



School Context and Students' Geometric Thinking Levels: Evidence from Three Ghanaian Senior High Schools

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Abstract

This study examined whether Van Hiele geometric thinking levels differed among Year Three Senior High School students in three public senior high schools in the Asante Akim South Municipality, Ghana. A quantitative cross-sectional design was used, and students' geometric thinking was assessed using the 25-item Van Hiele Geometry Test (VHGT). Descriptive statistics and a one-way analysis of variance (ANOVA) were used to compare the three school groups. The mean coded geometric thinking levels were 2.34 (SD = 0.79) for School A, 2.00 (SD = 0.82) for School B, and 1.82 (SD = 0.83) for School C. The analysis indicated a statistically significant difference among the three school groups, $F(2, 317) = 8.45$, $p < .001$. These findings indicate that students' coded geometric thinking levels varied across the participating schools. Because school resources, teaching practices, and other contextual conditions were not directly measured, the differences cannot be attributed to any particular contextual factor. The findings highlight the need for further research into school-related conditions associated with students' geometric reasoning.

Keywords: school context; geometric thinking; Van Hiele model; senior high school; Ghana; Van Hiele Geometry Test

1. Introduction

1.1. Background of the Study

Geometry is a core component of school mathematics because it develops learners' understanding of shapes, properties, spatial relationships, and logical reasoning. Students may recognize geometric figures visually without being able to describe their properties or explain relationships among them. The Van Hiele model provides a framework for describing qualitatively different levels of geometric reasoning and is widely used to assess students' geometric thinking [1–3].

The model distinguishes levels commonly described as Visualization, Analysis, Informal Deduction, Deduction, and Rigor. At the visualization level, learners identify figures mainly by appearance; at the analysis level, they identify properties; and at the informal-deduction level, they begin to reason about relationships among properties and classes of figures. Higher levels involve formal proof and reasoning about axiomatic systems [2, 3]. The Van Hiele Geometry Test developed by Usiskin [1] provides an established assessment approach for classifying students' geometric thinking. Research has documented difficulties in geometric reasoning among secondary-school students, including in Ghana. Asemani et al. [4], for example, reported that many Ghanaian senior high school students had not reached higher Van Hiele levels. Such findings establish the importance of examining students' geometric thinking, but overall descriptions alone do not show whether students in different school settings demonstrate similar patterns.

Schools may differ in instructional opportunities, teacher support, availability of learning materials, and classroom experiences. These are plausible contextual considerations when interpreting differences between schools. However, school membership by itself does not identify which contextual factor, if any, explains a difference. A comparison of students' attained Van Hiele levels across schools is therefore a useful first step, provided conclusions remain limited to the variables actually measured.

1.2. Statement of the Problem

Although prior studies have examined Van Hiele geometric thinking among Ghanaian learners, evidence comparing Year Three students across public senior high schools in the Asante Akim South Municipality remains limited. Without school-specific comparisons, it is unclear whether students in the selected schools demonstrate similar or different attained levels of geometric thinking. This study addresses that gap by comparing students' coded Van Hiele levels across three public senior high schools. It examines differences among school groups; it does not directly test whether school resources, teacher effectiveness, or instructional practices cause those differences.

1.3. Objective of the Study

The objective of this study is to examine differences in Van Hiele geometric thinking levels among Year Three Senior High School students in three selected public senior high schools in the Asante Akim South Municipality, Ghana.

1.4. Research Question

Do Van Hiele geometric thinking levels differ among Year Three Senior High School students in the three selected public senior high schools in the Asante Akim South Municipality, Ghana?

1.5. Research Hypothesis

H₀: There is no statistically significant difference in mean coded Van Hiele geometric thinking levels among students from the three selected schools.

H₁: At least one school's mean coded Van Hiele geometric thinking level differs from that of another school.

2. Literature Review

2.1. Theoretical Foundation: Van Hiele Theory of Geometric Thinking

The Van Hiele model provides the principal theoretical foundation for examining students' geometric thinking. It describes qualitatively different ways learners reason

about geometric figures and relationships, commonly presented as Visualization, Analysis, Informal Deduction, Deduction, and Rigor [1-3]. At the visualization level, figures are recognized by their overall appearance; at the analysis level, learners attend to properties; and at higher levels, they reason about relationships among properties and construct increasingly formal arguments. The model therefore offers a framework for describing the kinds of geometric reasoning students demonstrate rather than treating geometry achievement as a single undifferentiated ability.

Van Hiele's account emphasizes that movement between levels is associated with learning experiences, language, and instruction, rather than being determined by age alone [2, 3]. Crowley [3] explains the model's implications for teaching, including the importance of learning experiences that help students develop the reasoning appropriate to the next level. This perspective is relevant to comparisons among schools because students' opportunities to engage with geometric ideas may differ across learning environments. Nevertheless, the present study measures differences among school groups; it does not directly measure the teaching processes that may support progression.

