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Gender Differences in Van Hiele Geometric Thinking Levels Among Ghanaian Senior High School Students

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Charles Siaw Obeng
Department of Teacher Education
Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana

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Abstract
This study investigated whether gender differences exist in the Van Hiele geometric thinking levels of Year Three Senior High School students in the Asante Akim South Municipality, Ghana. Specifically, the study examined whether significant differences existed in the overall geometric thinking levels between male and female students and whether gender differences occurred across the individual Van Hiele geometric thinking levels. A quantitative descriptive cross-sectional research design was employed. The study involved 320 Year Three students selected from three public senior high schools using proportionate stratified random sampling. Data were collected using the Van Hiele Geometry Test (VHGT) developed by Usiskin (1982). Descriptive statistics, an independent samples *t*-test, and a chi-square test were used to analyze the data. Male students recorded a slightly higher mean geometric thinking level (M = 2.22, SD = 0.79) than female students (M = 2.07, SD = 0.84); however, the difference was not statistically significant, $t(318) = 1.86$, $p = .065$. Similarly, the chi-square test revealed no statistically significant association between gender and students' distribution across the Van Hiele geometric thinking levels, $\chi^2 = 2.38$, $p = .30$. The findings indicate that gender does not significantly influence students' overall geometric thinking levels or their progression through the Van Hiele hierarchy. The study concludes that male and female students demonstrate comparable levels of geometric reasoning. It is therefore recommended that geometry instruction should emphasize learner-centered teaching strategies and rich instructional experiences that enhance geometric thinking for all students rather than adopting gender-specific instructional approaches.

Keywords: Van Hiele geometric thinking, gender differences, geometry education, senior high school students, Van Hiele Geometry Test, Ghana

Introduction

Background of the study

Mathematics plays a vital role in scientific, technological, and socio-economic development, with geometry serving as one of its fundamental branches. Geometry enables learners to develop spatial visualization, logical reasoning, problem-solving abilities, and critical thinking skills that are essential for success in mathematics and related disciplines (Jones, 2002). Because of its practical applications in engineering, architecture, science, and everyday life, geometry has become an important component of mathematics education worldwide.

Despite its importance, geometry remains one of the most challenging areas of mathematics for many students. Reports from the West African Examinations Council (WAEC) have consistently shown that Ghanaian Senior High School students experience difficulties in solving geometry-related questions, resulting in poor performance in national examinations (WAEC, 2020). These persistent challenges have prompted mathematics educators and researchers to investigate factors that influence students' understanding of geometric concepts. The Van Hiele Theory of Geometric Thinking, developed by Pierre and Dina Van Hiele, provides a widely accepted framework for understanding how students develop geometric reasoning. According to the theory, learners progress through five hierarchical levels of geometric thinking, namely Visualization, Analysis, Informal Deduction, Deduction, and Rigor (Van Hiele, 1986). Advancement through these levels depends largely on instructional experiences rather than biological characteristics, suggesting that effective teaching plays a critical role in improving students' geometric understanding.

One demographic factor that has attracted considerable attention in mathematics education research is gender. Researchers have long debated whether male and female students differ in their ability to reason geometrically. Some studies have reported that male students demonstrate higher geometric thinking levels than female students, particularly in tasks involving spatial visualization and higher-order reasoning (Hamzeh, 2017; Nopriana, 2023). Other studies, however, have found no statistically significant gender differences in geometric thinking, suggesting that both male and female students are capable of achieving similar levels of geometric reasoning when provided with appropriate instructional opportunities (Halat, 2008; Patkin, 2014).

Within the Ghanaian context, research on students' geometric thinking has primarily focused on determining students' Van Hiele levels and improving geometry instruction. Studies by Asemani et al. (2017), Armah et al. (2017), and Anas et al. (2020) reported that many Ghanaian students operate at the lower Van Hiele levels, indicating limited geometric reasoning abilities. Although these studies have contributed significantly to understanding students' geometric thinking, relatively few have specifically examined whether male and female Senior High School students differ significantly in their overall geometric thinking levels and across the individual Van Hiele levels. The inconsistent findings reported in international studies and the limited empirical evidence within the Ghanaian Senior High School context underscore the need for further investigation. Understanding whether gender influences students' geometric thinking is important for designing equitable instructional strategies and ensuring that both male and female students receive appropriate support in geometry learning. This study therefore investigates whether significant gender differences exist in the overall Van Hiele geometric thinking levels and across the individual Van Hiele geometric thinking levels among Year Three Senior High School students in the Asante Akim South Municipality, Ghana.

