



Comparative Analysis of Van Hiele Instructional Model and Conventional Teaching Method for Effective Learning of Mensuration in Mathematics

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Abstract

This study conducted a comparative analysis of the Van-Hiele instructional model and conventional teaching method to assess their effectiveness in teaching mensuration concepts in mathematics. The research design employed was quasi-experimental. Two schools from Chanchaga Local Government area were selected using purposive sampling technique. The intact classes and students were chosen using simple random sampling, resulting in a total of 205 SSII students (comprising 121 males and 84 females). The researchers developed Mensuration Achievement Test (MAT), which underwent validation by three experts and achieved a reliability coefficient of 0.78 using the Cronbach Alpha formula. Mean, standard deviation, and mean difference, were utilized to address the research questions, while a t-test was applied to test the hypotheses. The results indicated a significant difference in the achievement scores between students taught mensuration concepts in mathematics using the Van-Hiele instructional model and those taught with the conventional teaching method. Moreover, there was no significant difference in the achievement scores of male and female students when taught mensuration using the Van-Hiele instructional model. It was recommended, among other things, that mathematics teachers should incorporate the Van-Hiele instructional model in their instruction of mensuration.

Keywords: Van-Hiele Instructional Model, Conventional Teaching Method, Mensuration, Mathematics, Achievement.

Introduction

Mathematics serves as the foundation of science and technology, encompassing the study of numbers, quantities, patterns, shapes, and space. Its applications extend to various fields such as Biology, Computer Science, Chemistry, Engineering, and Physics (Ahmad & Auwalu, 2021). In the educational system of Nigeria, mathematics is a crucial subject taught at all levels. Within the secondary school curriculum, mathematics is divided into six main areas, one of which is mensuration. Mensuration involves the study of two-dimensional (2-D) and three-dimensional (3-D) shapes, exploring parameters like length, surface area, and volume.

To pursue studies in science and science-related disciplines at tertiary institutions in Nigeria, students are required to achieve a credit pass in the senior secondary school certificate examination

(SSCE). However, student performance in this external examination has been consistently subpar (Aliyu & Ahmad, 2021). Chief Examiners' reports from 2018, 2019, and 2021 have consistently indicated that poor performance in mensuration questions can be attributed to several factors, including curriculum content, instructional materials, and teaching methods. Scholars like Ahmad and Auwal (2021) have also pointed to student anxiety, classroom environment, teacher attitudes, and instructional methods as contributors to this issue. The conventional teaching method, which is widely employed by mathematics teachers, has been labeled as teacher-centered and is criticized for not promoting meaningful and effective learning. This approach allows for comprehensive curriculum coverage, is less time-consuming, and appears efficient (Nurudeen, 2023). Nonetheless, Aliyu and Ahmad



(2021) emphasize that the persistent use of conventional teaching methods is a significant factor affecting mathematics performance, especially in mensuration. They highlight difficulties such as the inability to analyze identified geometric properties and a lack of understanding of formal geometric concepts as challenges that students face in learning geometry, including mensuration. These difficulties significantly influence students' learning experiences in the classroom.

An instructional model that holds promise for assisting learners in gaining a better understanding of mathematics, particularly geometry, is the Van Hiele Instructional Model (VHIM). This instructional strategy empowers mathematics teachers to deliver classroom instruction progressively and effectively, with a focus on assisting students in gaining a deeper understanding, rather than merely being authoritative conveyors of subject matter (Edward et al., 2021). According to Nurudeen (2023), the VHIM provides clear guidance on what both the teacher and students should be doing at each learning phase to promote the learning of geometric concepts. The VHIM was developed by two mathematics educators, Pier van Hiele and Dina Van Hiele, with the intention of improving the teaching and learning of geometric concepts in mathematics (Van Hiele, 1986).

The Van Hiele theory consists of two key operational elements: levels and phases. These elements are integral to the theory, as they describe the hierarchical and cognitive development aspects. The theory emphasizes the importance of the ability to think and reason at different levels within each scientific discipline. Once a particular level of understanding is achieved in one discipline, it becomes easier to attain that level in related disciplines. However, transitioning from one level to the next is not a natural or automatic process; it requires instruction involving the teacher, students, and the subject matter (Sadiki, 2016).

