

The Impact of Teaching Strategies on Students' Understanding of Circle Theorems

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DOI: <https://doi.org/10.51584/IJRIAS.2026.11080110>

Received: 30 April 2026; Accepted: 13 June 2026; Published: 13 September 2026

ABSTRACT

This action research focused on improving the understanding of Circle Theorems among Grade 11 students. Geometry is a core area of secondary school mathematics, yet many learners experience ongoing difficulties when working with geometric ideas, especially in reasoning and application. The purpose of this study was to examine the use of selected teaching strategies and visual aids to support students' understanding of Circle Theorems. The study used a mixed-methods approach. A pre-test and a post-test were used before and after the intervention to obtain quantitative information about students' performance. Qualitative information was gathered through classroom observations and semi-structured interviews. For quantitative analysis, descriptive statistics, a paired-samples t-test, the Wilcoxon Signed-Rank Test, and effect size measures were applied. The qualitative information was examined thematically to understand changes in students' learning behavior and the difficulties they encountered during the intervention. The findings showed that students' understanding of Circle Theorems improved after the intervention. Many students demonstrated better reasoning and were more confident when explaining geometric ideas. Classroom observations and interview data showed that students slowly shifted away from rote procedures and developed a better understanding of how concepts were connected, while the study also noted several changes during the intervention. These included limited lesson time, lack of access to digital devices, difficulty adjusting to new learning approaches, and anxiety when solving problems that required several steps. Based on these findings, the study concludes that the use of carefully planned teaching strategies and visual aids can support students' learning of Circle Theorems. Addressing the identified challenges may help to improve the effectiveness of geometry teaching in similar classroom contexts.

Keywords: circle theorems, inquiry- based learning, visualization, hand-on activities, student understanding

INTRODUCTION

Mathematics is a core subject in the Sri Lankan school system. It has a strong impact on students' academic progress and future prospects. At General Certificate of Education

(Ordinary Level), students' performance in mathematics plays a major role in determining whether they can continue their studies at a higher level. Because of this, students should not only prepare for the examinations but also develop a clear understanding of concepts.

Geometry is a key area of mathematics. It is different from other subjects because it requires students to think carefully and connect concepts. Students are required to understand diagrams, identify relationships, and explain their reasoning step by step. This is not always easy, as many students find geometry more challenging than other areas of mathematics.

Circle theorems are often considered one of the more difficult topics in geometry. Many students struggle to see how the different parts of a circle are connected. Instead of understanding the ideas, they often try to memorize the theorems. This becomes a problem when questions are slightly changed or presented in a different way. In

such cases, students find it difficult to apply what they have learned. Sometimes they are able to reach an answer, but they cannot clearly explain the steps. Questions that require justification or proof are especially difficult for them.

Another reason for this difficulty is the way the subject is usually taught. In many classrooms, teaching is largely based on explanation and practice. Teachers often focus on past exam questions. This helps students become familiar with the examination format, but it does not always lead to a deeper understanding. Due to time constraints and a heavy syllabus, there is little opportunity for discussion or exploration. As a result, students have fewer chances to ask questions, test their ideas, or develop their thinking. Therefore improving students' conceptual understanding in geometry is important.

In recent years, there has been a growing focus on student-centered teaching methods. These include inquiry-based learning, the use of visual aids, and hands-on activities. Such approaches encourage students to take an active role in their learning. They can explore ideas, observe methods, and make connections. Simple materials or tools such as GeoGebra can also help students see relationships more clearly. This can support better understanding, especially in geometry.

However, in the Sri Lankan context, classroom-based research on the use of these strategies for teaching circle theorems is still lacking. Many schools continue to follow traditional methods. There is a need to explore whether alternative approaches can be used effectively, especially in classrooms with limited resources.

In response to this issue, the present study was conducted to examine possible solutions in a real classroom context. It focused on a group of eleventh grade students who showed low performance in circle theorems. The study examines how selected teaching strategies, including inquiry-based learning, visualization, and hands-on activities, affect

students' understanding. The study aims to provide practical insights that can support the teaching of geometry in similar classroom settings, considering both examination results and classroom experiences.