Statement of the Problem

Geometry is a fundamental component of mathematics education because it develops students' spatial reasoning, logical thinking, and problem-solving skills. Despite its importance, students continue to perform poorly in geometry at the Senior High School level in Ghana, as reflected in the West African Examinations Council (WAEC) Chief Examiners' Reports and findings from previous studies. Research has shown that many Ghanaian students operate at the lower Van Hiele levels of geometric thinking, indicating limited understanding of geometric concepts and relationships (Asemani et al., 2017).One issue that has received considerable attention in mathematics education is whether male and female students differ in their geometric thinking abilities. Although several international studies have investigated gender differences in Van Hiele geometric thinking levels, their findings remain inconclusive. Some studies have reported that male students demonstrate higher levels of geometric reasoning than female students (Hamzeh, 2017; Nopriana, 2023), whereas others have found no statistically significant gender differences (Halat, 2008; Patkin, 2014). These inconsistent findings make it difficult to determine whether gender significantly influences students' geometric thinking.

In Ghana, existing studies have largely focused on determining students' Van Hiele geometric thinking levels and improving geometry instruction. However, relatively few studies have specifically examined whether significant gender differences exist in the overall Van Hiele geometric thinking levels and across the individual Van Hiele levels among Senior High School students. Furthermore, there is limited empirical evidence from the Asante Akim South Municipality, where no known study has comprehensively investigated gender differences in students' geometric thinking using both independent samples *t*-tests and chi-square analysis.

The absence of empirical evidence on gender differences in geometric thinking within this context creates a knowledge gap that may limit the development of evidence-based instructional strategies aimed at promoting equity in geometry education. It is therefore necessary to investigate whether male and female Year

Three Senior High School students differ significantly in their overall Van Hiele geometric thinking levels and across the individual Van Hiele levels. The findings of this study are expected to contribute to mathematics education research and provide evidence to support geometry instruction that promotes equal learning opportunities for both male and female students.

General Objective

To investigate whether gender differences exist in the geometric thinking levels of Year Three Senior High School students in the Asante Akim South Municipality.

Specific Objectives

1. To determine whether there is a significant difference in the overall Van Hiele geometric thinking levels between male and female students.
2. To determine whether there are significant gender differences across the individual Van Hiele geometric thinking levels.

Research Questions

This study seeks to answer the following research questions:

RQ1: Is there a significant difference in the overall Van Hiele geometric thinking levels between male and female students?

RQ2: Are there significant gender differences across the individual Van Hiele geometric thinking levels?

Research Hypotheses

H_{01}: There is no statistically significant difference in the mean Van Hiele geometric thinking levels between male and female students.

H_{11}: **There is a statistically significant difference in the mean Van Hiele geometric thinking levels between male and female students.**

H_{02}: **There is no statistically significant gender difference across the individual Van Hiele geometric thinking levels.**

H_{12}: **There is a statistically significant gender difference across the individual Van Hiele geometric thinking levels.**

Literature Review

Introduction

This chapter reviews the literature related to gender differences in students' geometric thinking levels based on the Van Hiele theory. The review focuses on the theoretical foundations of geometric thinking, empirical studies on gender differences in geometry learning, and previous studies conducted internationally, in Africa, and in Ghana. The review is organized according to the objectives and research questions of the study, which seek to determine whether significant gender differences exist in the overall Van Hiele geometric thinking levels and across the individual Van Hiele levels among Year Three Senior High School students.

Theoretical Foundation

The study is anchored on the Van Hiele Theory of Geometric Thinking developed by Pierre and Dina Van Hiele in the 1950s. The theory explains that students progress through five hierarchical levels of geometric understanding: Visualization, Analysis, Informal Deduction, Deduction, and Rigor. According to Van Hiele (1986), learners cannot move to a higher level until they have mastered the preceding level, and progression depends primarily on instruction rather than age or gender.

The theory further explains that meaningful geometry instruction should correspond to the learner's current level of thinking. When instruction is matched to students' cognitive development, learners gradually develop more advanced reasoning skills. Since the present study investigates whether gender influences students' geometric thinking levels, the Van Hiele theory provides an appropriate framework for classifying students according to their level of geometric reasoning and comparing male and female students.

