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Evaluating the Effectiveness of Van Hiele Model in Enhancing Geometric Thinking Levels among Secondary School Students' in Sokoto Metropolis, Nigeria

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Abstract

Geometry is a critical component of the mathematics curriculum, essential for developing spatial reasoning and foundational for numerous scientific fields. However, students in Nigeria persistently demonstrate low geometric thinking levels, a challenge this study addressed by investigating the effectiveness of the Van Hiele instructional model. Utilizing a quasi-experimental, non-randomized control group pretest-posttest design, the research involved 377 senior secondary students from Sokoto metropolis. An experimental group was taught using the Van Hiele Model, while a control group received conventional instruction. Data were collected using the Van Hiele Model Geometric Thinking Level Test (VHMGTLT). The findings revealed that the vast majority of students in both groups operated below the foundational Visualization (Level 1) stage. The results was analyzed using descriptive statistics and the Mann-Whitney U test, revealed a statistically significant improvement in the experimental group. All students in this group attained at least Level 1, with many progressing to Informal Deduction (Level 3). Conversely, the control group demonstrated no meaningful progress. The study concludes that the Van Hiele Model is a highly effective strategy for significantly enhancing students' geometric thinking levels and recommends its adoption by mathematics teachers and integration into the curriculum

Keywords: Van Hiele Model, Geometric Thinking Levels, Geometry, Secondary School, Conventional Approach

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Introduction

Geometry is recognized as a fundamental cornerstone within the mathematics curriculum, essential for understanding the relationships among geometric shapes (Hassan *et al.,* 2023). It encompasses the study of points, lines, surfaces, shapes, sizes, angles, and the properties of space (Mdyunus & Hock, 2019). Unlike other abstract mathematical disciplines such as Algebra, Zakariyya (2023) considers geometry as an important in mathematics that requires attention in the mathematics curriculum. Geometry plays a crucial role in both academic and real-world contexts, providing a framework for understanding spatial relationships, shapes, and structures, making it essential for various fields such as engineering, architecture, and design (Ozkan *et al.,* 2018).

Despite the significant importance of geometry, the difficulty in learning geometry continues to be a topical issue in mathematics education as difficult areas, not only in Nigeria (Hassan, 2021). Also, It is observed that basic students in Sokoto display low basic skills in geometry, lower skills in solving geometric problems contributed to the poor performance in mathematics (Hassan *et al.,* 2023). However, Van Hiele's Model is one of the best Model used to help students in achieving levels of geometric thinking and also provides an instructional model to achieve the geometric thinking levels (Hassan *et al.,* 2020). However, literature affirmed that teachers must understand the students' levels for better selection of materials in learning strategy. In view of this, Agnes (2023) investigated the problems of difficult concepts in the Senior Secondary School Mathematics curriculum in Nigeria. Some of the difficulties identified are problems based on the circle theorem, which include the angle at the Centre of the circle, the chord theorem, and angles, among others.

The Van Hiele Model describes five sequential levels of geometric thinking. At Level 1 (Visualization), students recognize shapes by their appearance. At Level 2 (Analysis), they identify properties of shapes. At Level 3 (Informal Deduction), they understand relationships between properties. At Level 4 (Formal Deduction), they can construct proofs and reason deductively. At Level 5(Rigor), they compare different axiomatic systems. Students must master each level sequentially, and instruction must align with their current level of thinking.

Different studies conducted indicated that students who received lessons using a conventional approach could not achieve the needed learning objectives as provided in the mathematics curriculum (Hassan, 2021). And that student who receives instruction using the Van Hiele approach consistently achieved higher levels of geometric thinking compared to those taught using conventional approach (Cho & Win 2020).

However, Sulistyorini (2018) indicates that, Van Hiele Model can help students to achieve a better understanding of geometry and serve as a framework to develop their geometric Thinking Levels (GTL) up to rigor. In view of this, the present research would use the Model with the hope of developing geometric thinking levels of students' in solving geometric problems in Sokoto metropolis.

