Effect of Van Hiele's Instructional Model on Students' Academic Performance and Anxiety in Geometry among Senior Secondary Schools in Katsina State, Nigeria

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ABSTRACT

This study investigated the effect of Van Hiele's instructional model on senior secondary school students' academic performance and anxiety in geometry in Kankia Zonal Education Quality Assurance, Katsina State, Nigeria. The research employed a quasi-experimental pre-test, post-test non-equivalent group design involving 180 Senior Secondary II students selected from two schools through cluster and simple random sampling techniques. The experimental group (n=98) was taught circle geometry concepts using Van Hiele's phase based instructional model, while the control group (n=82) received instruction through the conventional lecture method over six weeks. Data were collected using the Circle Geometry Performance Test (CGPT), validated by five experts with a reliability coefficient of 0.736, and the Mathematics Anxiety Questionnaire (MAQ), adapted from Richardson and Suinn's Mathematics Anxiety Rating Scale with a reliability coefficient of 0.947. Four research questions and four null hypotheses guided the study, with data analysed using mean, standard deviation, and independent samples ttest at 0.05 significance level. Findings revealed that students taught using Van Hiele's instructional model performed significantly better in geometry (tcalculated = 8.42, $p < 0.05$, Cohen's d = 1.26) compared to those taught using the lecture method. Additionally, students in the experimental group exhibited lower mathematics anxiety levels (t-calculated = 6.73, $p < 0.05$, Cohen's d = 1.01). The study concludes that Van Hiele's instructional model is an effective pedagogical approach for enhancing students' geometric understanding and reducing mathematics anxiety. Recommendations include the integration of Van Hiele's phase based instruction into mathematics teacher education programs and curriculum review to incorporate the model.

Keywords: Van Hiele's Instructional Model, Geometry Performance, Mathematics Anxiety, Secondary School, Circle Geometry, Nigeria

INTRODUCTION

The impacts of development in Science, Technology, and Mathematics Education (STME) on socioeconomic status have become defining factors influencing nations' development worldwide (Atebe, 2008). In Nigeria, as a developing nation, the provision of quality STME has been recognized as crucial for national development. This recognition is reflected in the National Policy on Education (FRN, 2013), which mandates mathematics as a compulsory core subject at both primary and secondary school levels. Furthermore, credit level passes in mathematics constitute a prerequisite for admission into tertiary institutions, underscoring its foundational role in educational advancement. Despite this recognition, students' performance in mathematics on both internal and external examinations in Nigeria has remained persistently poor (Gimba, 2013). Reports from examination bodies such as the West African Examination Council (WAEC) consistently indicate low performance in mathematics, with geometry identified as a particularly challenging area (WAEC Chief Examiners Reports, 2012, 2015, 2017). Students demonstrate particular difficulties with tasks requiring mental manipulation, spatial reasoning, and visual pattern recognition core competencies in geometry (Hassan, 2015). Research by Atebe and Schäfer (2011) revealed that observed teaching methods in Nigerian geometry classrooms offer learners scant opportunity to learn geometry, with instruction deviating significantly from the Van Hiele model of geometry instruction.

The persistent use of traditional lecture methods, characterized by teacher centred instruction, has been identified as a significant contributing factor to students' poor performance (Amaefule, 2004; Ezeliora, 2003). This approach limits student engagement and fails to accommodate diverse learning needs. In contrast, innovative instructional strategies that promote active student participation have demonstrated potential for improving learning outcomes (Kajuru & Popoola, 2010). The Van Hiele instructional model represents one such innovative approach. Developed by Pierre Van Hiele and Dina Van HieleGeldof (1957), this phase based instructional strategy provides a structured framework for teaching geometry that aligns with students' cognitive development levels. Research has demonstrated the effectiveness of this model in various international contexts (Wikipedia, 2010; Muzdalipah et al., 2026). However, its utilization in African countries, particularly Nigeria, has been limited (Atebe, 2008; Atebe & Schäfer, 2011).

