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Effect of Van Hiele Model of Instruction on Student Geometric Thinking and Alleviating Misconception in Solving Geometric Problem among Senior Secondary School Student in Sokoto Metropolis, Nigeria

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Abstract

Geometry, as a fundamental component of mathematics, is essential for developing spatial reasoning, spatial visualization, and problem-solving skills. However, students in Nigeria, like their peers worldwide, often experience persistent challenges and misconceptions in learning geometry. This study investigates the effectiveness of Van Hiele Model of Instruction on Students Geometric Thinking and Alleviating Misconception in Solving Geometric Problem among Senior Secondary School Students in Sokoto Metropolis, Nigeria. A quasi-experimental pre-test post-test design was employed with 377 Senior Secondary II students selected through proportionate sampling, divided into experimental and control groups. Two instruments the Van Hiele Geometric Thinking Level Test (VHGTLT) and a five-tier Students' Geometry Problem Misconception Test (5T-SGPMT) were used for data collection. Descriptive statistics was used to answer the research questions and Mann Whitney U test was used to test the null hypotheses. Findings revealed that students taught with Van Hiele Instructional Model progressed to higher geometric thinking levels and demonstrated stronger conceptual understanding with fewer misconceptions than those taught with conventional approach with differences statistically significant. The study concludes that the Van Hiele instructional model is an effective teaching strategy for developing geometric thinking and correcting misconceptions. It recommends the integration of the Van Hiele model into classroom practices, teacher training programs, and curriculum development to improve geometry learning outcomes.

Keywords: Geometry, Geometric Thinking, Misconception, Van Hiele Instructional Model, Conventional Teaching Approach

Introduction

Geometry is a distinct and fundamental branch of mathematics, concerned with shapes, sizes, spatial relationships, and logical reasoning. Within the mathematics curriculum, it is taught alongside other key areas such as algebra and calculus (Mdyunus & Hock, 2019). Scholars emphasize that understanding geometry requires more than memorization; students need conceptual knowledge to represent mathematical situations in multiple ways and solve problems meaningfully (Luneta, 2015). Despite its importance, geometry instruction in many schools often focuses on traditional teaching, which limits students' ability to grasp concepts deeply (Hassan, 2023; Cho & Win, 2020).

In Nigeria, as in other parts of the world, many students continue to struggle with learning geometry. Studies highlight that only a few achieve proficiency in national assessments, with low performance linked to weak problem-solving skills and misconceptions about basic geometric principles (Aremu et al., 2025; Hassan et al., 2023). Research shows that students taught using traditional approaches frequently fail to meet curriculum objectives, whereas those taught with the Van Hiele model demonstrate significant improvement in understanding and applying geometric concepts (Atebe, 2011; Hassan, 2020). Key problem areas for Nigerian learners include the circle theorem, angles, and geometric proofs, often worsened by teaching methods that overlook students' developmental levels of geometric thinking (Agnes, 2023).

The challenges students face in geometry are multifaceted, involving cognitive, perceptual, and instructional barriers. Many learners perceive geometry as more difficult than other areas of mathematics due to its demand for spatial reasoning, logical deduction, and problem-solving (Adolphus, 2011).

To address these challenges, researchers recommend adopting effective instructional models, such as the Van Hiele theory, which organizes students' progression through distinct levels of geometric thinking. The model supports learners in moving from basic visualization to advanced deductive reasoning through structured instruction.

In my view, adapting the Van Hiele model in Nigerian classrooms is not just a helpful strategy but a necessity. Traditional methods have proven insufficient, leaving many students with misconceptions and poor performance in geometry (Hassan, 2021). By implementing this approach, teachers can foster deeper learning, enhance students’ confidence, and develop transferable problem-solving and reasoning skills. Ultimately, adopting the Van Hiele model can transform how geometry is taught and significantly improve students’ geometric thinking skill. (Atebe, 2011; Hassan et al., 2020).

Statement of the Problem

Despite the recognized importance of geometry in various fields such as architecture, engineering, and the sciences, Nigerian students continue to face significant challenges in solving geometry problems. These difficulties are primarily attributed to the traditional, teacher-centered instructional methods that dominate current teaching practices. Research indicates that these conventional methods can lead to weak reasoning skills and hinder the development of higher levels of geometric thinking. Consequently, students exhibit poor geometric understanding, particularly in areas such as circle geometry and plane geometry, as highlighted in WAEC examiners' reports from 2017 to 2023.