Statement of the Problem

Geometry is a crucial component of mathematics education in Nigeria which is needed in various fields such as architecture, engineering, and the sciences, to boost students' spatial reasoning, problem solving skills and critical thinking. However, despite its importance, students in Sokoto continue to face significant challenges in solving geometry problem, exhibiting low levels of geometric thinking and persistent misconceptions. This is evident in their poor performance in mathematics examinations, particularly in Geometry related questions. particularly in areas such as circle geometry and plane geometry, as highlighted in WAEC chief examiners' reports as fluctuating from year by year.

Despite Government efforts to ameliorate the massive failure, several researches have shown that students' difficulties in geometry can be attributed to various factors, including inadequate teaching methods, lack of concrete materials, and students' cognitive unpreparedness. The Van Hiele Model, a theoretical framework that describes how students learn geometry, offers a structural approach to improving geometric thinking levels. The Model proposed that students' progress through levels of geometric thinking, from visualization to rigor, and that instruction should be tailored to their current level.

Objectives

The primary objective of this study was the effectiveness of Van Hiele Model on Student's Geometric Thinking Levels (GTL) among senior secondary school students in Sokoto metropolis. The specific objectives are to:

I. Determine the Geometric Thinking Levels of students taught using Van Hiele Model before and after treatment in Senior Secondary School Students in Sokoto metropolis.

II. Investigate the effectiveness of Van Hiele Model on Geometric Thinking Level scores in Senior Secondary School Students in Sokoto metropolis.

III. Investigate the effectiveness of Van Hiele Model on Geometric Thinking Level scores of male and female Senior Secondary School Students in Sokoto metropolis.

Research Questions

Based on the stated objectives, the following research questions ware used to guide the study.

I. What are the Geometric Thinking Levels of students taught using Van Hiele Model and those taught using conventional approach before and after among Senior Secondary School in Sokoto metropolis?

II. Is there any difference between the Geometric thinking test scores of students taught using Van Hiele Model and those taught using the conventional approach among Senior Secondary School in Sokoto metropolis?

III. Is there any difference between the post-test scores of male and female students taught using Van Hiele Model in Senior Secondary School in Sokoto metropolis?

Hypotheses

The following null hypotheses were formulated and tested at $\alpha = 0.05$ level of significance.

H_{o1}: There is no significant difference between the Geometric Thinking Levels mean scores of Senior Secondary School students taught using Van Hiele Model and those taught using conventional approach in Sokoto metropolis.

H_{o2}: There is no significant difference between the Geometric Thinking Levels mean scores of male and female Senior Secondary School students taught using Van Hiele Model in Sokoto metropolis.

Methodology

The research employed a non-randomized control group pretest posttest quasi-experimental research design. Two groups were selected and assigned experimental and control treatments. Students geometric thinking levels were established. The population consisted of 16,488 students across 48 schools, from which four (4) 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. The instruments used for data collection is Van Hiele Model Geometric Thinking Level Test (VHMGTLT) for measuring SS II Students' Geometric Thinking Levels and Scores, In this regard the test was adopted to measure the students' geometric thinking skills in Sokoto metropolis. The test contains 25-multiple choice questions the first five items represent level 1, second five items represent level 2, the third five items represent level 3, the fourth five items represent level 4, and the last five items represent level 5.

The instruments (VHMGTLT) was validated by expert in the department of science education Sokoto State University and one from the department of Mathematics Shehu Shagari College of Education, Sokoto. The reliability of the instruments Van Hiele Model Geometric Thinking Level Test (VHGTLT) was established using test retest method of testing reliability. The instrument was administered to 25 selected students in the pilot school and the result obtained was analyzed using Pearson product moment correlation coefficient using SPSS v20, and showed reliability coefficients of 0.69 (VHMGTLT). The collection of data in this research were firstly start with pre-test of Van Hiele's Model Geometric Thinking Level test to obtain the characteristics of students' Geometric Thinking Levels. After intervention, post-test were given to obtain the Thinking level of students. In the study, a 6-weeks instruction

was given to the experimental and control groups. Thus, an instruction based on the Van Hiele Model was carried out in the experimental group, and instruction using conventional method was used in the control group. 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 Students 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 Model 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.