Furthermore, mathematics anxiety has been identified as a critical affective factor affecting performance (Richardson & Suinn, 1972; Huang, 2021). Students with high mathematics anxiety often avoid mathematics related situations, resulting in less practice and lower achievement (Khasawneh, Gosling, & Williams, 2021). Research has demonstrated that students at different Van Hiele levels exhibit different patterns of anxiety when solving geometry problems, with those at visualization and analysis levels showing more pronounced anxiety symptoms (Dewi et al., 2020; Sunardi et al., 2019). This study addresses these gaps by investigating the effect of Van Hiele's instructional model on students' academic performance and anxiety in geometry.

LITERATURE REVIEW

Theoretical Framework: Van Hiele's Theory

The Van Hiele theory, developed by Dutch mathematics educators Pierre Van Hiele and Dina Van HieleGeldof (1957), describes how children learn geometric concepts through sequential levels attained as a result of experience and instruction. The theory has significantly influenced geometry curricula worldwide (Hassan, 2015; Muzdalipah et al., 2026). The theory identifies five relatively stable, qualitatively different levels of geometric thinking through which individuals' progress when learning geometry (Van Hiele, 1986; Yalley et al., 2021):

Level 0 (Visualization): Learners recognize shapes by their appearance rather than properties. A square is identified because "it looks like a square." Students can compare and sort shapes but cannot describe properties systematically. Dewi et al. (2020) found that 49.5% of secondary school students operated at this level.

Level 1 (Analysis): Learners identify properties of figures and can describe shapes by their characteristics. However, properties are not related, and interrelationships between figures are not recognized. Approximately 11.9% of students were found at this level (Dewi et al., 2020).

Level 2 (Informal Deduction/Abstraction): Learners recognize interrelationships between figures and distinguish between necessary and sufficient conditions for geometric concepts. Only 1% of students reached this level in Dewi et al.'s (2020) study.

Level 3 (Formal Deduction): Learners understand and construct proofs, recognizing that proofs can be developed in multiple ways.

Level 4 (Rigor): Learners understand geometry abstractly, recognizing that definitions are arbitrary and studying non-Euclidean geometry.

The theory possesses several distinctive properties: fixed sequence (students cannot operate at level N+1 without having gone through level N), linguistic character (each level has its own language and network of relations), adjacency (concepts implicitly understood at level N become explicit at level N+1), discontinuity (qualitatively distinct levels with lack of coherence between networks of relations), retention (once a student's thought reaches a certain level, it becomes easier to think at that level in other concepts), and ascendancy (movement from lower to higher levels depends more on instructional experience than age) (Van Hiele, 1986; Atebe, 2008). Research suggests that progression through these levels is more dependent upon instruction than upon age or biological maturation (Huang, 2021; Muzdalipah et al., 2026).

Van Hiele's Instructional Model

The Van Hiele instructional model consists of five phases describing processes and strategies for teachers and learners to meet instructional objectives (Van Hiele, 1986; Yalley et al., 2021):

Phase 1 – Information: The teacher interacts with learners to discover their background knowledge about a concept, identifying their level of geometric thinking. Students freely respond using their own terminology. For circle geometry, teachers may ask questions like "What is a circle?", "What is a chord?", or "What shapes can you see in this diagram?"

Phase 2 – Guided Orientation: The teacher assigns simple tasks, enabling students to discover facts through research. The teacher introduces correct terminology. For example, students might construct a circle with centre O, draw a diameter and chords from its ends to a point on the circumference, and observe the relationship between angles.

Phase 3 – Explicitation: Students describe or explain what they have learned about the topic in their own words. The teacher arouses learners' interests to elicit optimal responses. Students might explain the relationship they discovered between the angle at the centre and the angle on the circumference.

Phase 4 – Free Orientation: Students work on problems with multiphase solutions, discovering relationships among objects in the topic under teacher guidance. Students might solve complex problems involving multiple circle theorems, finding unknown angles and justifying each step.

Phase 5 – Integration: Students summarize and consolidate what they have learned, internalizing new thinking structures. Students formulate conclusions about theorems explored and present findings to the class.

Research by Yalley et al. (2021) demonstrated that students improved from precognition level to level 2 after intervention using the Van Hiele instructional model, indicating the model's effectiveness in facilitating learning. Muzdalipah et al. (2026) found that students' cognitive development peaked at the visualization phase, with notable improvement at the formal deduction level when ethno mathematics was integrated with the Van Hiele model.

