students need learning that helps understand the concept of triangles through clear examples and visualizations.

2. Subject Matter

Area and Volume Measurement

3. Graduate Profile Dimensions

√ Faith and Piety towards God Almighty	√ Critical Reasoning	√ Collaboration	Health
Kewargaan	√ Creativity	√ Independence	Communication

B. LEARNING DESIGN

1. Learning Outcomes

Students are able to recognize, compare, and explain various forms of simple flat buildings and identify their characteristics and properties.

2. Learning Topics

- Definition and elements of triangles.
- Types of triangles based on the length of the sides.
- Types of triangles based on the size of the angle.
- Properties and shape of triangles.
- Observation of changes in the shape of triangles using GeoGebra.

C. LEARNING EXPERIENCE

Learning Objective 1 : Recognize and understand the properties of triangles through the use of the GeoGebra application

4th meeting (2 minutes) x 35

Learning Goal Achievement Indicators:

1.2. Identify the shape and properties of triangles through observation using the GeoGebra application

1. Initial Activities

Conscious, Meaningful, Joyful

- The teacher opens the lesson with greetings, joint prayers and friendly greetings to create a positive atmosphere
- Teacher perception of triangle shapes found in daily life
- The teacher conveyed the learning objectives about the shape and properties of triangles using the GeoGebra application

2. Core Activities

Meaningful, Joyful

- Study**
Students observe an example of a triangular shape displayed by the teacher through a projector screen
The teacher explained the meaning of triangles and the parts of triangles
Students observe the display of the GeoGebra application that teachers use to show the shape of a triangle
- Exploration**
Teachers use the GeoGebra application to display and change the shape of triangles using the Slider, Polygon, Segment and Angle features
Students observe changes in shape, side length and large triangle angles displayed through a projector
Students ask questions and discuss the changes that occur in the triangle
- Formulate**
Students discuss the results of observations about the shape and properties of triangles
Students deduce the relationship between the length of the sides and the magnitude of the angles on the triangle
The teacher guides the students to formulate conclusions about the properties of triangles
- Presentation**
The group representative presented the results of his observations and conclusions
Other groups provide responses or questions
The teacher provides reinforcement and clarification of concepts

Closing Activities

- Worldly**
Students understand that triangular shapes can be found in various objects and activities in daily life.
- Ukhrani**
Teachers instill the value of precision, responsibility and gratitude in learning the regularity of form and size as part of the learning of a Muslim.

LEARNING ASSESSMENT

Initial Assessment

3. Cross-Disciplinary

Indonesian Language Subject (understanding the reading text in a discourse or fictional story)

4. Learning Objectives

- Explain the meaning of triangles.
- Identify the sides, corners, and corners of the triangle.
- Identifies the type of triangle based on the length of the sides.
- Identify the types of triangles based on the size of the angle.
- Observing changes in the shape of triangles through GeoGebra media.
- Explain the results of observations about the shape and properties of triangles.
- Convey the results of observations and discussions orally.

5. Learning Goal Achievement Indicators

- 1.1. Explain the meaning and elements of triangles.
- 1.2. Correctly identifying the shape and properties of the triangle
- 2.1. Explain the types of triangles based on sides and angles
- 2.2. Identify types of triangles through observation using the GeoGebra application
- 3.1. Explain the relationship between the length of the sides and the magnitude of the angles on the triangle
- 3.2. Observing changes in the shape of triangles through the GeoGebra app
- 4.1. Explain the properties of triangles based on observations
- 4.2. Convey the results of observations about the properties of triangles through discussion

6. Pedagogical Practice

Learning Model : problem based learning dan cooperative learning
Learning Methods: demonstrations, group discussions, questions and answers and assignments

7. Learning Partnerships

Principal
Parents

8. Learning Environment

Physical environment: classroom and outdoor classroom
Virtual environment: onboarding screen and dashboard screen
Teaching culture: encouraging positive **collaboration** through active **communication** by developing the habit of **critical thinking** so as to come up with solutions to a problem.