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 Geometric Thinking Levels of students taught using Van Hiele model and those taught using conventional approach before and after among Senior Secondary School in Sokoto metropolis?

The Table 3 and 4, provides pretest and post test score summary of students' Van Hiele's Levels of geometric thinking for experimental and control groups.

Table 3: Distribution of pretest scores of experimental group students' Van Hiele's Levels of geometric thinking.

van Hiele's levels	Sum of scores	Levels 1	2	3	4	5	3 out of 5 Correct Answer Criteria	Total (%)
0	0						184	187(83.1%)
	4			*			3	
1	1	*					32	32(14.2%)
2	3	*	*				6	6(2.7%)
3	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-
Total							225	100%

Table 3 shows the distributions of Van Hiele's Model Levels of students Geometric Thinking at the pretest in the experimental group. The result indicated that a total of 187 (83.1%) students in the pretest failed to achieve level 1 of thinking, however, three of the student's skipped levels 1 & 2 and obtained a sum score of 4 marks, thus based on the criteria they were assigned level 0 (pre-recognition) of thinking. Also 32(14.2%) out of 225 achieved 1 mark and were assigned level 1, and six students 6 (2.7%) achieved sum score of 3 marks and were assigned level 2 of Van Hiele's levels of thinking as mentioned in Van Hiele's Model level table.

Table 4: Distribution of students' Van Hiele's Model levels of geometric thinking at the pretest for the control group

van Hiele's levels	Sum of scores	Levels 1	2	3	4	5	3 out of 5 Correct Answer Criteria	Total (%)
0	0						129	129(84.9%
1	1	*					18	18(11.8%)
2	3	*	*				5	5(3.3%)
3	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-

Total	152	100%

Table 4 shows the results of students' Van Hiele Levels of geometric thinking from the pretest scores. The result indicated that 129 (84.9%) students failed to achieve level 1 of thinking based on the criteria. Thus, 18 (11.8%) students' achieved 1 mark and they were assigned level 1 (visualization) and that 5(3.3%) students achieve level 1 & 2 with a sum of 3 marks and were assigned level 2 (analysis) of Van Hiele's level of thinking. However, none of the students achieved level 3, 4 and 5. Thus, analysis of students' level of thinking in posttest for both experimental and control group are provided in Table 5 and 6.

Table 5: The Distribution of students' Van Hiele's Model Levels of geometric thinking of experimental group in the posttest

Van Hiele's levels	**Sum of scores**	**Levels**					**3 out of 5 Correct Answer Criteria**	**Total (%)**
		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 5 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. More so,49 (21.8%) students obtained 3 marks and were assigned level 2. Also 19 (8.4%) of the 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.

Table 6: Distribution of students' van Hiele's levels of geometric thinking of control Group in the Posttest

van Hiele's levels	**Sum of scores**	**Levels**					**3 out of 5 Correct Answer Criteria**	**Total (%)**
		1	**2**	**3**	**4**	**5**		
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 6 shows a total of 23 (15.1%) students failed to achieve level 1 at the post test of Van Hiele Model 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.

Research Question Two

Is there any difference between the Geometric thinking test scores of students taught using Van Hiele Model and those taught using the conventional approach among Senior Secondary School in Sokoto metropolis? This research question was answered using the result of the analysis is provided in Table7.

Table 7: Mean Rank of Students Levels of Geometric Thinking

Variable	N	MeanRank	Difference
Experimental group	225	207.66	46,28
Control group	152	161.38	

Table 7 shows the difference in geometric thinking levels between the two groups, the posttest scores were subjected to a Mann-Whitney U test. The analysis revealed a higher mean rank for the experimental group (207.66) compared to the control group (161.38). This result confirms that students who received instruction through the Van Hiele Model developed higher geometric thinking leves than those who were taught using conventional methods.