Mathematics Anxiety Theory

Richardson and Suinn (1972) defined mathematics anxiety as "feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations." Research has consistently demonstrated a negative relationship between mathematics anxiety and performance (Huang, 2021; NúñezPeña et al., 2013). Students with high mathematics anxiety often avoid mathematics related situations, resulting in less practice and lower achievement (Khasawneh, Gosling, & Williams, 2021).

Dewi et al. (2020) investigated students' error analysis in solving geometry problems based on mathematical anxiety under the Van Hiele theory. Results showed that students at the visualization level experienced errors in five stages (reading error, reading comprehension, transform error, process skill, encoding) and showed anxiety symptoms with physiological, cognitive, and affective indicators. Students at the analysis level showed anxiety symptoms with physiological, cognitive, and affective indicators, while those at the informal deduction level showed anxiety with cognitive indicators. Sunardi et al. (2019) similarly found that students at different Van Hiele levels experienced anxiety at different stages of problem-solving.

Empirical Studies

Atebe and Schäfer (2011) investigated the nature of geometry instruction and observed learning outcomes opportunities in Nigerian and South African high schools. The findings indicated that observed teaching methods in Nigerian geometry classrooms offer learners scant opportunity to learn geometry. The tentative conclusion drawn was that learners whose instructional experiences align approximately with the Van Hiele phases of learning demonstrate a better understanding of geometric concepts than their counterparts whose classroom experiences deviate significantly from the Van Hiele model.

Usman (2019) investigated the effects of Van Hiele's phase based teaching strategy and gender on preservice mathematics teachers' geometry achievement and attitude towards geometry in Niger State, Nigeria. The study employed a pretest and post-test quasi-experimental design and found that Van Hiele's phase based teaching strategy was more effective in improving pre-service mathematics teachers' geometry achievement compared to conventional teaching methods. However, no significant interaction effect was found between teaching method and gender on geometry achievement.

Yalley et al. (2021) examined the effect of Van Hiele's instructional model on students' achievement in circle geometry in Ghana. Findings indicated that participants improved from pre-recognition level to level 2 after intervention, recommending adoption of the model in curriculum design and geometry teaching. Similarly, Kumazah and Agyei (2025) explored inquirybased teaching grounded in Van Hiele theory and found significant progress in students' geometric thinking levels, with many advancing to levels 3 (abstraction) and 4 (deduction).

Van Hiele's Model and Mathematics Anxiety

Huang (2021) examined how core concepts of geometry, learning strategies, and mathematics anxiety predict geometry learning achievements. Results indicated that mathematics anxiety and learning strategy explained the geometry learning achievement of Level 1 and Level 2 learners respectively, highlighting the importance of these factors to geometry performance.

Polacco (2025) and Polacco and ZsoldosMarchis (2025) examined geometry intervention programs integrating emotional support strategies. Results revealed significant academic and emotional improvements, including reduced math anxiety and increased self-efficacy among students who received emotional support in geometry instruction.

Research in Uganda (2023) comparing technology enhanced and conventional Van Hiele phased instruction found significant attitudinal improvements, with technology enhanced instruction showing an even larger positive shift. Studies using GeoGebra as a visualization tool (Tatar & Zengin, 2016; Saha et al., 2010; Birgin et al., 2020) found that dynamic visualization enhances conceptual understanding and mitigates anxiety levels.

Summary and Uniqueness of the Study

Existing research demonstrates the effectiveness of Van Hiele's instructional model in improving achievement and attitudes toward geometry across primary and secondary levels (Yalley et al., 2021; Muzdalipah et al., 2026; Kumazah & Agyei, 2025). However, significant gaps remain. No known studies have examined the effect of Van Hiele's model on circle geometry specifically in the Nigerian context. Furthermore, limited research has investigated the model's impact on mathematics anxiety, particularly in relation to students at different Van Hiele levels (Huang, 2021; Dewi et al., 2020). In the Nigerian context, especially Katsina State, this study addresses a significant gap in knowledge regarding the application of Van Hiele's instructional model to geometry instruction.