Constructivist Learning Theory also supports this study by emphasizing that learners actively construct knowledge through exploration and interaction with geometric concepts. Similarly, Piaget's Cognitive Development Theory explains that logical reasoning develops progressively as learners mature cognitively. Together, these theories suggest that although learners may differ in learning experiences, progression in geometric thinking depends mainly on instruction and cognitive development rather than biological characteristics such as gender.

Empirical Review

Gender Differences in Overall Van Hiele Geometric Thinking Levels

Several international studies have examined whether male and female students differ in their overall geometric thinking levels. Hamzeh (2017) investigated Jordanian secondary school students and reported that male students demonstrated slightly higher geometric thinking levels than female students. The study suggested that differences in classroom participation and spatial reasoning activities contributed to the observed variation. Similarly, Fitriyani et al. (2020) found that male students showed greater potential for improvement in geometric reasoning than females during geometry instruction.

Likewise, Nopriana (2023) examined prospective mathematics teachers and reported that male students performed better at the higher Van Hiele levels, particularly at the rigor level. Sayin (2015) also reported that gender significantly influenced students' geometric thinking levels, with males generally outperforming females.

However, several studies have produced contrary findings. Halat (2008) found no statistically significant difference between male and female mathematics teachers in their geometric thinking levels. Similarly, Patkin (2014) reported that gender had no significant influence on teachers' geometric reasoning abilities. These findings support the proposition of the Van Hiele theory that instructional experiences, rather than gender, determine students' progression through the Van Hiele levels.

In Ghana, Salifu (2018) found no statistically significant gender difference in overall geometric thinking among students except at one higher level of reasoning. Similarly, Anas et al. (2020) emphasized that instructional strategies were more influential than gender in determining students' geometric thinking development. These findings suggest that differences observed between male and female students may be attributed more to classroom experiences than to gender itself.

The reviewed literature presents mixed findings regarding gender differences in overall Van Hiele geometric thinking. While some studies report male superiority, others conclude that gender has little or no influence. These inconsistencies justify the need for further investigation among Year Three Senior High School students in the Asante Akim South Municipality.

Gender Differences across the Individual Van Hiele Levels

Apart from comparing overall geometric thinking levels, several researchers have investigated whether male and female students differ at specific Van Hiele levels.

Fitriyani et al. (2020) reported that male students demonstrated stronger performance at the visualization and analysis levels, whereas female students performed relatively better in verbal explanations of geometric concepts. Similarly, Maharani et al. (2019) found that male students excelled in visual and spatial reasoning tasks, while female students demonstrated stronger communication skills when explaining geometric ideas. Hamzeh (2017) also observed gender-related differences across specific Van Hiele levels among Jordanian students. The study reported that male students were more likely to attain higher levels of geometric reasoning than female students.

In contrast, Salifu (2018) found no statistically significant gender differences across most Van Hiele levels among Ghanaian students, except at the formal deduction level where female students slightly outperformed males. Halat (2008) similarly reported no significant gender differences across the Van Hiele hierarchy.

These inconsistent findings indicate that gender differences at individual Van Hiele levels remain inconclusive. While some studies suggest that males perform better at certain levels, others report no significant differences. Consequently, further investigation is required to determine whether male and female students differ significantly across the individual Van Hiele levels in the Ghanaian context.

Studies on Van Hiele Theory in Ghana

Research conducted in Ghana consistently shows that many students operate at the lower Van Hiele levels.

Asemani et al. (2017) found that a large proportion of Senior High School students had not progressed beyond the visualization and analysis levels, with very few students attaining higher-order geometric reasoning. Armah (2017) similarly reported inadequate geometric thinking skills among pre-service mathematics teachers. Anas et al. (2018) observed generally low performance on the Van Hiele Geometry Test among teacher trainees and recommended increased emphasis on geometry instruction based on the Van Hiele learning phases. Bonyah (2021) further recommended strengthening geometry instruction in teacher education programmes to improve students' reasoning abilities.

Although these Ghanaian studies provide valuable information on students' geometric thinking levels, relatively few have specifically examined gender differences using both independent samples t-tests and chi-square analysis across the individual Van Hiele levels. Furthermore, limited evidence exists for Year Three Senior High School students in the Asante Akim South Municipality. The present study therefore contributes to the existing literature by addressing this gap.

Research Gap

The reviewed literature indicates inconsistent findings regarding gender differences in students' geometric thinking levels. While some studies report significant differences favouring male students, others conclude that no significant gender differences exist. Most Ghanaian studies have concentrated on describing students' Van Hiele levels without examining gender differences comprehensively across both the overall geometric thinking levels and the individual Van Hiele levels.