The theory outlines five distinct levels that form the foundation for the Van Hiele Instructional Model (VHIM). These levels guide students in constructing a concrete understanding of the relationships between geometric concepts. The five levels are as follows:

1. **Level one:** Visualization - At this stage, students can identify geometric shapes based on their visual appearance, without necessarily considering their properties.
2. **Level two:** Descriptive/Analytical - In this level, students not only recognize features of shapes but

also learn to use appropriate vocabulary to describe these characteristics.

3. **Level three:** Abstract/Rational - At this stage, students can identify relationships between various properties of shapes and follow logical arguments based on these properties.
4. **Level four:** Deduction - Students at this level can construct geometric proofs using postulates, axioms, and definitions.
5. **Level five:** Rigor - This is the highest level in the model, where students are capable of working with distinct geometric systems in a sophisticated and comprehensive manner.

Van Hiele (1986) asserted that cognitive development in geometry can be enhanced through instructional support. Moving a student from one level of understanding to the next necessitates direct teacher involvement in the processes of exploration and reflection. These processes are time-consuming, and teachers must not only recognize a student's progression through the levels but also be patient and allow students the time they need to advance to the next level.

A study by Emeji et al. (2023) reported an increase in students' thinking levels from pre-recognition to a higher level. This change was attributed to a statistically significant difference in the average scores of students in the experimental group after the intervention, indicating that the Van Hiele instructional model influenced classroom interactions and facilitated learning. The findings also demonstrated that the Van Hiele instructional model contributed to improved geometric thinking among students in the experimental geometry group. Scholars like Vojkurkova (2012), Sadiki (2016), and Nurudeen (2023) have emphasized that adopting Van Hiele's Model (VHM) in geometry instruction effectively rectified students' difficulties in learning geometry, including mensuration, and enhanced their performance.

Furthermore, the Van Hiele instructional model has provided insights for curriculum developers and teachers about its significance in test development and educational improvement. It has been particularly effective in improving learners' geometric thinking through the various levels it employs (Nurudeen, 2023). Scholars like Vojkurkova (2012) and Emeji et al. (2023) have outlined several benefits that can be derived from the Van Hiele instructional model, including:

- i. The model provides mathematics teachers with a framework to conduct geometric activities while considering the specific level of understanding of their students. This



framework guides the development of instructional content and activities tailored to the students' cognitive levels.

- ii. It enhances the learners' geometric thinking abilities and logical reasoning. Additionally, it fosters positive social relationships among various stakeholders in the educational process, including teacher-student relationships and cooperation among students themselves.
- iii. The model creates a conducive learning environment where self-evaluation and active participation in the learning process are encouraged. This encourages students to be more actively engaged in their own learning and helps them reflect on their progress.
- iv. The model also allows learners to ask questions that are appropriate for their current cognitive level or challenge them to think beyond their current level. This promotes intellectual curiosity and fosters a deeper understanding of geometric concepts.

In the Van Hiele Instructional Model (VHIM), effective language communication and cooperation are crucial for students to become successful learners, as this model is centered around the learners themselves. Language plays a pivotal role in helping students move between different cognitive levels and in understanding the structural aspects of the subject matter. Through language, students acquire knowledge, strategies, self-determination, and empathy. Van Hiele (1986) emphasized that the value of this model lies in its proper integration into the teaching phases and should not be seen as a substitute for cognitive development. Simply memorizing facts and applying routine algorithms without genuine understanding represents a form of cognitive stagnation and does not promote the development of reasoning abilities.

The teaching and learning process in this model creates a dynamic environment of generated tasks, encouraging students to explore and reflect on the subject matter as they progress through the five teaching phases (Nurudeen, 2023). These phases are approximately sequential but not discrete, and their implementation in the VHIM includes:

- i. Information or Inquiry
- ii. Directed Orientation
- iii. Explication
- iv. Free Orientation
- v. Integration

Phase One: Information or Inquiry

The first phase in the Van Hiele Instructional Model provides learners with the opportunity to discover the inherent structure and organization within the subject material. For instance, in the context of geometric shapes, this phase involves hands-on exploration and manipulation of physical objects, which helps learners develop their understanding of shapes and their properties. It engages learners in purposeful actions and encourages perceptual experiences that form the foundation for deeper understanding. This phase sets the stage for learners to engage with the subject matter in a tangible and meaningful way.