The Van Hiele Geometry Test (VHGT), developed by Usiskin [1], operationalizes geometric thinking through items associated with the model's levels. In this study, the test provides the basis for classifying students' attained levels. The resulting classifications should be interpreted specifically as levels of geometric thinking indicated by the instrument, not as comprehensive measures of students' overall mathematical ability.

2.2. Geometric Thinking and the Challenges of Learning Geometry

Geometry involves recognizing figures, identifying their properties, understanding relationships, and reasoning about those relationships. These demands can make it difficult for learners to move beyond visual recognition toward analytical and deductive reasoning. The Van Hiele framework is useful in this context because it distinguishes these forms of thinking and helps explain why students who can identify a shape may not necessarily be able to describe its defining properties or justify relationships among classes of figures [1-3, 5].

Burger and Shaughnessy [5] examined the characterization of Van Hiele levels and helped establish the model as a framework for investigating differences in geometric reasoning. Their work supports the use of level-based descriptions when studying how learners reason about geometry. For school-level comparisons, this framework allows the analysis to consider whether the distribution or average coded level differs among student groups, while recognizing that the test results alone do not explain why such differences occur.

2.3. School Context and the Learning of Geometry

School context is relevant to mathematics education because schools may differ in the learning opportunities available to students, including instructional time, classroom activities, use of diagrams and geometric models, opportunities for mathematical discussion, and expectations for explaining or justifying answers. Jones [6] discusses issues in the teaching and learning of geometry, providing a broader pedagogical basis for considering how classroom experiences may shape students' engagement with geometric ideas. These contextual factors are plausible explanations to investigate when school groups display different outcomes, but they should not be assumed to have caused differences unless they have been measured directly. The distinction between school membership and measured school conditions is important for the present study. The analysis compares students from three selected public senior high schools and examines their attained Van Hiele levels. School identity acts as a grouping variable; it is not, by itself, a direct measure of teacher knowledge, instructional quality, school resources, or classroom climate. Accordingly, the findings can establish whether the participating school groups differ statistically, but they cannot identify which particular contextual feature accounts for any observed difference.

2.4. Evidence from Ghana and the Research Gap

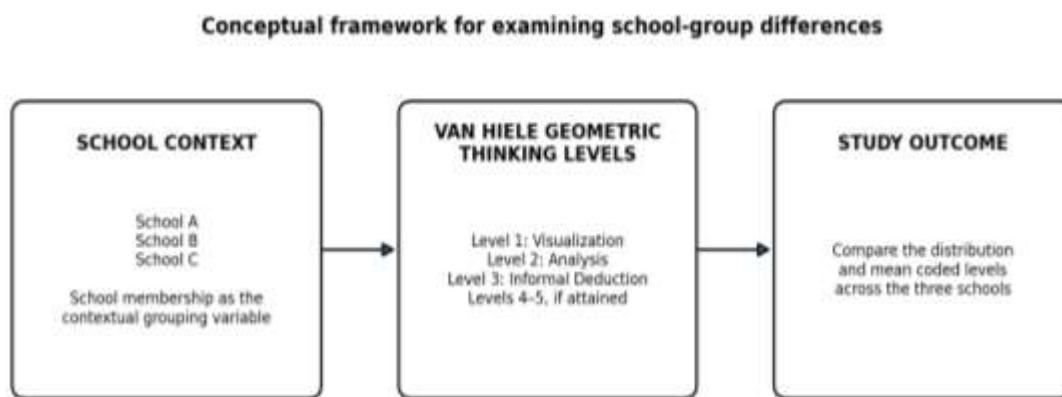
Asemani, Oppong, and Asiedu-Addo [4] investigated senior high school students' geometric thinking using the Van Hiele model in Ghana. Their work provides a relevant national reference point for examining the geometric thinking levels attained by Ghanaian learners and highlights the value of assessing geometry through a level-based

framework. Read alongside foundational accounts of the Van Hiele model [1-3, 5], this study supports continued investigation of geometric thinking among senior high school students.

Although the cited literature establishes the theoretical basis for classifying geometric thinking and provides evidence relevant to geometry learning, a focused comparison of students' attained Van Hiele levels across the three selected public senior high schools in the Asante Akim South Municipality addresses a specific local question. The present study therefore examines whether students' coded Van Hiele levels differ across these school groups. It does not claim that school context causes any differences, nor does it attribute differences to particular resources or teaching practices that were not directly measured. The contribution is a school-level comparison that can inform more targeted follow-up research into the contextual conditions associated with geometric thinking.

2.5 Conceptual Framework of the Study

The conceptual framework links school membership to students' attained Van Hiele geometric thinking levels. The three selected schools are comparison groups, while students' geometric thinking levels, measured using the Van Hiele Geometry Test, form the study outcome.



Note: School membership is measured; resources, teaching quality, and school climate are not directly measured.

3. Methodology

3.1. Research Design and Setting

A quantitative cross-sectional design was used to compare Year Three students' Van Hiele geometric thinking levels in three public senior high schools in the Asante Akim South Municipality, Ashanti Region, Ghana. Data were collected at one point in time. Accordingly, the findings describe the observed school groups and do not establish change over time or causal effects.