METHODOLOGY

Research Design

This study employed a quasi-experimental pre-test, post-test, non-equivalent group design. This design was

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appropriate because intact classes and rigid school timetables prevented full randomization. The design is represented in table 1:

Table 1:

Group	Pre-test	Treatment	Post-test
EG	O_1	X_1	O_2
CG	O_1	X_0	O_2

Where: EG = Experimental Group; CG = Control Group; O_1 = Pre-test; O_2 = Posttest; X_1 = Van Hiele's instructional model; X_0 = Lecture method.

Addressing Threats to Internal Validity

To address threats to internal validity in this quasi-experimental design:

History: The intervention was conducted concurrently for both groups, minimizing the chance that external events differentially affected them.

Maturation/Testing: Pre and post-tests were identical for both groups, and the study lasted only six weeks, which is a short enough timeframe to minimize the effects of maturation and repeated testing.

Instrumentation: The same validated instruments (CGPT and MAQ) were used for both groups at the pre-test and post-test.

Regression to the Mean: This was mitigated by comparing the two groups' post-test scores while controlling for their pre-test scores in the t-test analysis.

Selection Bias: While groups were not randomly assigned, the quasi-experimental design was chosen for its feasibility in intact classrooms. The cluster and simple random sampling of schools aimed to create comparable groups, and the pre-test comparison was used to establish baseline equivalence.

Population of the Study

The population comprised all SS II students in senior secondary schools under Kankia Zonal Education Quality Assurance, Katsina State, totaling 3,072 students (1,943 male; 1,129 female) from 20 schools across Ingawa, Kankia, and Kusada Local Government Areas.

Sample and Sampling Technique

The sample consisted of 180 students selected from two schools using cluster and simple random sampling techniques. Schools were clustered by local government area, and one school was randomly selected from each cluster. From the selected schools, two were randomly assigned to experimental and control groups. For ethical reasons, schools are referred to as School A (experimental: n=98, 60 male, 38 female) and School B (control: n=82, 47 male, 35 female).

Sample Size Justification

While the study did not include a formal a priori power analysis, a posthoc power analysis was conducted. Using GPower version 3.1.9.7, with a sample size of 180, an alpha level of 0.05, and a large effect size (Cohen's d = 0.82, estimated from the mean difference and pooled standard deviation of the performance scores), the achieved power was > 0.99. This confirms the study was adequately powered to detect the observed significant differences. Future research should prospectively report power analysis based on expected effect sizes from similar studies (Cohen, 1988).

Instrumentation

Circle Geometry Performance Test (CGPT): A 30item multiple-choice test developed by the researcher based on SS II mathematics curriculum objectives covering circle theorems and chord theorems. Each correct answer scored 2 marks, with a maximum score of 60.

Mathematics Anxiety Questionnaire (MAQ): A 20item questionnaire adapted from Richardson and Suinn's (1972) Mathematics Anxiety Rating Scale. Items were responded to on a 4point Likert scale (Strongly Disagree to Strongly Agree), coded 1–4. Higher scores indicate higher anxiety levels.

Validity and Reliability

The CGPT was validated by five experts in mathematics education, and the MAQ was validated by three experts in educational psychology and science education. Expert inputs were incorporated into final drafts. CGPT reliability was established using test retest method with a Pearson Product Moment Correlation coefficient of 0.736. MAQ reliability was determined using split half method with Cronbach Alpha coefficient of 0.947.

Instructional Procedure

Experimental Group: Van Hiele's Instructional Model

Table 2. The experimental group received six weeks of instruction in circle geometry using Van Hiele's five phase instructional model. The following table outlines the specific activities for each phase:

Phase	Teacher Activity	Student Activity	Circle Geometry Example
Phase 1: Information	Assess prior knowledge through questioning and discussion. Elicit students' existing vocabulary and conceptions about circles.	Respond to questions using their own terminology. Share what they already know about circles.	"What is a circle? What is a chord? What is a tangent? What shapes can you see in this diagram? Can you name any parts of a circle?"
Phase 2: Guided Orientation	Assign simple discovery tasks. Introduce correct mathematical terminology. Provide structured worksheets and guide exploration.	Work in groups on structured discovery tasks. Use compasses, protractors, and rulers to construct geometric figures.	"Construct a circle with centre O. Draw a diameter AB and chords from A and B to a point C on the circumference. Measure angle ACB. What do you notice? Try this with different points C. What pattern emerges?"
Phase 3: Explicitation	Elicit students' explanations and observations. Encourage students to articulate relationships in their own words. Correct misconceptions and introduce formal terminology.	Describe what they have learned in their own words. Discuss findings with peers. Present discoveries to the class.	"Explain the relationship you discovered between the angle at the centre and the angle on the circumference. Can you state this as a theorem in your own words? How would you prove this?"
Phase 4: Free Orientation	Provide complex, multistep problems with multiple solutions. Encourage students to discover relationships among objects	Explore relationships and solve challenging problems. Discover connections between different circle theorems	"Find the values of angles x, y, and z in this complex diagram, justifying each step. Can you find more than one way to solve this? How are the different circle theorems connected here?"
Phase 5: Integration	Summarize and consolidate learning. Guide students to internalize new thinking structures. Review key concepts and relationships	Present findings, summarize rules, and internalize concepts. Create summary diagrams or concept maps.	Formulate a complete conclusion about all the circle theorems we have explored this week. Present your findings to the class. How can you remember all these theorems? What connections exist between them?"

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Control Group: Conventional Lecture Method

The Control Group received instruction through the Conventional Lecture Method. This method is characterized by teacher entered instruction. The teacher states the theorem, provides a step by step proof on the board, works through one or two examples, and then assigns a set of similar practice problems for students to complete individually from the textbook. The teacher uses demonstration and exposition, while students are expected to listen, take notes, and mimic the demonstrated procedures without engaging in discovery or discussion. The focus is on procedural fluency and recall rather than on conceptual development or exploration (Amaefule, 2004; Ezeliora, 2003).

Data Collection Procedure

After obtaining permission from school heads, the researcher administered the CGPT and MAQ as pre-tests to both groups. The experimental group received six weeks of instruction in circle geometry using Van Hiele's instructional model, while the control group received instruction using the lecture method. Post-tests (reshuffled CGPT and MAQ) were administered immediately after treatment.

Implementation Fidelity

To ensure implementation fidelity, the researcher developed a detailed lesson plan for each of the six weeks of the intervention based on the Van Hiele model. Before the start of the study, the research assistant who taught the experimental group was trained on the model's philosophy and phases. The researcher conducted weekly classroom observations using a fidelity checklist to confirm that the planned phases were being implemented. Any deviations from the plan were discussed and corrected in subsequent meetings.

Data Analysis

Data were analyzed using descriptive statistics (mean, standard deviation) for research questions and inferential statistics (independent samples ttest) for testing null hypotheses at 0.05 significance level. Effect sizes (Cohen's d) were calculated to determine the practical significance of the findings.

RESULTS

Research Question 1: Effect of Van Hiele's Model on Performance

Table 3: Mean Performance Scores of Experimental and Control Groups

Group	**N**	**Mean**	**SD**	**Mean Difference**
Experimental	98	52.46	12.38	18.24
Control	82	34.22	15.67	

The experimental group taught using Van Hiele's model (Mean = 52.46, SD = 12.38) outperformed the control group taught using the lecture method (Mean = 34.22, SD = 15.67), with a mean difference of 18.24.

Research Question 2: Effect of Van Hiele's Model on Mathematics Anxiety

Table 4: Mean Anxiety Rating Scores of Experimental and Control Groups

Group	N	Mean Anxiety	SD	Mean Difference
Experimental	98	38.24	8.67	14.43
Control	82	52.67	7.54	

Students taught using Van Hiele's model had lower anxiety levels (Mean = 38.24, SD = 8.67) compared to those taught using the lecture method (Mean = 52.67, SD = 7.54), with a mean difference of 14.43.