Phase Two: Directed Orientation

In this phase of the Van Hiele Instructional Model, students or learners progress to a new stage of learning through active discussions and continued manipulation of geometric concepts. Manipulation remains a significant part of the learning process. Students examine shapes by folding and unfolding them, and during this process, they intentionally observe and consider the equalities and relationships between different parts of the figures. This phase encourages students to have a disposition toward exploration, being willing and eager to carry out the assigned operations. It promotes a deeper understanding of the subject matter through hands-on activities and guided discussions.

Phase Three: Exploitation

The third phase of the Van Hiele Instructional Model involves expressing the manipulations of material objects in words. Learners articulate the equalities they have observed, exchange their subjective experiences, and transform this into objective knowledge. During this phase, the geometric figures acquire specific properties, and theorems are formulated. The teacher's role is to introduce the essential technical terms that help formalize and structure this emerging understanding of geometry.

Phase Four: Free Orientation

At this phase the learners comparing symbols with another, by searching for similarities and differences. The learners orient themselves in domain of symbols.



Phase Four: Integration

In this phase, learners engage in comparing symbols with one another as they seek out similarities and differences. This process helps them become more familiar with and orient themselves within the domain of symbols, allowing them to work with abstract representations of geometric concepts.

This study is grounded in the progressivist theory and draws its inspiration from the work of Van Hiele (1986). Van Hiele's theory was developed in response to the challenges posed by Piaget's writings, particularly Piaget's concept of levels of thinking, which significantly influenced the direction of Van Hiele's thinking. Additionally, the theory incorporates structural concepts borrowed from Gestalt theory.

In the theory, the emphasis is placed on the idea that achieving understanding is a more significant goal than the mere acquisition of facts. The theory encompasses three key aspects, which include:

- The sequence of levels of insight, which are clearly defined and represent different stages of cognitive development.
- The properties associated with each level, which detail the specific characteristics and capabilities of learners at each stage.
- The phases of learning, which provide the framework that enables learners to progress through the various levels of understanding in an organized manner.

The Van Hiele theory underscores the importance of thinking and reasoning at various levels within each scientific discipline (Sadiki, 2016). Once a particular level of understanding is achieved in one discipline, it becomes more efficient to attain that level in related disciplines (Vojkurkova, 2012). However, the variation in student performance, particularly in mathematics and mensuration at the secondary level in Nigeria, is not solely attributed to the inherent cognitive differences between individuals. It is strongly influenced by the pedagogical strategies adopted by mathematics teachers (Ahmad & Auwal, 2021; Nuraddeen, 2023). Therefore, the researchers aim to investigate whether implementing the Van Hiele Instructional Model (VHIM) in teaching mensuration can positively impact student achievement.

Furthermore, the influence of gender on students' academic performance in mathematics has been a long-standing concern for educators, parents, and teachers. Research on this topic has yielded mixed findings. Some studies, like Adeniji (2018) and Dalu (2016), suggest that female students may outperform

their male counterparts in mathematics, especially in areas like mensuration. However, other research, as highlighted by Immassuen and Omorogbe (2016), indicates that gender equity is lacking in certain subjects, including mathematics, and that female students may not always have an advantage. Conversely, Okan and Zakari (2017) have argued that girls excel in geometry, while Mwalya (2017) found variations in performance between males and females, with males performing better in measurement and problem-solving and females outperforming in computational skills.

Given these mixed findings, there is a call for further research to explore the impact of the Van Hiele Instructional Model on gender-related academic achievement in mensuration concepts. This study aims to shed light on whether this instructional model can help bridge the performance gap between male and female students in the specific context of mensuration.

Researcher Questions

1. What are the mean scores of students taught mensuration concepts in mathematics through Van Hiele Instructional model and those exposed to conventional teaching method?
2. What are the mean achievement scores of the male and female students taught mensuration concepts in mathematics using Van Hiele instructional model?

Null Hypotheses

The following null hypotheses, which were tested at $\alpha = 0.05$ level of significance

H₀₁: There is no significant difference in the mean achievement scores of students taught mensuration concepts in mathematics through van Hiele Instructional model and conventional teaching method.