Furthermore, many students are found to be at the pre-recognition level of geometric thinking, unable to apply precise reasoning or recognize geometric figures effectively. The prevalent use of conventional teaching strategies has proven ineffective in improving students' geometric thinking skills and understanding. In view of this, the present study used a Van Hiele instructional model and theory to help students, particularly in Sokoto metropolis, in developing their basic understanding of geometry and alleviating their misconceptions and difficulties in learning geometry.

Objectives of the Study

The aim of this study is to identify student’s geometric thinking skills and reduce its misconception using Van Hiele instructional model among secondary school students in Sokoto metropolis Nigeria. The specific objectives are to:

1. Investigate the difference between the level of GTS of students taught using van Hiele model of instruction and those taught using conventional approach in the posttest among senior secondary school students in Sokoto metropolis.

2. identify the levels of misconceptions of senior secondary school students in solving geometric problem when taught using Van Hiele model of instructions and those taught using conventional approach in Sokoto metropolis

Research Questions

Base on the above stated objectives, the following research questions will be used to guide the study.

1. What are the levels of GTS of students taught using van hiele model of instruction and those taught using conventional approach in the posttest among senior secondary school students in Sokoto metropolis?

2. What are the levels of misconceptions of senior secondary school students in solving geometric problem when taught using Van Hiele model of instructions and those taught using conventional approach in Sokoto metropolis?

Research Hypotheses

The following null hypotheses were be formulated and tested to guide the study.

Ho_1: There is no significant difference between the level of GTS of students taught using Van Hiele model of instructions and those taught using conventional approach among senior secondary school students in Sokoto metropolis.

Ho_2: There is no significant difference between the levels of misconceptions of senior secondary school students in solving geometric problems when taught using the Van Hiele model of instruction and those taught using the conventional approach in Sokoto metropolis.

Methodology

The study adopted a quasi-experimental pre-test post-test design with experimental and control groups to assess senior secondary (SS II) students' geometric thinking skills and address misconceptions in Sokoto metropolis.

The population consisted of 16,488 students across 48 schools, from which four schools were randomly selected using proportionate sampling to ensure gender and population representation. A total of 377 students were chosen through Krejcie and Morgan's (1970) table, with 225 assigned to the experimental group and 152 to the control group. Two instruments were employed: the Van Hiele Geometric Thinking Test (VHGTLT), developed by Usiskin (1982) with 25 multiple-choice items covering five levels of geometric thinking, and the Five-Tier Students' Geometry Problems Misconceptions Test (5T-SGPMT), adapted from Widodo et al. (2020) to evaluate students' understanding and reasoning. Both instruments were validated by experts, piloted with 25 students, and showed reliability coefficients of 0.69 (VHGTLT) and 0.83 (SGPMT). Data were analyzed using descriptive statistics for research questions and the Mann-Whitney U test for hypotheses, with tables used to summarize scoring and grading criteria.

Table 1: Criteria for making and grading in van Hiele geometric thinking test

Marks	3 out 5 correct answer criteria	van Hiele Levels
1	1-5	1
2	6-10	2
4	11-15	3
8	16-20	4
16	21-25	5

Table 1: Students can achieve a certain level of thinking if they answer 3 out 5 questions correctly and that one mark is given in level one and two marks are given for answering 3 out 5 questions between 6-10 correctly in level two, to determine the van Hiele's levels of thinking, the weighted sum score is used as a reference as explained in (Usiskin, 1982). Table 2 provides the weighted sum score.

Table 2: The Weighted sum score for van Hiele levels

Forced van Hiele levels	Weighted Sum Score of VHL							
0	0	2	4	8	16	18	20	24
1	1	5	9	17	21	25		
2	3	11	19	27				
3	6	7	22	23				
4	13	14	15	29	30			
5			31					
Not fit	10	12	26	28				

Source: (Usiskin, 1982)

Table 2 was developed based on the van Hiele's theory of geometric thinking, in which the levels are achieved sequentially in order for the students to move from lower to a higher level of thinking (Hassan,et al., 2023). For example, student who answers at least three or more questions in levels 1 and 3 will be given 1 and 4 marks. Adding up the score we have 1+ 4= 5 in reference to Table 2 he/she achieved level one of VHL of thinking.