Furthermore, limited research has focused on Year Three Senior High School students in the Asante Akim South Municipality. This study therefore fills this gap by investigating whether significant gender differences exist in overall Van Hiele geometric thinking levels and across the individual Van Hiele levels using independent samples t-tests and chi-square analysis. The findings are expected to contribute to mathematics education research and provide evidence for improving geometry instruction in Ghana.

Conceptual Framework

The conceptual framework for this study is based on the Van Hiele Theory of Geometric Thinking, which explains that students progress through hierarchical levels of geometric reasoning through appropriate instruction and learning experiences. The framework assumes that gender is the independent variable, while students' Van Hiele geometric thinking level is the dependent variable. The study seeks to determine whether gender influences students' overall geometric thinking levels and their distribution across the individual Van Hiele levels. The findings will establish whether male and female students differ significantly in their geometric reasoning abilities.

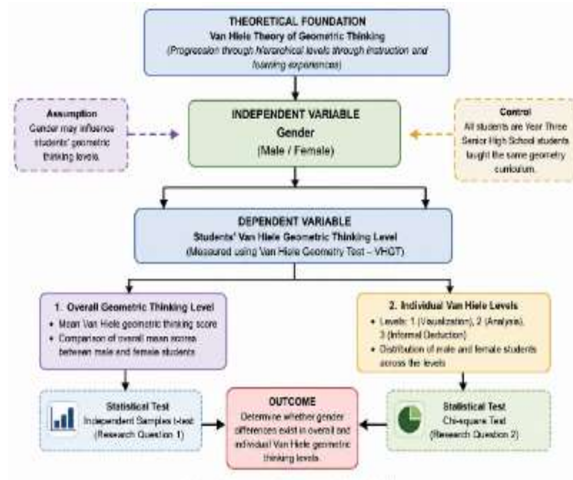

Figure 1. Conceptual Framework Showing the Relationship between Gender and Students' Van Hiele Geometric Thinking Levels.

Explanation of the Framework

The conceptual framework illustrates the relationship investigated in this study. Gender serves as the independent variable and is categorized into male and female students. The dependent variable is students' Van Hiele geometric thinking level, measured using the Van Hiele Geometry Test (VHGT). The framework proposes that gender may influence students' overall geometric thinking levels as well as their distribution across the individual Van Hiele levels. These relationships are examined using an independent samples *t*-test to compare the overall mean geometric thinking levels of male and female students and a chi-square test to determine whether gender differences exist across the individual Van Hiele levels.

This framework is directly aligned with the study's objectives:

1. To determine whether there is a significant difference in the overall Van Hiele geometric thinking levels between male and female students.
2. To determine whether there are significant gender differences across the individual Van Hiele geometric thinking levels.

Research Methodology

Research Design

A quantitative descriptive cross-sectional research design was employed to investigate whether gender differences exist in the geometric thinking levels of Year

Three Senior High School students in the Asante Akim South Municipality. The design was considered appropriate because it enabled the researcher to collect quantitative data from a large number of students at a single point in time and compare the geometric thinking levels of male and female students using inferential statistical techniques. The study focused on describing students' Van Hiele geometric thinking levels and determining whether statistically significant gender differences existed in the overall geometric thinking levels and across the individual Van Hiele levels.

Population

The study was conducted in the Asante Akim South Municipality of the Ashanti Region of Ghana. The target population comprised all Year Three (SHS 3) students enrolled in the three public senior high schools in the municipality during the 2024/2025 academic year**.** These schools were selected because they implement the standardized mathematics curriculum prescribed by the Ghana Education Service (GES), thereby providing a comparable educational setting for investigating students' geometric thinking levels.

The total target population consisted of 898 Year Three students, distributed across the three schools as follows:

- **School A:** 515 students
- **School B:** 298 students
- **School C:** 85 students

This population provided an appropriate basis for investigating whether gender differences exist in students' Van Hiele geometric thinking levels within the municipality.

Sampling Procedure and Sample

A combination of purposive sampling**,** proportionate stratified random sampling, and simple random sampling was employed to select participants for the study.

First, the three public senior high schools in the Asante Akim South Municipality were **purposively selected** because they constitute the public second-cycle schools within the municipality and provide a representative picture of the educational context. Furthermore**,** School A is located in the municipal capital, whereas Schools B and C are located in rural communities, allowing the study to capture students from different geographical settings.