LITERATURE REVIEW

The teaching and learning of geometry, especially Circle Theorems, has been widely discussed in mathematics education. Many students continue to face difficulties when working with geometric concepts, mainly when they are required to apply ideas in new situations. Geometry is often seen as more challenging than other areas of mathematics because it involves analyzing diagrams, identifying relationships, and thinking logically. In classroom practice, it is often observed that students depend more on memorization than real understanding. Because of this, they find it difficult to use theorems when questions are presented in a different form. As a result, their performance, especially in proof based questions, remains low.

One theory that is often used to explain how students learn geometry is Van Hiele's theory of geometric thinking. It suggests that students do not learn geometry all at once, but gradually move through different levels. These levels include visualization, analysis, informal deduction, and formal deduction. At the beginning, students usually recognize shapes based on their appearance. However, they may not fully understand the properties or relationships within those shapes. As they continue learning, they start to analyse ideas more carefully and make connections between them. With further progress, they are able to develop logical arguments and understand proofs. Even so, many students remain at the lower levels, especially when they do not receive enough support during learning. As Lwanga (2023) pointed out, teaching that is structured according to Van Hiele's levels can improve students' problem solving skills and engagement. At the same time, such approaches often require careful planning and more time. This shows that well-organized teaching plays an important role in helping students develop their understanding of geometry.

Vygotsky's Social Development Theory is also useful in understanding how students learn mathematics. Learning, according to this view, does not happen alone. It develops through interaction with others and through

support given during the learning process. The idea of the Zone of Proximal Development explains this further. It shows that students can reach a higher level of understanding when they receive guidance from a teacher or work together with their peers. In geometry lessons, this can be seen when students discuss ideas, share their thinking, and try to solve problems together. Such situations help them to think more clearly. Gradually, their reasoning improves. When students are given chances to explain their ideas and listen to others, they begin to understand concepts in a deeper way.

APOS theory provides another way of looking at how students build mathematical understanding. It explains that learning develops step by step, moving through stages such as action, process, object, and schema. At first, students may only follow steps without much thinking. Gradually, they begin to understand what they are doing. Later, they are able to connect ideas and use them in different situations. This is important in topics like Circle Theorems, where students need to link several ideas together. Learning, therefore, should not stop at memorizing rules. It should help students see connections and use concepts in problem solving. As noted by Enoch (2024), students who were able to apply the correct theorems performed better in circle geometry. This clearly shows the value of conceptual understanding.

Several empirical studies have shown the value of student-centered approaches in learning geometry. For example, Mifetu (2023) found that activity-based learning helped improve students' problem-solving skills and their understanding of geometric concepts. Students were more involved during lessons, and this seemed to support their learning. In a similar way, Assan-Donkoh et al. (2019) reported that cooperative learning had a positive effect on students' achievement and confidence. When students worked together, they were more engaged in discussions and problem-solving activities. This kind of involvement seems to support better understanding. Overall, these findings show that when students take an active role in learning, their understanding of geometry can improve.

The use of visualization tools, particularly GeoGebra, has been widely discussed in geometry education. Many researchers have shown that these tools can support students' understanding. For example, Chimuka (2017) found that students who used GeoGebra performed better and developed stronger visualization skills than those taught through traditional methods. In a similar way, Zakelj and Klancar (2022) reported that digital tools helped students solve problems more effectively and understand geometric relationships more clearly. Nxumalo et al. (2022) also pointed out that features such as dynamic movement and visual representation make it easier for students to see and understand concepts. Overall, these findings highlight the important role of visualization in learning geometry.

However, in the Sri Lankan context, only a limited number of studies have looked directly at teaching Circle Theorems using these methods. In many classrooms, traditional methods are still commonly used. This is mainly because of syllabus pressure, large class sizes, and limited resources. As a result, students do not always get the chance to experience participatory or meaningful learning. In practice, this creates a gap between what research recommends and what actually happens in classrooms. These findings highlight the importance of using effective teaching strategies to improve students' understanding of geometry.