Marking and Grading of 5T-Students Geometry Problems Misconception Test (5T-SGPMT)

The 5T-Students Geometry Problems Misconception Test (5T-SGPMT) uses a five-tier assessment model, where students' responses are evaluated across different tiers, such as correct answers, confidence level, and drawings. The marking and grading process is based on the combination of these answers, leading to different decisions about the students' level of understanding of geometry concepts. The details of the marking, grading and decision are presented in Table 3

Table 3: Marking, grading and decision for SGPMT

S/N	Decision	Description	Marking	Grading
1.	GC (Geometry Conception)	Students provide correct answers at the macroscopic level (the main geometry question) and sub-microscopic levels (Tiers 1-5), are confident in their answers, and their drawings are aligned with geometry problem.	Full marks are awarded. This is the highest level of understanding, reflecting complete mastery of the geometry problem, confidence in their answers, and accurate representation through drawings.	Connected
2.	AGC (Almost Geometry Conception)	Students give correct answers at both the macroscopic and sub-microscopic levels, with high confidence. However, their drawings are either not fully accurate or do not entirely match the geometry problem or explanation	High marks are given but slightly reduced compared to GC due to the issue with the drawings. The student understands the concepts but lacks full alignment between explanation and representation.	Unconnected
3.	LC (Lack of Confidence)	Students provide correct answers at both levels (macroscopic and sub-microscopic), and their drawings are accurate, but they express uncertainty about their answers.	Marks are awarded for correct answers and proper drawings, but there is a deduction due to the lack of confidence. This suggests understanding but hesitancy in applying the concepts.	Connected
4.	LK (Lack of	Students provide answers	Partial marks are	Unconnected

	Knowledge)	that are partly correct at either the macroscopic or sub-microscopic levels, with varying confidence. Their drawings only partially align with geometry problem.	awarded. The answers show some knowledge, but the incomplete or inaccurate drawings and answers suggest gaps in understanding.	
5.	MC (Misconception)	Students may provide either correct or incorrect answers at both levels, but they lack full confidence, and their drawings are not in line with geometry problem.	Marks are deducted due to misconceptions and incorrect or inappropriate drawings. This reflects confusion or misunderstanding of the geometry problems.	Connected
6.	HNC (Have No Conception)	Students give incorrect answers at all levels, have no confidence in their responses, and their drawings are completely unrelated to Geometry concepts	Minimal or no marks are awarded. This decision reflects a lack of understanding and severe misconceptions	Unconnected

Source: (Widodo, et al., 2020

Results

Based on the result obtained the analysis were done with the use of table to provide a clear picture of the finding as follows.

Research Question One

What are the levels of GTS of students taught using van hiele model of instruction and those taught using conventional approach in the posttest among senior secondary school students in Sokoto metropolis?

Analysis for the Distribution of Students' Van Hiele Levels of Thinking for experimental Group Posttest

The scores obtained at the post-test for the Van Hiele test based on the established criteria were used to analyze the experimental group after the intervention learning geometry using Van Hiele model. Table 4 provides a summary of the students' distributions based on the van Hiele's levels of geometric thinking for experimental group.

Table 4: The Distribution of students' van Hiele's levels of geometric thinking of experimental group in the posttest

van Hiele's levels	Sum of scores	Levels	3 out of 5 Correct Answer	Total (%)

		Criteria						
		1	**2**	**3**	**4**	**5**		
0	0							
1	1	*					153	157(69.8%)
	5						4	
2	3	*	*				49	49(21.8%)
3	7	*	*	*			19	19(8.4%)
4	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-
Total							225	100%

Table 4 shows that none of the students failed to achieve level 1 (visualization). However, out of 157 (69.8%) students who achieved level 1 by scoring 1 mark four 4 of them, obtained sum scores of 5 marks for skipping level 2 and were assigned at level 1 based on the van Hiele table. 49 (21.8%) students obtained 3 marks and were assigned level 2. 19 (26.7%) students obtained 7 marks by answering at least three out of five questions in levels 1, 2 and 3 correctly and were assigned level 3 informal deduction.

Analysis for the Distribution of Students' Van Hiele Levels of Thinking of control Group in the Posttest

The analysis of 152 students' distribution based on van Hiele's levels of geometric thinking at the posttest for the control group after intervention involved in learning geometry using conventional approach the summary of the result is provided in Table 5

Table 5: Distribution of students' van Hiele's levels of geometric thinking of control Group in the Posttest

van Hiele's levels	**Sum of scores**	**Levels** 1	2	3	4	5	**3 out of 5 Correct Criteria Answer**	**Total (%)**
0	0						23	23 (15.1%)
1	1	*					107	107(70.4%)
2	3	*	*				22	22(14.5%)
3	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-
Total							152	100%

Table 5: A total of 23 (15.1%) students failed to achieve level 1 at the posttest of van Hiele test of geometric thinking. 107 (70.4%) students achieved visualization level (level 1) where 1 mark was assigned based on van Hiele's level table. A total of 22 (14.5) also achieved sum scores of 3 and assigned level 2 of van Hiele's levels.