H₀₂: There is no significant difference in the mean achievement scores of male and female students exposed to mensuration concepts in mathematics through Van Hiele Instructional model.

Methodology

The study employed a quasi-experimental design with two groups: an experimental group and a control group. To ensure the comparability of the groups, they were pretested to establish their homogeneity. The experimental group was exposed to the Van Hiele Instructional Model (VHIM), while the

control group received instruction using the Conventional Teaching Method (CTM). The study was conducted in the Chanchaga Local Government Area, which comprises seven senior secondary schools with a total of 4,707 SSII students. These schools are distributed across the local government area and follow a coeducational system. Two schools were purposively selected and randomly assigned to the experimental and control groups. From each of these two schools, one intact class was selected using a simple random sampling method. This resulted in a total sample size of 205 SSII students, with 109 students (58 males, 51 females) in the experimental group and 96 students (63 males, 33 females) in the control group.

Two distinct lesson models were developed to teach the groups over a period of 5 weeks, focusing on mensuration concepts in mathematics. The lesson model for the experimental group consisted of the following phases: Information or Inquiry, Directed Orientation, Explication, Free Orientation, and Integration. The control group received instruction based on a conventional lesson model that was adopted and modified from the National Teachers' Institute (NTI, 2010).

Data for the study was collected using the Mensuration Achievement Test (MAT), which had been validated by three experts from Niger State College of Education, Minna and Federal University of Technology, Minna. The validated test was pilot tested on 20 students, and a reliability coefficient of 0.78 was obtained using the Cronbach Alpha formula. Data analysis involved using mean, standard deviation, and mean difference to address the research questions, while a t-test was applied to test the hypotheses at a significance level of 0.05.

Table 2: t-test Analysis of MAT for Experimental and Control Group

Group	N	Mean (\bar{X})	SD	Dt	t.cal	P-value	Remark
Experimental	109	62.34	9.30	203	-20.65	0.000	Sign
Control	96	59.00	12.61				

Table 2 presents the results of the t-test in relation to Ho1. The mean achievement score for the experimental group was 62.34, while the combined control group had a mean of 59.00. The standard deviation for the experimental group was 9.3, and for the control group, it was 12.61. The degrees of freedom (df) for the test were 203, and the t-test

Results

Table 1: Analysis of Mean and Standard Deviation in MAT

Group	N	Mean (X)	SD
Experimental	109	65.34	9.30
Control	96	59.00	12.61
Mean		6.34	
Difference			

The results presented in Table 1 indicate that the mean score of the experimental group was 65.34, with a corresponding standard deviation of 9.30. On the other hand, the control group had a mean score of [mean score of control group], and their standard deviation was [standard deviation of control group]. It's worth noting that the experimental group had a higher mean score compared to the control group, with a mean difference of 6.34 points.

Additionally, the higher standard deviation observed in the control group suggests that their individual scores exhibited more variation or deviation from the group's mean compared to the students in the experimental group. This could imply that the differences in individual performance within the control group were more pronounced than in the experimental group. The data suggests that the higher mean score observed in the experimental group may indeed be a valid reflection of their better performance as it appears, given the smaller standard deviation, which indicates less variability in their scores compared to the control group.

statistic was -20.65, while the p-value at the alpha level of 0.05 was found to be 0.000.

Based on the decision rule, Ho1, which likely pertained to the hypothesis of no difference between the Van Hiele Instructional Model (VHIM) and the Conventional Teaching Method (CTM), was rejected. Therefore, the findings indicate a significant difference between the two teaching methods,

suggesting that one of them likely led to higher achievement scores compared to the other.

Table 3: Analysis of mean and standard deviation in MAT

Group	N	Mean (\bar{X})	SD
Males	58	63.00	13.36
Females	51	61.72	12.94
Mean Difference		1.28	

Table 3 provides a breakdown of the mean achievement scores for male and female students who were taught mensuration concepts in mathematics using the Van Hiele Instructional Model (VHIM). The

mean achievement scores are reported as 63.00 for male students and 61.72 for female students. There appears to be a slight mean difference in achievement between male and female students. However, this difference is not significant, as indicated by the relatively small variation in the mean scores and the similar standard deviations of 13.36 for males and 12.94 for females. To determine whether this mean difference is statistically significant or not, the null hypothesis H_{02} was subjected to a t-test analysis, as provided in Table 4. The results of this analysis will help clarify whether the observed difference between male and female students' achievement is statistically meaningful or if it could have occurred due to random chance.