Second, proportionate stratified random sampling was used to determine the number of students selected from each school. Each school constituted a stratum, and the sample allocated to each school was proportional to its Year Three student population.

Within each school, the student population was further stratified by gender (male and female**)**. Thereafter**,** simple random sampling was used to select the required number of male and female students from each gender stratum. This ensured that every eligible student had an equal chance of being selected while maintaining proportional representation of both schools and gender groups in the final sample (Cohen et al., 2007).

The proportional allocation of the sample was determined using:

$$n_h = \frac{N_h}{N} \times n$$

where n_h is the sample size selected from stratum h, N_h is the population size of the stratum h, N is the total population size (898), n is the total sample size (320)

Using this procedure, the sample comprised:

School	Population (N)	Sample (n)	Sampling Fraction (%)
A	515	184	35.73
B	298	106	35.57
C	85	30	35.29
Total	**898**	**320**	**35.63**

The final sample consisted of **320 Year Three students**, comprising **186 females (58.13%)** and **134 males (41.88%)**. This sampling procedure ensured that the sample accurately reflected the composition of the target population and enhanced the representativeness of the study findings.

Instrument (Revised)

The **Van Hiele Geometry Test (VHGT)** developed by **Usiskin (1982)** was used to assess the geometric thinking levels of the participants. The VHGT is a standardized multiple-choice instrument designed to classify students according to the Van Hiele Theory of Geometric Thinking**.** The instrument consists of **25** multiple-choice items, with five items assessing each of the five hierarchical Van Hiele levels: Visualization, Analysis, Informal Deduction, Deduction, and Rigor.

Students' responses were scored using **Usiskin's (1982)** scoring procedure. A student was considered to have attained a particular Van Hiele level if he or she answered at least three of the five questions correctly at that level. Each student was then assigned the highest Van Hiele level attained, resulting in one geometric thinking level for each participant.

The present study adopted **Usiskin's (1982) numbering convention**, in which the five levels are designated as:

- **Level 1 – Visualization**

- **Level 2 – Analysis**
- **Level 3 – Informal Deduction**
- **Level 4 – Deduction**
- **Level 5 – Rigor**

This numbering differs from the original Van Hiele model, where the visualization stage is designated as **Level 0**. Usiskin renumbered the hierarchy to begin with **Level 1**, and this convention has been widely adopted in studies that use the Van Hiele Geometry Test (VHGT). Consequently, Level 0 does not appear in this study because the instrument follows **Usiskin's** numbering system rather than the original Van Hiele numbering**.**

Although the VHGT assesses all five hierarchical levels, analysis of the data showed that the participants attained **only** Levels 1 (Visualization), 2 (Analysis), and 3 (Informal Deduction)**.** No student attained Level 4 (Deduction)**.** Since the Van Hiele theory proposes that learners progress sequentially through the hierarchy, students who do not attain Level 4 cannot attain **Level 5 (Rigor)**. Therefore, only **Levels 1–3** are presented and discussed in the results section. This presentation reflects the actual performance of the participants rather than any limitation of the instrument.

Reliability and Validity of the Instrument

A pilot study involving 37 Year Three Senior High School students was conducted to establish the reliability of the Van Hiele Geometry Test before the main data collection. Internal consistency was estimated using the Kuder–Richardson Formula 20 (KR-20) because the instrument comprised dichotomously scored multiple-choice items. The analysis produced a KR-20 reliability coefficient of 0.77, indicating acceptable internal consistency and confirming that the instrument was sufficiently reliable for the study.

The face validity and content validity of the instrument were established through expert review by **two** experienced mathematics educators. The experts evaluated the clarity, relevance, appropriateness, and alignment of the test items with the Ghana Senior High School Mathematics Curriculum and the constructs measured by the Van Hiele Theory. Their recommendations were incorporated into the final version of the instrument before it was administered to the participants.

Data Collection Procedure

Permission to conduct the study was obtained from the heads of the selected public senior high schools in the Asante Akim South Municipality before the commencement of data collection. Following approval, the purpose of the study was explained to the participants, and informed consent was obtained before the administration of the instrument. The Van Hiele Geometry Test (VHGT), developed by Usiskin (1982), was administered under standardized examination conditions in February 2025. Participants were given 45 minutes to complete the 25-item multiple-choice test.