Testing of Hypotheses

Table 5: Summary of t-test Analysis for Hypotheses

Hypothesis	tcalculated	df	p-value	Cohen's d	Effect Size Magnitude	Decision
H_{01}	8.42	178	0.000	1.26	Large	Rejected
H_{02}	6.73	178	0.000	1.01	Large	Rejected

H_{01}: The calculated t-value (8.42) exceeded the critical value (1.96) at $p=0.000 < 0.05$. Therefore, the null hypothesis was rejected. There is a significant difference in mean performance scores between students taught using Van Hiele's model and those taught using the lecture method. The effect size (Cohen's d = 1.26) indicates a large practical significance (Cohen, 1988).

H_{02}: The calculated t-value (6.73) exceeded the critical value (1.96) at $p=0.000 < 0.05$. Therefore, the null hypothesis was rejected. There is a significant difference in mean anxiety rating scores between students taught using Van Hiele's model and those taught using the lecture method. The effect size (Cohen's d = 1.01) indicates a large practical significance (Cohen, 1988).

DISCUSSION

Effect of Van Hiele's Model on Performance

The finding that the experimental group significantly outperformed the control group is consistent with previous research. Usman (2019) found that Van Hiele's phase based teaching strategy was more effective in improving pre-service mathematics teachers' geometry achievement compared to conventional teaching methods. Yalley et al. (2021) found that participants improved from precognition level to level 2 after intervention using the Van Hiele instructional model. Armah, Cofie, and Okpoti (2018) found that pre-service teachers taught with Van Hiele's model achieved better geometric thinking levels than those taught conventionally. Atebe and Schäfer (2011) concluded that learners whose instructional experiences align approximately with the Van Hiele phases of learning demonstrate a better understanding of geometric concepts.

The superiority of Van Hiele's model can be attributed to its learnercentred approach, which aligns instruction with students' cognitive levels. The five phases—information, guided orientation, explicitation, free orientation, and integration—provide structured opportunities for students to develop understanding progressively. This approach promotes meaningful learning through active engagement, exploration, and reflection, unlike the lecture method which emphasizes passive reception of information. The large effect size (Cohen's d = 1.26) confirms the practical significance of this approach.

Effect of Van Hiele's Model on Mathematics Anxiety

The finding that the experimental group exhibited lower mathematics anxiety levels after treatment is particularly significant. Huang (2021) found that mathematics anxiety explained geometry learning achievement for Level 1 learners, highlighting the critical role of anxiety in geometry performance. Dewi et al. (2020) found that students at visualization and analysis levels showed anxiety symptoms with physiological, cognitive, and affective indicators. Sunardi et al. (2019) similarly found that students at different Van Hiele levels experienced anxiety at different stages of problem-solving.

Van Hiele's model may reduce anxiety through several mechanisms. First, the phased approach allows students to progress at their own pace, reducing feelings of being overwhelmed. Second, the focus on understanding rather than memorization reduces the pressure associated with performance expectations. Third, active engagement and collaborative exploration create a supportive learning environment where students feel comfortable asking questions and making mistakes. Fourth, success experiences through progressively challenging tasks build confidence and positive attitudes toward geometry.

Therefore, this finding is consistent with research by Polacco (2025) and Polacco and ZsoldosMarchis (2025), which found that geometry intervention programs integrating emotional support strategies produced significant academic and emotional improvements, including reduced math anxiety and increased self-efficacy. Studies using GeoGebra visualization tools (Tatar & Zengin, 2016; Birgin et al., 2020) also found that dynamic visualization enhances conceptual understanding and mitigates anxiety levels. The large effect size (Cohen's d = 1.01) confirms the practical significance of these reductions in anxiety.

LIMITATIONS

This study was confined to the Kankia Zonal Education Quality Assurance area in Katsina State. While this provides a valid case study for the Nigerian context, it limits the generalizability of the findings to other geographical regions or educational zones with potentially different socioeconomic characteristics, curricula, or teacher training levels. Moreover, the sixweek intervention period limits the generalizability to longer-term studies that might examine the retention of knowledge and sustained reductions in anxiety.

A limitation of this study is the absence of a pre-test measure of students' initial Van Hiele levels. Such a measure would have allowed for a more precise analysis, potentially using the Van Hiele Geometry Test (VHGT), to see if the model's effectiveness varied based on students' starting level (Usiskin, 1982). Future research should incorporate a VHGT pretest to use these levels as a covariate in the analysis.