Tables 4: t-test Analysis of Male and Female Students in MAT

Group	N	Mean (\bar{X})	SD	Df	t-test	p-value	Remarks
Males	58	63.00	13.36	107	1.35	0.18	Sign
females	51	61.72	12.94				

Based on the results presented in Table 4, the degree of freedom for the t-test was 107, the t-test statistic was 1.35, and the p-value at the 0.05 level of significance was 0.18. In accordance with the decision rule, H_{02} , which likely pertained to the hypothesis that there is no significant difference between the academic achievement of male and female students in the study, was retained. This implies that the observed difference in academic achievement between male and female students is not statistically significant. The data does not provide sufficient evidence to conclude that one gender outperformed the other in terms of academic achievement in this study.

Discussion

The results of the statistical analyses related to research question one and null hypothesis one indicates that there is a significant difference in the mean achievement scores of students taught mensuration concepts in mathematics using the Van Hiele Instructional Model (VHIM) compared to those taught using the Conventional Teaching Method (CTM). This suggests that the Van Hiele Instructional Model significantly enhances the academic achievement of the experimental group. These findings align with prior research by Sadiki (2016), Edward et al. (2021), and Nurudeen (2023), all of

whom have reported that using the Van Hiele Instructional Model to teach geometric concepts promotes learning by fostering interaction and relationships among the teacher, students, and the subject matter. This interaction and relationship-building contribute to the cognitive development of learners, and, as a result, the VHIM facilitates active classroom interaction and aids in the learning process. The results also indicate that male students achieved slightly higher scores in mensuration concepts compared to their female counterparts. However, the findings suggest that this difference is not statistically significant. In other words, the Van Hiele Instructional Model is gender-friendly, and it does not favor one gender over the other. These findings are in agreement with the studies of Adeniji (2018) and Nurudeen (2023), which suggest that both male and female students achieve equally when exposed to mensuration concepts using the Van Hiele Instructional Model. Consequently, the Van Hiele Instructional Model can effectively assist learners in gaining a deeper understanding of mathematical concepts and progressing in their cognitive development. Van Hiele's belief that cognitive development can be promoted through instruction, involving students directly in the processes of exploration and reflection, appears to be validated by the study's findings.



Conclusion

Based on the results obtained from this study, it is clear that the experimental group, which was taught using the Van Hiele Instructional Model (VHIM), achieved significantly higher academic performance compared to the control group, which was taught using the Conventional Teaching Method (CTM). This suggests that VHIM is an effective instructional model for enhancing the academic achievement of senior secondary school students in the area of mensuration concepts in mathematics. The findings support the idea that VHIM can provide students with a more comprehensive and effective learning experience in this particular mathematical domain.

Additionally, the study revealed that VHIM is gender friendly. It was observed that VHIM led to increased academic achievement for both male and female students, effectively bridging the academic gap between the two genders. This demonstrates the model's ability to promote equal opportunities and outcomes for students of different genders in the context of mensuration concepts in mathematics. Overall, the study's findings highlight the potential of the Van Hiele Instructional Model to improve academic performance and promote gender equity in mathematics education.

Recommendations

Based on the study's findings and conclusions, the following recommendations can be made:

1. The Van Hiele Instructional Model is highly recommended for teaching mensuration concepts and other mathematical topics, as it has proven to be effective in improving academic achievement.
2. It is essential to provide adequate instructional materials to support the implementation of the Van Hiele Instructional Model, as these materials can enhance the teaching and learning experience, especially in subjects like mathematics.
3. Mathematics teachers should receive induction training and ongoing professional development through conferences, workshops, and seminars to ensure they are well-prepared to effectively use the Van Hiele Instructional Model in the classroom.

By adopting these recommendations, educational institutions can enhance the quality of

mathematics education, foster better student performance, and promote a more equitable learning environment for all students.

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