African Journal of Educational Studies in Mathematics and Sciences Vol. 21, No. 1. 2025

Enhancing High School Geometry Learning with Inquiry-Based Teaching: Impact on Student Understanding, Performance, and Attitudes

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Abstract

This study explored the impact of inquiry-based teaching on high school students' understanding, performance, and attitudes toward geometry. Grounded in constructivist principles and the van Hiele theory of geometric thinking, the study adopted a design-based research approach within a descriptive case study framework. Eight in-service mathematics teachers (IMTs) and 87 students from two senior high schools (SHSs) participated in the study. The IMTs underwent professional development training to design and implement inquiry-based lessons. Data were collected using the van Hiele Geometry Test (VHGT), Geometry Achievement Test (GAT), and Geometry Attitude Scale (GAS) and analysed through descriptive and inferential statistics. Findings revealed that students who engaged in inquiry-based learning demonstrated significant improvements in their geometric thinking levels, with many progressing to higher van Hiele levels. Additionally, students showed enhanced performance in geometry and developed positive attitudes characterised by increased motivation and self-confidence. The study concludes that integrating inquiry-based teaching into constructivist classrooms fosters student-centred learning and enhances geometric reasoning. It recommends that mathematics educators adopt inquiry-based instructional strategies to improve student engagement and achievement in geometry.

Keywords inquiry-based learning; constructivism; van Hiele theory; geometric thinking; student performance in geometry

Introduction

The study of geometry is very significant in our education and daily lives. The items we use daily in our environment mostly comprise geometrical shapes and objects. Their effective and efficient use heavily depends on our understanding of the relationship between geometrical objects and shapes (Altun, 2004 cited in Serin, 2017). The study of geometry provides countless basic skills and assists in developing the "thinking skills of logic, deductive reasoning, analytical reasoning, and problem-solving" (Russell, 2014). Students' understanding of geometric concepts helps them to analyse and solve problems and also describe the world they live in.

Despite the immense importance of studying geometry, learning and understanding geometry is often considered a difficult topic of study by most students. Nevertheless, efforts made by the government, stakeholders, and teachers to promote the teaching and learning of geometry could not produce the expected outcome (Tsao, 2017) as students could not learn and comprehend geometry since the problems and difficulties of understanding and applying the theories and concepts of geometry persists. Achievement of students in geometry has been generally poor compared to other areas of study in Mathematics (Mammana & Villani, 2012).

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Studies conducted to measure SHS students' geometric thinking levels after being taught geometry showed that students could not reach the required geometric thinking level (van Hiele level 4) to enable them to perform well in geometry (Bashiru & Nyarko, 2019; Asemani et al, 2017; Baffoe & Mereku, 2010). Also, the West Africa Examination Council (WAEC) chief examiners' report (2011 to 2022) expressed that most candidates displayed various levels of weakness in answering geometry questions in the examination and hence performed woefully in Mathematics, especially when the examination was geometry-dominated. This resulted in students' failure in the following years: 2011 - 53.9%, 2012 - 48.1%, 2013 - 63.6%, 2014 - 71.1%, 2015 - 76.1%, and 2016- 64.7% (Abreh et al., 2018).

Studies investigating the challenges students face in learning geometric concepts have identified ineffective instructional approaches as a key contributing factor (Juman et al., 2022; Salman, et al., 2012). For example, studies showed that most students are normally passive during mathematics instructional sessions (Suryabayu & Handayani, 2017; Martin et al., 2010). This situation is very prevalent in Ghanaian Mathematics classrooms, as highlighted in the WAEC Chief examiners' reports. This points to the inadequacy of the current teaching methods as they continue to be the basis on which students continue to perform poorly. Therefore, Juman et al. (2022) and the Ministry of Education [MOE] (2010) recommended inquiry-based teaching as a practical teaching approach to guide students to overcome their difficulties and appreciate geometry in their daily lives.

Inquiry-based teaching emphasises students' active participation in instruction and promotes discoveries of new knowledge (Mensah-Wonkyi & Adu, 2016; Pedaste et al., 2015). This approach to teaching provides the opportunity for students to construct their knowledge and appreciate what they have learned. Clarke, Breed and Fraser (2004); and Boaler and Staples (2008) argued that students learn effectively when they are actively involved in the instruction. It is worth noting that many studies have not been conducted in Mathematics using an inquiry-based teaching approach, especially in geometry. Therefore, the current study intended to address "How can the improvements in students' learning of concepts in geometry using the inquiry-based pedagogical approach be understood and or explained?"