The VHGT comprises 25 items**, with** five items assessing each of the five hierarchical Van Hiele geometric thinking levels: Visualization, Analysis, Informal Deduction, Deduction, and Rigor. Students' responses were scored according to the classification procedure proposed by **Usiskin (1982)**. A student was considered to have attained a particular Van Hiele level after correctly answering at least three of the five items associated with that level. Each participant was then assigned the highest Van Hiele level attained, resulting in one geometric thinking level for every student.

Consequently, the dataset consisted of 320 individual student observations, with each student representing one case in the database. The individual Van Hiele level assigned to each participant was entered into **IBM SPSS** Statistics Version 26 for analysis. The software computed the descriptive statistics, including the overall **mean (M = 2.13) and** standard deviation (SD = 0.82)**,** from these 320 individual observations.

The frequencies and percentages reported in the results section were subsequently generated by summarizing the number of students who attained each Van Hiele level. Thus, the descriptive statistics were calculated from the individual student-level data rather than from the frequency table itself. For example, if four students attained Level 2 and five students attained Level 1, SPSS first recorded the individual observations (2, 2, 2, 2, 1, 1, 1, 1, 1) before computing the overall mean and standard deviation. The frequency distribution was then produced by counting the number of students assigned to each Van Hiele level.

This procedure ensured that the descriptive and inferential statistics were based on the complete set of individual student observations and accurately represented the geometric thinking levels of the participants.

Data Analysis

The collected data were coded and entered **into** IBM SPSS Statistics Version 26 for analysis. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize the participants' geometric thinking levels.

To address Research Question One **and test** Hypothesis **H_{01}**, an independent samples t-test was conducted to determine whether a statistically significant difference existed between the mean Van Hiele geometric thinking levels of male and female students.

To address Research Question Two and test Hypothesis H_{02}**, a** chi-square test of independence was performed to determine whether gender was significantly associated with students' distribution across the individual Van Hiele geometric thinking levels.

For all inferential analyses, statistical significance was determined at the **0.05 level (α = 0.05)**. The results are presented using tables, accompanied by appropriate interpretations and discussions based on the study objectives. This analytical approach was selected because it aligns with the study's objectives and the nature of the variables investigated.

Results

Descriptive statistics of overall van Hiele levels by gender

Table 2

Independent Samples t-test Analysis of Gender Differences in Van Hiele Levels

Gender	N	Mean	SD
Male	134	2.22	0.79
Female	186	2.07	0.84

***t* (318) = 1.86, *p* = .065**

Hypothesis Testing

Based on the results of the analysis, the null hypothesis (H_01), which stated that there is no statistically significant difference between male and female students in their geometric thinking levels, is not rejected. The findings indicate that there is no statistically significant difference between male and female students in relation to their geometric thinking performance.

Interpretation

Although male students recorded slightly higher mean scores than female students, the observed difference is minimal and not statistically significant. This suggests that gender does not have a meaningful influence on students' geometric thinking levels within the selected schools. Both male and female students therefore demonstrate relatively comparable abilities in geometric reasoning.

Comparison with Previous Studies

The findings of this study are consistent with the work of Mensah and Boateng (2021), who also reported no significant gender differences in students' mathematics performance in similar contexts. However, the results contrast with Weber (1995), who found significant gender-based differences in mathematical reasoning in earlier studies. The present findings therefore suggest that increased educational equity and improved access to learning opportunities may be contributing to the reduction of gender gaps in mathematics education in Ghana.

Table 3

Chi-square Test of Gender Differences across Van Hiele Levels.

Level	Male (%)	Female (%)
1	36.57	32.26
2	44.78	42.47
3	18.65	25.27

Chi-square = 2.38, *p* = .30

Hypothesis Testing

Based on the results of the analysis, the null hypothesis (H_02), which stated that there is no statistically significant gender difference at each Van Hiele level, is not rejected. The findings indicate that there is no significant difference between male and female students across the different Van Hiele levels of geometric thinking.

Interpretation

The results reveal that both male and female students are similarly distributed across the Van Hiele levels. This suggests that gender does not influence the stage at which students operate within the hierarchy of geometric thinking. In essence, male and female students demonstrate comparable progression through the Van Hiele levels, indicating a level of gender equity in geometric reasoning development among the sampled students.

Comparison with Previous Studies

The findings of this study are consistent with Agyeman (2018), who also reported no significant gender differences in students' progression through geometric thinking levels. They further align with the theoretical propositions of Van Hiele (1986), which emphasize that progression through geometric thinking levels is more dependent on instructional experiences and cognitive development rather than gender differences.