9. Digital Utilization

Geogebra applications and other applications that are in the direction of triangular matter

Frequently asked questions

Process Assessment

Observation and demonstration

Final Assessment

Written and practice tests

Know
Principal

of Mathematics Teacher School


Dian Marlina, S.Pd.

Muhammad Hizbul Wathoni, S.Pd

Figure 2. Lesson Plan for Triangle Learning Using GeoGebra

Implementation of learning

The interview findings revealed that GeoGebra-assisted mathematics learning used dynamic visualization to support students' understanding of triangle concepts. During the lesson, the teacher introduced the learning material by displaying the GeoGebra application using a projector, allowing all students to observe the visualization simultaneously. The teacher then explained the characteristics and properties of triangles while demonstrating how changes in side lengths and angle measurements affected triangle shape using the Slider, Polygon, Segment, and Angle tools in GeoGebra. According to the participant, *"I display the GeoGebra application through a projector, then show the changes in the shape of the triangle when its sides or angles are changed, and the students observe the process."* Throughout this stage, students observed the visualization, followed the teacher's explanations, and focused on identifying the relationships among the elements of triangles presented through the application. These findings indicate that GeoGebra enabled abstract mathematical concepts to be presented through dynamic visual representations, making the learning process more interactive and easier for students to understand.

Table 1. Empirical Findings on the Classroom Implementation of GeoGebra-Assisted Mathematics Learning

Implementation Aspect	Empirical Findings from the Interview
Instructional media	The teacher used the GeoGebra application as the primary instructional medium and displayed it through a projector so that all students could observe the visualization simultaneously during the mathematics lesson.
Teacher's instructional practices	The teacher explained the characteristics and properties of triangles while demonstrating changes in side lengths and angle measurements using the Slider, Polygon, Segment, and Angle tools available in GeoGebra.
Students' learning activities	Students observed the GeoGebra visualization, followed the teacher's explanations, and actively asked questions while observing the changes in triangle shapes and their properties during the lesson.
GeoGebra features utilized	The teacher used the Slider, Polygon, Segment, and Angle tools to visualize triangle concepts and demonstrate relationships among triangle elements through dynamic representations.
Classroom interaction	Classroom interaction occurred through teacher explanations, GeoGebra demonstrations, and students' questions about the visualizations presented during the learning process.
Evaluation practices	The teacher evaluated students' understanding by observing their ability to identify different types of triangles and explain their characteristics based on the visualizations presented during the lesson.

After the visualization phase, the instructor continued the lesson by facilitating a classroom discussion, addressing students' questions, and clarifying the concepts shown in GeoGebra. The interview findings revealed that students became more focused and

actively participated by asking questions while observing the visualizations. At the end of the lesson, the teacher evaluated students' understanding by observing their ability to identify different types of triangles and explain their characteristics based on the visualizations presented during the learning activities. Overall, implementing GeoGebra-assisted mathematics learning shows that integrating dynamic visualization into classroom instruction supported students' conceptual understanding while encouraging greater participation throughout the learning process. To summarize the implementation findings, Table 1 presents empirical findings from the interview, including the instructional media used, teacher activities, student participation, GeoGebra features used, classroom interaction, and evaluation practices. The table summarizes the participant's actual classroom practices rather than an idealized instructional sequence.

Table 1 summarizes the empirical findings obtained from the interview regarding the implementation of GeoGebra-assisted mathematics learning. The findings indicate that GeoGebra supported the visualization of triangle concepts through teacher demonstrations, while students actively observed the learning process and participated by asking questions. Overall, these findings reflect the actual classroom practices reported by the participant during mathematics instruction.