For this reason, it is important to look at how these teaching strategies work in real classroom situations, especially where resources are limited. In this study, an attempt was made to examine how inquiry-based learning, visualization tools, and hands-on activities influence students' understanding of Circle Theorems. The focus was mainly on low achieving students. The aim was to gain some practical ideas that can help teachers improve the way geometry is taught.

METHODOLOGY

This study was carried out using an action research design to examine how selected teaching strategies influence students' understanding of Circle Theorems. Action research was considered suitable for this study. It allows the teacher to identify a classroom problem and try out possible solutions. At the same time, the teacher can observe

changes in students' learning. It also provides an opportunity to reflect on teaching practices. Based on this, adjustments can be made during the process.

The study took place in a secondary school in Sri Lanka. The participants were Grade 11 students who were preparing for the G.C.E. (O/L) examination. From this group, ten low-achieving students were selected through purposive sampling. Their selection was based on their third term mathematics examination results. Most of them had scored between 30 and 40 marks. They were identified as students who needed additional support, especially in understanding certain theorems and dealing with proof based questions.

Both quantitative and qualitative methods were used to collect data. At the beginning, a pre-test was given to identify students' initial level of understanding. After the intervention, a post-test was conducted. This was done to see whether there was any improvement. Classroom observations were also carried out during the lessons. These helped to understand how students responded and participated. In addition, semi-structured interviews were used to gather students' views about the learning process. Students were also asked about the challenges they faced and the strategies that helped them.

The intervention was conducted over several weeks and was organized in stages based on

Van Hiele's levels of geometric thinking. At the first stage, the focus was on visualization. Students were introduced to circle concepts using simple materials, such as everyday circular objects and basic diagrams.

In the next stage, attention shifted to understanding properties and relationships within the circle. Visual tools like GeoGebra were used to support this learning. During the third stage, students worked with guided worksheets. These helped them see how different theorems are connected. In the final stage, students were encouraged to move towards more formal reasoning. They also tried to solve proof based problems with less help.

Through these stages, the aim was to improve students' understanding step by step.

During the intervention, different teaching strategies were used. These included inquiry-based learning, visualization, and hands-on activities. Students were encouraged to ask questions, share their ideas, and take part actively in lessons, rather than only memorizing steps. Since the school did not have much access to advanced technology, simple teaching aids and available resources were mainly used.

For data analysis, the results of the pre-test and post-test were examined using basic statistics such as mean and standard deviation. A paired-sample t-test was used to check whether there was a significant difference between the two sets of scores. In addition, the Wilcoxon Signed-Rank Test was used to support the results.

Qualitative data from observations and interviews were also analyzed. A thematic approach was used to identify common patterns related to students' understanding, participation, and learning difficulties.

Ethical aspects were also considered. Permission was taken from the school principal, and students participated voluntarily. Their identities were kept confidential, and the information collected was used only for research purposes. Care was taken to ensure that the study did not disturb normal classroom activities. The study followed ethical guidelines to ensure fairness and confidentiality.

RESULTS

Overall Improvement in Students' Performance

To examine the impact of the intervention, students' performance in the pre-test and posttest was compared. The results showed a clear improvement after the intervention.

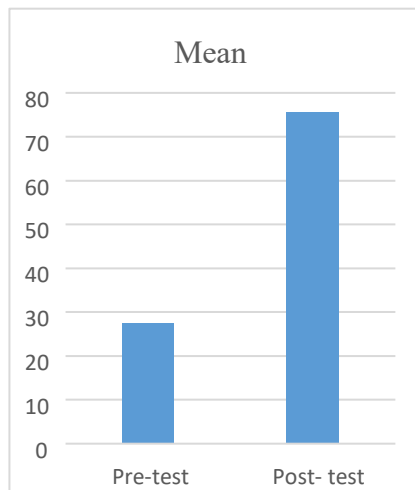
Table 1 Summary of Pre-test and Post-test Scores

Measure	Pre-test	Post-test
N	10	10
Mean	27.4	75.5
Standard Deviation	4.99	6.69
Mean Difference	48.1	
t-value	-24.57	
p-value	< 0.001	
Effect Size (Cohen's d)	8.15	

The results indicate a substantial improvement in students' performance following the intervention. The mean score increased from 27.4 in the pre-test to 75.5 in the post-test.