Research Question Three

Is there any difference between the post-test scores of male and female students taught using Van Hiele Model in Senior Secondary School in Sokoto metropolis? This research question was answered using the result of the analysis provided in Table 8.

Table 8: Mean Rank of Students Levels of Geometric Thinking in Experimental Group

Variable	N	Mean Rank	Difference
Female	150	118.03	
			15.11

Male	75	102.92

Table 8 shows the difference based on gender, the analysis shows that the sample of female students obtained higher mean rank (118.03) than the sample of male students with a mean rank of (102.93). This shows that the sample of female students have a higher geometric thinking level. The score was further subjected to test hypothesis,

Hypotheses Testing

This section presents the results of null hypotheses testing corresponding to the research questions. Mann-Whitney U test were employed to analyse the data observed between male, female, experimental and control groups are statistically significant. The null hypotheses were tested at $\alpha = 0.05$ level of significance.

Hypothesis One

H_{o1}: There is no significant difference between the Geometric Thinking Levels mean scores of Senior Secondary School students taught using Van Hiele Model and those taught using conventional approach in Sokoto metropolis.

Table 9: Summary of Mann-Whitney U test Analysis for Experimental and Control Groups

Group	N	Mean Rank	Z	U	P-value
Experimental	225	207.66	-4.05	12,902,500	.001
Control	152	161.38			

Table 9 presents the analysis of students GTL 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, Z= -4.05 and a P-value of 0.001. 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 test scores between the experimental and control groups, in favor of experimental group that were taught using Van Hiele Model.

Hypothesis Two

H_{02}: There is no significant difference between the Geometric Thinking Levels mean scores of male and female Senior Secondary School students taught using Van Hiele Model in Sokoto metropolis.

Table 10: Summary of Mann-Whitney U test Analysis for male and female in Experimental Group.

Group	N	Mean Rank	U	Z	P-value
Female	150	118.3	6,380,000	13,848,74	.046
Male	75	102.93			

Table 10 presents the analysis of students GTS based on the H_{o2} whether if there are significant. The results reveal a statistically significant difference between male and female in the experimental group, with U = 6,380,000, Z = 13,848,74 and a P-value of 0.046. 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 between male and female in the experimental group.

Discussion

The finding revealed that the vast majority of students in both experimental and control groups were functioning below Van Hiele Level 1 (Visualization), with only a minimal number reaching Level 1 or 2 and no student attaining higher levels. This outcome empirically confirms the longstanding challenge documented in the literature regarding students' low basic skills in geometry, particularly within the Nigerian context. Hassan (2021) and Hassan et al. (2023) have consistently reported that students in Sokoto display poor foundational geometry skills, which this finding substantiates. Cho & Win (2020) similarly observed that students like their global counterparts, struggle with basic geometric competencies. This low baseline is particularly concerning given that geometry serves as a fundamental cornerstone of the mathematics curriculum, essential for understanding spatial relationships and shapes (Hassan et al., 2023; Ozkan *et al.,* 2018). The absence of students at higher Van Hiele levels reflects the inadequacy of conventional instructional approaches, which Hassan (2020) confirms are not aligned with Van Hiele's Model in Nigerian classrooms.