Summary of Posttest for Students' Van Hiele Levels of Geometric Thinking for experimental and control group

The analysis provides the characteristics of students' van Hiele's levels of geometric thinking in experimental and control groups in the posttest, the summary of the result is provided in Table 9

Table 6: Summary of the Distribution of van Hiele's levels in the experimental and control groups at the posttest

van Hiele's level	Distribution for the frequency and percentage of the van Hiele levels	
	Experimental Group	Control Group
0		23 (15.1%)
1	157 (69.8%)	107 (70.4%)
2	49 (21.8%)	22 (14.5%)
3	19 (8.4%)	-
4	-	-
5	-	-
Total	225	152

The results in Table 6 reveal clear differences in students' distribution across the Van Hiele levels between the experimental and control groups. In the experimental group, most students (69.8%) were at Level 1 (analysis), while 21.8% advanced to Level 2 (informal deduction) and 8.4% reached Level 3 (deduction), with none remaining at Level 0 or progressing to Levels 4 and 5. Conversely, the control group showed 70.4% at Level 1, but a higher proportion (15.1%) at Level 0 and only 14.5% at Level 2, with no students progressing beyond this stage. These findings indicate that the Van Hiele-based instruction enabled broader progression across levels, including advancement to Level 3, while the conventional method limited students to lower levels of geometric thinking.

Null Hypothesis One

Ho_1: There is no significant difference between the level of GTS of students taught using Van Hiele model of instructions and those taught using conventional approach among senior secondary school students in Sokoto metropolis.

The null hypothesis was tested at 0.05 level of significant.

Table 7: Summary of Mann-Whitney U test Analysis for Experimental and Control Groups

Group	***N***	**Mean Rank**	**U**	***P*-value**
Experimental (Van Hiele)	225	207.66		
Control (Conventional)	152	161.38	12,902,500	.000

Table 7 presents the analysis of students GTS based on the H_{o1} whether if there are significant. The results reveal a statistically significant difference between the two independent groups, with U = 12,902,500 and a P-value of 0.000. Since the P-value is less than the 0.05 significance level, the null hypothesis is rejected. This leads to the conclusion that there is a significant difference in the van Hiele levels of geometric thinking skills between the experimental and control groups, in favor of experimental group that taught using Van Hiele model of instructions.

Research Question Two

What are the levels of misconceptions of senior secondary school students in solving geometric problem when taught using Van Hiele model of instructions and those taught using conventional approach in Sokoto metropolis?

Table 8: Students level of Misconception in the experimental Group

S/N	**Decisions**	**Overall conceptual understanding**	
		Frequency	**%**
1	GC (Geometry Conception)	141	62.7%
2	AGC (Almost Geometry Conception)	46	20.4%
3	LC (Lack of Confidence)	18	8%
4	LK (Lack of Knowledge)	6	2.7%
5	MC (Misconception)	9	4.%
6	HNC (Have No Conception)	5	2.2%
		225	100%

Table 8 presents the performance of 225 students in a geometry test based on their levels of understanding. The results show that 62.7% (141 students) demonstrated a clear understanding of geometry, while 20.4% (46 students) were categorized as having "Almost Geometry Conception," reflecting partial but incomplete knowledge. Smaller proportions of students showed challenges: 8% (18 students) lacked confidence, 2.7% (6 students) lacked knowledge, 4% (9 students) held misconceptions, and 2.2% (5 students) had no conception of geometry at all. Overall, 83.1% of the students either had a strong or nearly strong grasp of geometry, whereas a minority struggled with misconceptions, uncertainty, or lack of knowledge, highlighting the need for additional instructional support.