Discussion of Findings

The discussion of the findings is presented in relation to the two research questions, namely whether significant gender differences exist in the overall Van Hiele geometric thinking levels and whether significant gender differences exist across the individual Van Hiele geometric thinking levels among Year Three Senior High School students.

Regarding the first research question, the independent samples t-test revealed that there was no statistically significant difference in the overall Van Hiele geometric thinking levels between male and female students ($t(318) = 1.86$, $p = .065$). Although male students obtained a slightly higher mean score (M = 2.22, SD = 0.79) than female students (M = 2.07, SD = 0.84), the observed difference was not statistically significant. This finding suggests that both male and female students possess comparable levels of geometric thinking and that gender does not significantly influence students' overall geometric reasoning abilities.

The findings are consistent with those of Halat (2008), who reported no statistically significant gender differences in Van Hiele geometric thinking levels among mathematics teachers. Similarly, Patkin (2014) found that gender had no significant effect on geometric thinking among pre-service and in-service teachers. Within the Ghanaian context, Salifu (2018) also reported that male and female students demonstrated comparable geometric thinking abilities, with no significant gender differences at most Van Hiele levels. These findings support the proposition of the Van Hiele Theory that progression through the hierarchical levels of geometric thinking depends primarily on instructional experiences and learning opportunities rather than gender (Van Hiele, 1986).

The second research question examined whether significant gender differences existed across the individual Van Hiele geometric thinking levels. The chi-square analysis indicated that there was no statistically significant association between gender and students' distribution across the Van Hiele levels ($\chi^2 = 2.38$, $p = .30$). Although minor differences were observed in the proportions of male and female students at Levels 1, 2, and 3, these differences were not statistically significant. This indicates that male and female students progress through the Van Hiele hierarchy in a similar manner and attain comparable levels of geometric reasoning.

This finding agrees with Halat (2008), who concluded that gender does not significantly influence learners' progression through the Van Hiele levels. It is also consistent with the findings of Agyemang et al. (2022), who reported that male and female students were similarly distributed across the lower Van Hiele levels. However, the findings differ from those of Hamzeh (2017), Fitriyani et al. (2020), and Nopriana (2023), who found that male students demonstrated higher geometric thinking levels than female students. The differences between these studies and the present study may be attributed to variations in educational contexts, instructional approaches, sample characteristics, and assessment methods.

Overall, the findings of this study suggest that gender is not a significant determinant of students' geometric thinking levels among Year Three Senior High School students in the Asante Akim South Municipality. The absence of statistically significant gender differences indicates that both male and female students have similar opportunities to develop geometric reasoning when exposed to comparable instructional experiences. Consequently, efforts to improve students' geometric thinking should focus on enhancing the quality of geometry instruction, promoting learner-centred teaching approaches, and providing adequate learning resources rather than emphasizing gender-specific instructional strategies.

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APPENDICES

Appendix A:

Section A:

Adapted Van Hiele Geometry Test (Based on Usiskin, 1982)

This instrument was adapted from Usiskin (1982) to assess students' levels of geometric thinking. It consists of 25 multiple-choice items distributed across the five Van Hiele levels: Visualization, Analysis, Informal Deduction, Deduction, and Rigor. Students select the one best answer for each item.

Level 1 – Visualization

1. Which of the following figures is a square?
   (a) A shape with all sides equal and all right angles
   (b) A shape with two long sides and two short sides
   (c) A triangle with equal sides
   (d) A shape with curved sides

2. Which figure below is not a triangle?
   (a) A shape with three sides
   (b) A figure with four corners
   (c) A figure with three corners
   (d) A closed figure made of three straight lines

3. A rectangle can best be recognized because:
   (a) It looks like a box
   (b) It has four right angles
   (c) It has all sides equal
   (d) It has only two right angles

4. Which figure is a circle?
   (a) A figure with three equal sides

(b) A figure with no corners
(c) A figure with four sides
(d) A figure with two equal sides

5. Which of the following figures is not a polygon?
(a) Triangle
(b) Rectangle
(c) Circle
(d) Pentagon

Level 2 – Analysis

6. Which statement about a parallelogram is true?
(a) It has one pair of parallel sides
(b) Opposite sides are parallel and equal
(c) All angles are right angles
(d) All sides are unequal

7. The diagonals of a rectangle:
(a) Are equal in length
(b) Are always perpendicular
(c) Never meet
(d) Are longer on one side

8. In a rhombus, the diagonals:
(a) Are equal and perpendicular
(b) Are not equal but perpendicular
(c) Are not equal and not perpendicular
(d) Are equal but not perpendicular