This shows a large gain in students' understanding of Circle Theorems. The paired-sample t-test revealed that the difference between the pre-test and post-test scores was statistically significant ($p < 0.001$). In addition, the effect size was extremely large ($d = 8.15$), indicating that the intervention had a strong impact on students' learning.

Figure 1: Comparison of pre- test and post- test mean scores



Stage- wise Progress of Students

To further understand students' progress, performance across different stages of the intervention was examined.

Table 2 Stage-wise Mean Scores

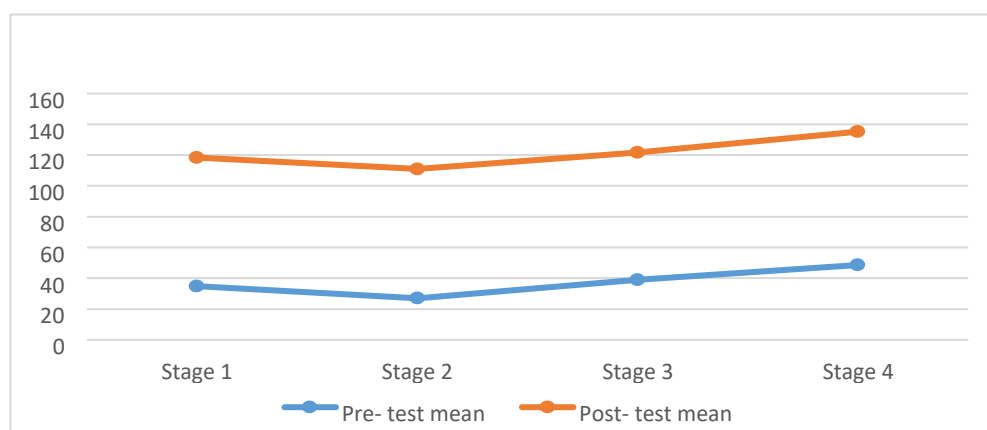
Stage	Pre- test mean	Post- test mean
Stage 1	35	83.3
Stage 2	27	84

Stage 3	39	82.8
Stage 4	48.6	86.6

The stage-wise results indicate a consistent improvement in students' performance across all stages. In each stage, the post-test scores were higher than the pre-test scores. This difference was clearly noticeable. In Stage 1, students showed better understanding. They were able to identify and visualize basic circle concepts more effectively. Overall, this stage helped them build a stronger foundation for further learning. In Stage 2, their ability to understand relationships within the circle improved further. During Stage 3, students demonstrated better understanding of theorem connections. By Stage 4, students were able to apply formal reasoning and solve proof based problems more effectively.

Overall, the results suggest that students' understanding developed gradually as they progressed through the stages.

Figure 2: Stage-wise Comparison of Pre- test and Post- test Mean Scores



4.3 Students' Learning Experience (Qualitative Findings)

Table 3 Summary of Qualitative Findings

Theme	description
Increased participation	Students became more active in discussions and classroom activities
Better understanding	Students showed improved ability to explain concepts and relationships
Increased confidence	Students felt more confident in solving geometry problems
Remaining difficulties	Some students still faced challenges in proof based questions

The qualitative findings are in line with the quantitative results. Students became more active during the lessons. This was especially noticeable when hands-on activities and visualization tools were used. Many students mentioned that the concepts were clearer to them. They were also able to explain their reasoning with more confidence. In addition, an improvement in confidence could be observed, particularly when solving geometry problems. However, a small number of students continued to face difficulties. This was mainly seen in more complex, proof-based questions. Even so, their overall performance showed clear improvement.

DISCUSSION

The purpose of this study was to examine how selected teaching strategies influence students' understanding of circle theorems. The findings showed that students performed better after the intervention. Their scores increased, and this improvement could be clearly seen in the results. The qualitative data also reflected a similar

pattern. Students were more active during lessons, and their understanding appeared to improve. In addition, they took part more confidently in classroom activities. One clear pattern in the results is the gradual improvement across the stages. At the beginning, many students struggled with basic ideas and found it hard to see relationships within the circle. This was noticeable in their early responses. As the lessons went on, their understanding started to improve. By the final stage, most students were solving problems with more confidence.