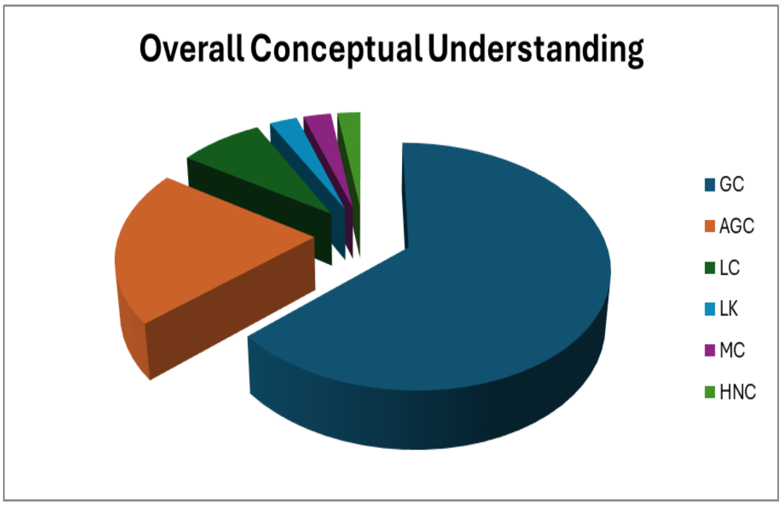

Figure 1: Students level of misconception in the experimental group

Figure 1 illustrates students' performance in geometry by categorizing their levels of understanding. The majority, 62.7%, fell into the Geometry Conception (GC) category, reflecting a strong grasp of geometric concepts, while 20.4% were in the Almost Geometry Conception (AGC) category, showing partial understanding with minor errors. Smaller proportions faced challenges: 8% were in the Lack of Confidence (LC) group, 2.7% in Lack of Knowledge (LK), 4% in Misconceptions (MC), and 2.2% in Have No Conception (HNC). Overall, the chart highlights that most students had a sound or near-sound understanding of geometry, while a smaller portion struggled with uncertainty, limited knowledge, or misconceptions.

Table 9: Students level of Misconception in the control group

S/N	Decisions	Overall conceptual Understanding	
		Frequency	%
1	GC (Geometry Conception)	7	4.6%
2	AGC (Almost Geometry Conception)	9	5.9%
3	LC (Lack of Confidence)	18	11.8%
4	LK (Lack of Knowledge)	24	15.9%
5	MC (Misconception)	35	23%
6	HNC (Have No Conception)	59	38.8%
		152	100.00%

Table 9 highlights the overall conceptual understanding of geometry among students taught with the conventional approach. Out of 152 students, only 4.6% (7 students) demonstrated clear understanding (GC), while 5.9% (9 students) showed partial understanding (AGC). A small group, 11.8% (18 students), lacked confidence (LC), and 15.9% (24 students) had limited knowledge (LK). Larger proportions struggled significantly: 23% (35 students) held misconceptions (MC), and the majority, 38.8% (59 students), had no conception (HNC) of geometry. Overall, 77.5% of these students displayed inadequate understanding, underscoring the limitations of conventional teaching methods and the need for more effective instructional strategies.

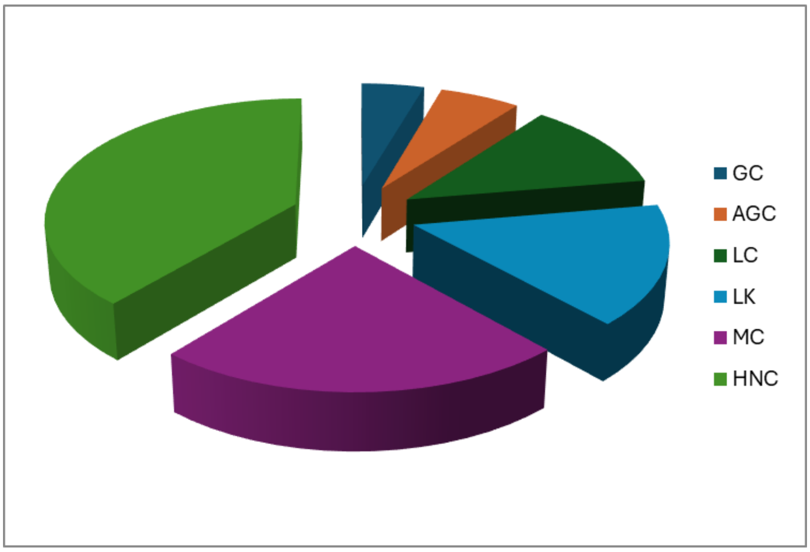

Figure 2: Students level of misconception in the control group

Figure 2 represents the level of conceptual understanding in geometry among students taught using the conventional approach. From the chart, it is clear that the largest portion of students, represented by the orange and teal sections, falls under Have No Conception (HNC) and Misconception (MC), indicating serious gaps in understanding. The orange slice, which is the largest, shows that 38.8% of students had no idea about geometry concepts at all. The teal section, making up 23%, represents students who thought they understood but held incorrect beliefs. The purple and green sections represent Lack of Knowledge (15.9%) and Lack of Confidence (11.8%), showing that many students either didn't know the content or were unsure of their answers. Only a small portion, shown in blue (4.6%) and red (5.9%), reflects students who had clear or partial understanding. This chart highlights that the conventional teaching method left most students struggling with understanding basic geometry concepts.