Learning obstacles

Although the implementation of ICT-based learning using GeoGebra generally went well, the participant reported several challenges. Based on the interview findings, the identified barriers included limited school infrastructure, unstable internet connectivity, and the need to improve teachers' digital competence further. One main challenge was the limited availability of projectors and other technological devices in classrooms, which reduced flexibility in using GeoGebra during mathematics lessons. Teacher H stated, *"The number of projectors is limited, not all classrooms have complete equipment, and the internet connection is unstable."* Unstable internet access occasionally disrupted the implementation of GeoGebra, particularly when online features were required, requiring the teacher to adjust the learning process according to the available facilities. In addition, the participant acknowledged the need to improve further digital skills in operating GeoGebra and designing more engaging visual learning materials appropriate for elementary school students. To address these challenges, the teacher prepared the available equipment before the lesson, adapted the instructional process to the school's existing facilities, and recognized the need to improve their ability to use GeoGebra continuously. The results indicate that effective use of GeoGebra relies not just on having the necessary technological resources but also on teachers' skills in modifying their teaching methods to accommodate current constraints.

Learning evaluation

The participant evaluated the implementation of GeoGebra-assisted mathematics learning primarily through observations of students' responses and participation during classroom activities. Based on the interview findings, the evaluation focused on students' enthusiasm, classroom participation, and their ability to respond to the teacher's questions

after observing the GeoGebra visualizations. Teacher H stated, “*Students are more enthusiastic and quickly understand the differences between triangles*”. The participant mentioned that the question-and-answer session flowed well and that the students were able to describe the characteristics of triangles after the learning activities. These findings imply that, according to the participant, GeoGebra enhanced student engagement and their ability to identify and articulate triangle characteristics during the lesson. However, no formal assessment tools, student work samples, or structured evaluation data were available to measure students’ learning outcomes objectively. Therefore, these findings should be interpreted as the participant’s professional reflections based on reported classroom experiences rather than as objective evidence of measurable learning improvement. The interview results indicated that, according to the teacher’s observations, GeoGebra-supported mathematics learning appeared to help students recognize and explain triangle characteristics through interactive and dynamic visual presentations.

Discussion

This finding aligns with Dual Coding Theory proposed by Allan Paivio (1986), which explains that information is easier to understand and remember when conveyed through two processing channels: verbal (spoken or written language) and nonverbal (visual representation). In this learning process, teachers combined verbal explanations of triangle concepts with interactive visualizations using GeoGebra. The synergy between these two forms of representation helped students build two cognitive codes in their memory, strengthening understanding and retention of the material.

In addition, the increase in student enthusiasm and participation during the learning process aligns with the basic assumptions of Dual Coding Theory proposed by Paivio (1986), which states that presenting information visually can strengthen students’ focus and cognitive engagement. Although students do not interact directly with the GeoGebra application, the attractive, interactive visual display still helps them connect abstract concepts with concrete representations. Thus, applying GeoGebra in teaching triangle material not only strengthens students’ conceptual understanding but also increases learning motivation by simultaneously activating verbal and visual cognitive systems, as described in Dual Coding Theory (Paivio, 1986).

Planning

The findings suggest that careful instructional planning supported effective GeoGebra integration. Before the lesson, the teacher prepared the lesson plan, selected GeoGebra features aligned with the learning objectives, and adjusted activities to students’ characteristics and learning needs (Bueno et al., 2021). This indicates that the effectiveness of GeoGebra depends not only on the software itself but also on how teachers integrate its features into instructional design (Bretscher, 2023). In line with the Technological Pedagogical Content Knowledge (TPACK) framework, the teacher’s selection of the Slider, Polygon, Segment, and Angle tools shows an effort to connect technology with the mathematical content and instructional objectives (Yildiz and Arpaci,

2024). Thus, careful planning helped ensure that GeoGebra was used purposefully to support the teaching of triangle characteristics and properties (Kartal and Çınar, 2024).