3.2. Population and Sample

The target population comprised Year Three students enrolled in the three selected public senior high schools. The study sample consisted of 320 students: 120 from School A, 110 from School B, and 90 from School C. The schools are identified by letters to preserve their anonymity.

Table 1 presents the distribution of the 320 participants across the three schools.

School	Achieved sample (n)	Share of total sample
School A	120	37.50%
School B	110	34.38%
School C	90	28.13%
Total	320	100%

The sample included 320 students from the three participating schools. The numbers of students in each school group were used in the school-level comparisons.

3.3. Instrument and Scoring

Data were collected using the 25-item Van Hiele Geometry Test developed by Usiskin [1]. The instrument contains five items for each of the five Van Hiele levels. According to the scoring procedure described in the manuscript, a student was considered to have attained a level after answering at least three of the five items associated with that level correctly, and the highest level attained was assigned to the student. The study used the

numbering convention Level 1 (Visualization), Level 2 (Analysis), Level 3 (Informal Deduction), Level 4 (Deduction), and Level 5 (Rigor) [1]. A pilot study involving 37 students produced a Kuder–Richardson Formula 20 (KR-20) reliability coefficient of 0.77. Two experienced mathematics educators reviewed the instrument for relevance, clarity, and appropriateness to the Ghanaian senior high school context.

3.4. Data Collection and Ethical Considerations

Permission was obtained from the heads of the participating schools before data collection. Students were informed about the study, participation was voluntary, confidentiality and anonymity were assured, and students could withdraw without penalty.

3.5. Data Analysis

Data were analysed using IBM SPSS Statistics Version 26. Frequencies and percentages were used to describe attained Van Hiele levels, while school-level summaries were used to compare the three groups. A one-way analysis of variance (ANOVA) was used to test the null hypothesis of equal school means. Because Van Hiele levels are ordered categories, means and standard deviations are descriptive summaries of coded levels and should be interpreted cautiously. An omnibus significant result indicates that at least one group mean differs but does not identify which school pairs differ without an appropriate post-hoc test.

4. Results and Discussion

4.1. Differences in Geometric Thinking Levels among Schools

The sample comprised 120 students from School A, 110 from School B, and 90 from School C, giving a total of 320 students.

School	Reported N	Mean coded level	Standard deviation
School A	120	2.34	0.79
School B	110	2.00	0.82
School C	90	1.82	0.83

A one-way ANOVA indicated a statistically significant difference in mean coded Van Hiele geometric thinking levels among the three schools, $F(2, 317) = 8.45$, $p < .001$. School A had the highest reported mean ($M = 2.34$, $SD = 0.79$), followed by School B ($M = 2.00$, $SD = 0.82$) and School C ($M = 1.82$, $SD = 0.83$). The results indicate variation in attained geometric thinking levels among the three school groups.

The finding is relevant to school-level investigation of geometry learning. However, the observed differences do not establish that school location, resource availability, teacher effectiveness, or instructional quality caused the pattern. These contextual factors were not directly measured in the reported analysis. In addition, the reported omnibus ANOVA does not by itself establish which specific pairs of schools differ significantly; such claims require suitable post-hoc comparisons.

4.2. Implications for Mathematics Education

The results point to the value of examining geometric thinking at school level rather than assuming that students across schools have identical learning needs. Teachers may use diagnostic assessment aligned with the Van Hiele model to identify students' current reasoning levels and plan instruction that supports movement from visualization toward analysis and informal deduction [1-3]. This is a practical implication of the framework, not evidence that a particular instructional approach caused the observed school differences.

For school leaders and education authorities, the findings suggest that school-specific follow-up may be useful. Future research should directly measure relevant contextual variables—such as teacher preparation, instructional practices, access to geometry materials, and time devoted to geometry—to determine whether these factors are associated with differences in Van Hiele levels.

5. Conclusion

This study examined whether Year Three students' Van Hiele geometric thinking levels differed across three public senior high schools in the Asante Akim South Municipality. The school-comparison results showed differences in descriptive means and a statistically

significant omnibus ANOVA, indicating variation in coded geometric thinking levels among the participating school groups.

The study does not identify the causes of the differences because school resources, teaching practices, teacher knowledge, and classroom conditions were not directly measured. The main implication is that school-level variation merits further investigation and that diagnostic assessment may help teachers plan geometry instruction around students' current reasoning levels. Conclusions should remain limited to the participating schools and should not be generalized automatically to other municipalities or regions.

6. Limitations

The study involved Year Three students from three public senior high schools in one municipality, limiting generalizability. Its cross-sectional design cannot establish causal relationships. School context was represented by school membership rather than direct measures of instructional quality, teacher characteristics, learning resources, or school climate. In addition, the original manuscript contains inconsistent school-specific sample sizes and data-collection details. These must be verified against the field records and dataset before the reported inferential statistics are treated as final.

7. Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper

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