Some of them even attempted proof-based questions with less support. This gradual change suggests that learning did not happen suddenly. It developed step by step.

This pattern can be explained using Van Hiele's theory of geometric thinking. According to this theory, students move through different levels when learning geometry. In this study, students first worked at the visualization level, where they recognized shapes and basic features. Later, they moved to analysis and began to understand properties and relationships. During the next stage, they started connecting ideas, which reflects informal deduction. By the final stage, a few students were able to use formal reasoning when solving problems. This change could be seen in the results. It suggests that learning developed step by step, rather than all at once. Teaching that followed these levels seems to have helped students understand the concepts more clearly. At the same time, the findings also point to the role of working together and discussing ideas. In the learning process. Students were not learning alone. They asked questions, shared ideas, and worked together during activities. This can be linked to Vygotsky's Social Development Theory, which emphasizes interaction-based learning. When students received guidance and worked with others, they were able to understand concepts more clearly. This was especially visible during group discussions and guided tasks. Over time, students became more confident in explaining their thinking. Additionally, this study relied heavily on visualization. Students were able to identify relationships that were difficult to comprehend through explanation alone with the aid of tools like GeoGebra and diagrams. Students' comprehension increased when they could see patterns and changes. The results of previous research, which also emphasize the importance of visualization in learning geometry, are comparable to this. It also implies that learning can be aided by even basic materials, particularly in classrooms with limited resources.

Students' engagement is the subject of another finding. Students seemed more engaged than normal during the intervention. They expressed more interest in the activities and asked more questions. This was not always seen in traditional lessons. This involvement appeared to be encouraged by the use of inquiry-based learning and practical exercises. Students are more likely to comprehend what they are learning when they are actively involved. This could be one factor contributing to their improved performance.

It's crucial to remember, though, that not every challenge was eliminated. Some students continued to struggle with challenging proof-based questions. To improve their reasoning abilities, they required more time and practice. This demonstrates that even though the techniques were beneficial, some students still find it difficult to learn geometry, particularly proofs. Thus, ongoing assistance is required. Overall, this study's results are consistent with earlier investigations. Research has demonstrated that student-centered strategies, like inquiry-based learning and the use of visual aids, can enhance students' comprehension and involvement. These conclusions are supported by the study's findings. In addition, it offers proof from an actual classroom with constrained resources. This adds practical value to the study.

Overall, the findings suggest that the teaching strategies used in this study had a positive effect on students' understanding of circle theorems. The improvement was not limited to test scores. Changes were also seen in students' participation, confidence, and their ability to explain ideas. This indicates that using suitable teaching methods can make a real difference in how students learn geometry.

CONCLUSION

This study set out to examine how selected teaching strategies influence students' understanding of circle theorems. The findings suggest that these strategies had a positive effect on students' learning. Students showed improvement not only in their test scores but also in their participation and confidence during lessons.

The results also showed that students' understanding developed gradually. At the beginning, many students struggled with basic concepts and showed limited understanding of the relationships between them. As the lessons progressed, their understanding improved gradually. They became more confident in identifying connections and applying their knowledge. By the final stage, some students were able to attempt proof-based questions with minimal support.

The implementation of various teaching strategies, such as inquiry-based learning, visualization, and hands-on activities, appeared to help this improvement. These methods encouraged students to actively participate in their learning. They asked questions, exchanged ideas, and collaborated, making the lessons more meaningful.

However, some issues remained still present. A few students still struggled with complex proof-based questions. This suggests that learning geometry requires time and regularity. Teachers should therefore provide continuous support to help students develop their reasoning skills. One limitation of this study is the small sample size. Future studies could include a larger group of students. Overall, the findings of this study emphasize the importance of choosing appropriate teaching strategies in the classroom. Even simple methods and tools can have a big impact, especially in low-resource environments.

This study offers some practical ideas to help teachers improve their teaching of geometry, particularly circle theorems.

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