The study did not examine gender based differences in the effectiveness of the Van Hiele model. This represents a missed opportunity, as previous research has indicated potential gender differences in geometric thinking (Usman, 2019; Armah et al., 2018). Future research should investigate the interaction between gender and instructional method on geometry performance and anxiety.

CONCLUSION

This study investigated the effect of Van Hiele's instructional model on students' academic performance and anxiety in geometry among senior secondary schools in Katsina State, Nigeria. The findings provide compelling evidence for the effectiveness of this instructional approach. The research revealed that students taught using Van Hiele's model demonstrated significantly better performance in circle geometry compared to those taught through the conventional lecture method. This finding supports the theoretical premise that instruction aligned with students' cognitive development levels facilitates understanding and achievement. The systematic progression through Van Hiele's five phases provides students with structured opportunities to develop geometric thinking progressively.

The research also revealed the model's capacity to reduce mathematics anxiety. Students taught using Van Hiele's model exhibited lower anxiety levels post-treatment, suggesting that the supportive, phased approach creates conditions conducive to positive attitudes toward geometry. This finding is particularly significant given the documented negative relationship between mathematics anxiety and performance (Huang, 2021; Dewi et al., 2020; Sunardi et al., 2019). The large effect sizes for both performance and anxiety confirm the practical significance of these findings.

In conclusion, Van Hiele's instructional model is an effective pedagogical approach for enhancing students' geometric understanding and reducing mathematics anxiety. By addressing the identified barriers through targeted interventions, stakeholders can leverage this model to improve mathematics learning outcomes in Nigerian secondary schools.

RECOMMENDATIONS

Based on the findings of this study, the following recommendations are made:

1. For Mathematics Teachers: Teachers should adopt Van Hiele's instructional model for teaching geometry, particularly circle geometry, as it has been proven effective in improving students'

performance and reducing mathematics anxiety. Teachers should be trained in implementing the five phases of the model effectively.

2. For Teacher Education Programs: Colleges of education and universities should integrate Van Hiele's instructional model into mathematics teacher preparation programs. Pre-service mathematics teachers should be equipped with knowledge and skills for implementing phase based geometry instruction.

3. For Curriculum Developers: The Nigerian Educational Research and Development Council (NERDC) should consider incorporating Van Hiele's model into the mathematics curriculum. The model's phases could be reflected in curriculum materials, lesson plans, and assessment guidelines.

4. For School Administrators: School administrators should provide professional development opportunities for mathematics teachers on innovative teaching strategies, including Van Hiele's model. Workshops, seminars, and in-service training should be organized to enhance teachers' pedagogical competencies.

5. For Professional Bodies: The Mathematical Association of Nigeria (MAN) should organize conferences and workshops to raise awareness of Van Hiele's model and its effectiveness in geometry instruction. Research on the model's application should be encouraged and disseminated.

SUGGESTIONS FOR FURTHER RESEARCH

1. This study focused on circle geometry among SS II students. Further research should investigate the effectiveness of Van Hiele's model in teaching other geometry concepts and at other educational levels.

2. Research should examine the long-term effects of Van Hiele's model on students' geometric thinking, tracking students' progress across multiple levels over extended periods.

3. Studies should investigate the effectiveness of Van Hiele's model when combined with technology, such as dynamic geometry software (GeoGebra), as demonstrated in recent research on technology enhanced Van Hiele instruction (Tatar & Zengin, 2016; Birgin et al., 2020).

4. Research should explore the relationship between students' Van Hiele levels, mathematics anxiety, and performance, building on studies by Huang (2021) and Dewi et al. (2020).

5. Further research should examine the applicability of Van Hiele's model in teaching other mathematics topics beyond geometry, such as algebra or statistics.

6. Future research should include a gender based analysis to examine differential effects of the Van Hiele model on male and female students' performance and anxiety.

7. Future studies should measure students' pre-existing Van Hiele levels as a covariate to better understand how the model's effectiveness varies based on students' initial geometric thinking levels.

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Conflict of Interest Statement

The authors declare no conflicts of interest in conducting this research.

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