9. The sum of interior angles of a triangle is:
(a) 90°
(b) 180°
(c) 270°
(d) 360°

10. A trapezium (trapezoid) has:
(a) All sides equal
(b) Two pairs of parallel sides
(c) One pair of parallel sides
(d) No parallel sides

Level 3 – Informal Deduction

11. Every square is a rectangle because:
(a) Both have four equal sides
(b) Both have all angles equal to 90°
(c) A square has all properties of a rectangle
(d) They look the same

12. Which statement is correct?
(a) Every rectangle is a rhombus
(b) Every square is a rhombus
(c) Every rhombus is a rectangle
(d) Every parallelogram is a rectangle

13. If a figure is a rectangle, then:
(a) Its opposite sides are equal and parallel
(b) It has only one right angle
(c) Its diagonals never meet
(d) Its diagonals are unequal

14. Which statement correctly relates triangles?
(a) All equilateral triangles are isosceles
(b) All isosceles triangles are equilateral
(c) Some scalene triangles are equilateral
(d) Right triangles are always equilateral

15. A kite is different from a parallelogram because:
(a) It has opposite sides parallel
(b) It has two pairs of adjacent equal sides
(c) It has all sides equal
(d) It has all right angles

Level 4 – Deduction

16. If two triangles have all three sides equal, then they are:
(a) Congruent
(b) Similar only
(c) Different in size
(d) Right-angled

17. The sum of angles in a quadrilateral equal:
(a) 90°
(b) 180°
(c) 270°
(d) 360°

18. If two lines are parallel and cut by a transversal, alternate interior angles are:
(a) Equal
(b) Complementary
(c) Supplementary
(d) Unequal

19. The diagonals of a square are:
(a) Equal and perpendicular
(b) Unequal and perpendicular
(c) Equal and not perpendicular
(d) Unequal and not perpendicular

20. If the radius of a circle is doubled, its area:
(a) Doubles
(b) Becomes four times larger
(c) Remains the same
(d) Is halved

Level 5 – Rigor

21. In non-Euclidean geometry, the sum of interior angles of a triangle can be:
(a) Always 180°
(b) Less or greater than 180°
(c) Exactly 360°
(d) Cannot be measured

22. Two straight lines on a sphere (great circles):
(a) Never meet
(b) Meet at two points
(c) Are parallel everywhere
(d) Are perpendicular

23. In Euclidean geometry, through a point not on a line there is:
(a) One parallel line
(b) No parallel line
(c) Many parallel lines
(d) A perpendicular line only

24. A theorem in geometry is:
(a) A definition
(b) A statement that can be proved
(c) A postulate
(d) A guess

25. If two lines are perpendicular to the same line, they are:
(a) Parallel to each other
(b) Perpendicular to each other
(c) Intersecting
(d) Skew

Appendix B:

MARKING SCHEME - Instructions to Examiner:

Use the answers to score each respondent's highest Van Hiele level (from Level 1 to Level 5).
Based on: Usiskin (1982) – Cognitive Development and Achievement in Secondary School Geometry (CDASSG)

Level	Van Hiele Level	Question Nos.	Expected Student Performance	Mark Allocation (per question)	Level Mastery Criteria
L1	**Recognition (Visualization)**	1–5	Correctly identifies shapes (e.g., triangle, square, and circle) without necessarily knowing properties.	1 mark each (Total = 5 marks)	Achieves at least 3/5 correct responses.
L2	**Analysis (Properties)**	6–10	Recognizes and states correct properties of figures (e.g., "A rectangle has opposite sides equal").	1 mark each (Total = 5 marks)	Achieves at least 3/5 correct responses.
L3	**Order / Informal Deduction (Abstraction)**	11–15	Classifies shapes correctly (e.g., "All squares are rectangles but not all rectangles are squares").	1 mark each (Total = 5 marks)	Achieves at least 3/5 correct responses.

L4	**Deduction (Formal Deduction)**	16–20	Provides valid logical reasoning or proofs (e.g., applies Pythagoras theorem or angle sum theorem).	1 mark each (Total = 5 marks)	Achieves at least 3/5 correct responses.
L5	**Rigor (Axiomatic Systems)**	21–25	Demonstrates ability to compare Euclidean and non-Euclidean systems; uses axioms or postulates correctly.	1 mark each (Total = 5 marks)	Achieves at least 3/5 correct responses.