Null Hypothesis Two

Ho_2: There is no significant difference between the levels of misconceptions of senior secondary school students in solving geometric problems when taught using the Van Hiele model of instruction and those taught using the conventional approach in Sokoto metropolis.

Man Whitney U test was compared using the data collected from 5T-SGPMT. Result was presented in the table below.

Table 10: Mann–Whitney U Test Summary for Students' Levels of Misconceptions

Group	*N*	Mean Rank	U	P-value
Experimental (Van Hiele)	225	126.51		
Control (Conventional)	152	281.50	3040.50	.001

Table 10: Mann–Whitney U test was conducted to statistically compare the levels of misconceptions between two groups. The results indicated a significant difference, **U = 3040.50, p < .001**, with the experimental group having a higher mean rank (**M = 281.50**) compared to the control group (**M = 126.51**). This finding shows that the experimental group had significantly lower levels of misconceptions than the control group. The result therefore suggests that the Van Hiele model of instruction was more effective in enhancing students' conceptual understanding and reducing misconceptions in solving geometric problems compared to the conventional teaching approach.

Summary of the Major Findings

This section presents an overview of the key findings derived from the research questions and hypothesis that guided the study

1. The findings revealed that Students taught with the Van Hiele model progressed to higher levels of geometric thinking, while those taught conventionally remained at lower levels.
2. The findings also revealed that Students taught with the Van Hiele model developed better understanding and had fewer misconceptions, while those taught conventionally showed poor understanding and serious misconceptions.

Discussions of Findings

The findings revealed that Students taught with the Van Hiele model progressed to higher levels of geometric thinking, while those taught conventionally remained at lower levels. This finding aligns with the study Joshi (2017) and Cho & Win (2020) confirmed that the Van Hiele model enhanced student achievement and progression in geometry compared to conventional approaches. These results suggest that the structured phases of learning in the Van Hiele model (visualization, analysis, abstraction, deduction, and rigor) provide a clear developmental pathway that supports students in moving beyond mere visualization to advanced reasoning. In contrast, studies such as Hassan (2015) and Thapa (2017) found that students exposed to traditional instruction often stagnated at the visualization level or below, reflecting the same pattern seen in the control group of the present study.

The findings also revealed that Students taught with the Van Hiele model developed better understanding and had fewer misconceptions, while those taught conventionally showed poor understanding and serious misconceptions. This finding is supported by Arman (2021), who demonstrated that the Van Hiele model was effective in correcting misconceptions in geometry construction, with the experimental group outperforming the control. Additionally, Agnes (2023) found that diagnostic tools reveal widespread misconceptions among junior secondary students, reinforcing the importance of instructional approaches like Van Hiele that actively address and correct misunderstandings. Together, these studies affirm that the Van Hiele model not only improves geometric thinking but also plays a crucial role in reducing persistent misconceptions compared to traditional approaches.

Conclusion

The study conclude that Van Hiele instructional model is the most effective teaching strategy in enhancing geometric thinking and reducing misconceptions in senior secondary school students in Sokoto metropolis, compared to conventional approach. Van Hiele model led to higher thinking level and conceptual understanding.

Recommendation

1. Mathematics teachers should be encouraged to adopt the Van Hiele model and shift from conventional teaching approach to interactive, student-centered learning.
2. Workshops and seminars should be organized by the ministry for Basic and Secondary Education to train teachers' on how to implement the model in mathematics classrooms.
3. Curriculum developers and policymakers should integrate the Van Hiele model into formal education frameworks.

Suggestion for Further Study

The following suggestions are made to guide the future research in related areas.

1. The study focused on plane shapes, it is recommended that other content of geometry like solid geometry, will be investigated using the strategy.
2. The results of this study were derived from senior secondary school students. Further study should be extended to investigate other students in different level of education to provide more generalize findings.
3. Future research should explore more about the misconceptions of students in learning geometry using other approach.

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