The finding also demonstrated a striking contrast between the two groups: students taught using the Van Hiele Model achieved remarkable progress, with all reaching at least Level 1 and a significant portion advancing to Level 3 (Informal Deduction), while control group students taught conventionally remained largely below Level 1 with none progressing beyond Level 2. This differential outcome provides robust empirical support for the efficacy of the Van Hiele instructional framework. The experimental group's successful progression through sequential levels validates Hassan et al.'s (2020) assertion that Van Hiele's Model is one of the most effective approaches for helping students achieve geometric thinking levels. Their advancement to Level 3, where students begin to understand relationships between properties, demonstrates mastery of the sequential hierarchy that characterizes Van Hiele's Model. This finding aligns perfectly with Cho & Win (2020) concluded that students receiving Van Hiele-based instruction demonstrate superior understanding of geometric concepts compared to those taught conventionally. Conversely, the control group's stagnation confirms Hassan's (2021) finding that conventional teaching methods fail to achieve the learning objectives outlined in the mathematics curriculum. The differential results also support Sulistyorini's (2018) claim that the Van Hiele Model serves as an effective framework for developing geometric thinking up to higher levels of rigor. Furthermore, this outcome validates the literature's emphasis on the importance of aligning instruction with students' cognitive levels, as Hassan et al. (2023) stress that teachers must understand and teach according to students' current levels of geometric thinking for optimal learning outcomes.

Conclusion

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

Recommendations

I. Mathematics teachers in senior secondary schools should adopt the Van Hiele Model as an instructional strategy for teaching geometry, as it has proven significantly more effective than conventional methods in enhancing students' geometric thinking levels.

II. Curriculum planners and educational policymakers should integrate the Van Hiele Model into the mainstream mathematics curriculum and provide instructional materials that support its implementation.

Suggestions for Further Studies

I. A similar study should be conducted in other states and geopolitical zones across Nigeria to determine whether the effectiveness of the Van Hiele Model in enhancing geometric thinking is consistent across diverse cultural and educational contexts, thereby strengthening the generalizability of the findings.

II. Further research should investigate the long-term retention of geometric thinking levels among students taught using the Van Hiele Model through longitudinal studies, examining whether the gains achieved are sustained over time and whether students continue to progress through higher Van Hiele levels in subsequent academic years.

Reference

Agnes, O. O. (2023). Determining the conceptual and misconceptual. *Journal of Science, Technology and Mathematics Pedagogy, 1*(1), 180–188.

Cho, P. T., & Win, H. (2020). A study of misconceptions about geometry in middle school learners. *Journal of Myanmar Academy of Arts and Science*, 18(9 C), pages 165–182.

Hassan, M. N. (2021). Integrating iSTEM into Van Hiele phases of learning geometry to alleviate students' geometric thinking and attitude towards learning geometry (Unpublished doctoral dissertation). *universiti teknologi malaysia*.

Hassan, M. N., Abdullah, A. H., & Ismail, N. (2020). Effects of VH-iSTEM learning strategy on basic secondary school students' degree of acquisition of Van Hiele levels of thinking in Sokoto State, Nigeria. *Universal Journal of Educational Research, 8*(9), 3799–3807. https://doi.org/10.13189/ujer.2020.080948

Hassan, M. N., Abdullah, A. H., & Ismail, N. (2023). Rethinking strategy on developing students' levels of geometric thinking in Sokoto State, Nigeria. *International Journal of Evaluation and Research in Education, 12*(1), 444–450. https://doi.org/10.11591/ijere.v12i1.23531

Mdyunus, A.S., & Hock, T.T. (2019). Geometric Thinking of Malaysian Elementary School Students. *International Journal of Instruction, 12*(1), 1095–1112.

Ozkan, A., Ozkan, E. M., & Karapıcak, S. (2018). On the misconceptions of 10th grade students about analytical geometry. *Education Research International, 2*(8), 417–426. https://doi.org/10.26855/er.2018.08.002

Sulistyorini, Y. (2018). Error analysis in solving geometry problem on pseudo-thinking students. *Journal of Physics: Conference Series, 160*, 103–107.

Development, 1(1), 1–8.Zakariyya, N. (2023). Effect of Van Hiele's instructional model on students' academic performance and anxiety in geometry. *Journal of Educational Research and Practice, 13*(2), 45–56. https://doi.org/10. /jerp.v13i2.2023 *(replace with actual DOI if available)*