Implementation

The findings indicate that GeoGebra's dynamic visualization supported students' understanding of triangle concepts by making changes in shape, side lengths, and angle measures easier to observe (Sieng and Thai, 2024; Zhang et al., 2025). Through teacher-guided demonstrations, students could directly observe the relationships among these geometric elements rather than relying solely on verbal explanations (Birgin and Uzun Yazıcı, 2021). This finding supports Dual Coding Theory, as verbal explanations were combined with visual representations to facilitate the understanding of abstract concepts (Paivio, 1986). It is also consistent with Piaget's view that elementary school students benefit from concrete and visual representations. More importantly, GeoGebra's dynamic features enabled the teacher to show changes in triangle properties visibly and immediately, helping students recognize relationships among geometric elements (Gurmu et al., 2024; Kohen et al., 2022). Thus, GeoGebra's contribution in this study lies not merely in providing visual representations, but in making mathematical relationships more observable during instruction.

Obstacles

The results indicate several challenges affecting GeoGebra implementation, including limited access to devices, unstable internet connectivity, and differences in students' digital abilities. These conditions suggest that the effective use of GeoGebra depends not only on the application itself but also on the technological and learning environment in which it is implemented (Agyei et al., 2022). Such challenges are consistent with broader barriers reported in technology-enhanced mathematics education, particularly those involving inadequate infrastructure and varying levels of digital competence (Yuan et al., 2023). In this context, these limitations did not prevent the teacher from using GeoGebra but influenced how the technology was integrated into classroom instruction (Benning et al., 2023). Therefore, meaningful technology integration requires appropriate technological support and consideration of students' digital abilities.

Evaluation

The evaluation of the learning process indicated positive changes in students' motivation, classroom participation, and conceptual understanding during the use of GeoGebra (Zakaria et al., 2024). Students showed greater enthusiasm and became more active in asking and responding to questions throughout the lesson. This increased classroom engagement is consistent with Hamzah & Hidayat (2022), who reported that GeoGebra use was associated with students' conceptual understanding and engagement in mathematics learning. This result aligns with Jabnabillah & Fahlevi (2023), who found that GeoGebra generated positive student responses and supported students' interest in learning mathematics. Similar outcomes have been reported in recent studies, suggesting that GeoGebra can facilitate students' conceptual understanding when its visual and dynamic features are incorporated into purposeful learning activities (Birgin and Uzun

Yazıcı, 2021; Bullock et al., 2021). Thus, the positive responses observed in this study may be associated with using GeoGebra to make mathematical relationships more visible while encouraging students to participate in classroom discussions.

Research Contributions and Limitations

This study offers a contextual perspective on using GeoGebra in elementary mathematics instruction, particularly for teaching triangle concepts. Although researchers have widely investigated GeoGebra in mathematics education, research on its implementation in primary school contexts remains comparatively limited (Yunianto et al., 2025). In this respect, the present study adds to the existing literature by examining how a teacher planned and implemented GeoGebra during actual classroom instruction and by identifying the practical challenges encountered during its use (Romero Albaladejo and García López, 2024). Rather than assessing GeoGebra primarily through learning outcomes, this study provides contextual insight into its integration within teacher-guided mathematics instruction. However, the study involved only one mathematics teacher as the main informant and did not include direct classroom observation or students as primary data sources. Therefore, interpret the results as contextual insights from the teacher's perspective, not as generalizable findings for elementary mathematics classrooms.

D. Conclusion

The results demonstrate that GeoGebra can support the teaching of triangle concepts in elementary mathematics through dynamic visual representations that make geometric relationships easier for students to observe and understand. Its implementation also indicates that meaningful use of GeoGebra requires careful instructional preparation, particularly in selecting technological features that align with learning objectives and students' needs. From a theoretical perspective, the research provides contextual insight into integrating dynamic visualization into teacher-guided mathematics instruction at the elementary school level. From a practical perspective, the findings emphasize the importance of teachers' instructional planning and adequate technological support in facilitating GeoGebra use. Nevertheless, the study relied on one mathematics teacher and did not include direct classroom observation or students as primary data sources. Consequently, the results provide contextual insights from the teacher's perspective and have limited transferability to other elementary school settings. Future research should involve broader participation, incorporate direct classroom observations and student perspectives, and examine GeoGebra implementation across different elementary mathematics learning contexts.

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