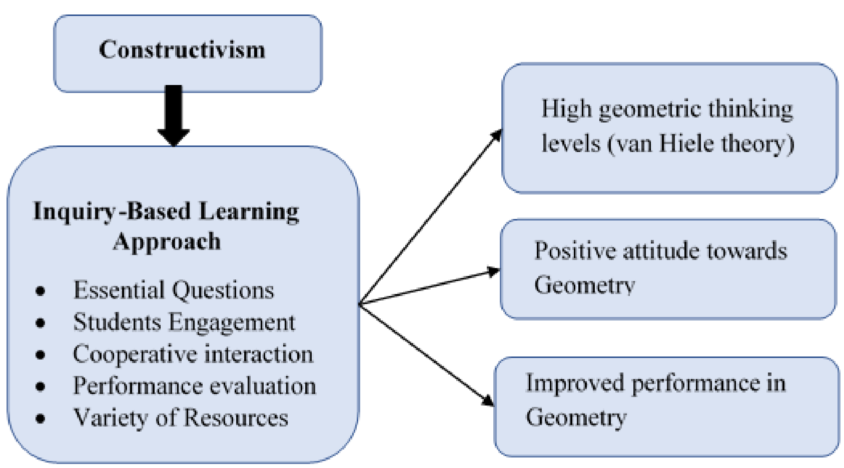


Figure 1. Conceptual Framework for the Study

Conceptual Framework of the Study

The study adopted constructivism as the overarching theory, an inquiry-based learning (Larson, 2005) approach to form the basis of the design, development, and implementation of the study intervention and van Hiele's theory of geometric thinking (van Hiele level) (VHL) as a lens to measure students' level of geometric thinking. Constructivism theory and inquiry-learning approach were contextualized to form the conceptual framework that grounded this study (see Figure 1). This framework provided the basis to fuse an inquiry-based learning approach into a constructivist approach to train participating in-service teachers to design, develop and implement the study intervention. The framework explains that if mathematics teachers use an inquiry-based teaching strategy to teach geometric ideas or concepts in constructivist classrooms successfully, the teaching and learning of geometry will become more student-centred and improve students' geometric thinking levels, attitudes and performance.

Constructivism is a learning theory based on observation and practical research. Constructivism is a teaching and learning methodology that emphasizes the notion that learning is the result of mental construction (Bada & Olusegun, 2015). It states that people increase their awareness and knowledge of the world through engaging in experiences and reflecting on those experiences (Bada & Olusegun, 2015). Also, constructivism is a theory that explains how people might acquire knowledge and learn hereby indicating that students learn by reconciling new information together with what they already know. When we are faced with something new, we have to resolve it with our past ideas and experiences. This is done by either altering our beliefs or neglecting the new ideas as not important. By asking questions, exploring, and analysing what we know, in turn, makes us active creators of our knowledge. Constructivism changes students from passive learners to active learners where they effectively construct their knowledge (Kusumaryono & Suyitno, 2016). Constructivists trust students' beliefs and attitudes, and the environment in which the idea is taught influences their learning, hence, it is very useful to education. This theory further advocates that through the experience of humans, knowledge and meaning were constructed. Constructivism is not a particular method of teaching.

The inquiry-based learning approach is deep-rooted in the constructivist approach. Spronken-Smith (2007) defines inquiry-based learning as an instructional method that encourages learners to encounter knowledge development processes and learning stimulated by a student-centred approach to inquiry, a more self-directed learning approach, and an active learning approach. Also, Friesen and Scott (2013) described inquiry-based learning as a teaching and learning approach that places the students' questions, thoughts, and observations at the core of the learning experience. Throughout the inquiry process, educators play an active role by developing a learning situation in which ideas are respectfully questioned, checked, redefined, and seen as improvable, shifting students from a position of questioning to a position of implemented comprehension and further questioning (Scardamalia, 2002). Inquiry-based learning is built around multiple characteristics of inquiry that work to construct an inquiry cycle as an expressive group. This study adopted the five components of inquiry-based learning. These components are essential questions, student engagement, cooperative interaction, performance evaluation, and a variety of responses (Larson, 2005).

The *essential question* feature is considered to be the teacher starting his lesson with open questions posed to the students to solve at the beginning and end of the lesson. These questions generate curiosity among the students throughout the lesson (Larson, 2005). These questions are classroom-generated, and answers are constructed by students. The students' inability to solve the question informed the teacher to guide the students to develop the needed concepts to answer the question. The *student engagement* feature is characterised by the students' active participation in constructing their knowledge by manipulating teaching and learning resources, observing, evaluating and recording information, sorting, and deciding which information is most appropriate. Also, the *cooperative interaction* feature is characterised by students' interaction among themselves to create their understanding. Students were paired or put into small groups to discuss their ideas. Each group selected a leader and set the rules governing the groups. Students discuss the knowledge or idea constructed when they engage within and among the groups. The *performance evaluation* feature is characterised by the teacher creating an effective assessment procedure to measure each student's level of understanding. Both formative and summative assessments were used by the teacher. The last feature of inquiry-based learning is the *variety of resources*. The variety of resources is considered as the provision of multiple teaching and learning resources to students to aid in the construction of their knowledge and understanding.

Methods

Research Design

This study used a descriptive case study design as the appropriate design to explore and understand the effect of using a constructivist approach, specifically an inquiry-based teaching and learning instructional approach, in teaching mathematics in SHS to improve the student's performance, geometric thinking level, and attitude. Also, this design was considered because it consolidated the views of participating in-service mathematics teachers and students at the various stages of the study to develop a solid and firm instructional approach to promote favourable learning outcomes. Furthermore, the study included professional development programmes (PDP) for in-service mathematics teachers from the two different SHSs (schools A and B). In total, the in-service mathematics teachers were put into four teams purposely to develop inquiry-based lessons as an intervention based on their experiences from the PDP. Moreover, a descriptive case study is a method used to describe the intervention designed to tackle a specific problem (Neale, Thapa, and Boyce, 2006) to provide an alternative and practical solution to the seemly non-interactive and purely teacher-centred approaches that dominate Ghanaian SHS mathematics classrooms.

Participants

This study sampled 95 participants. Out of 95 participants, 8 of them were in-service mathematics teachers and 87 were senior high school students. Four IMTs and 50 students were selected from school A, and the remaining 4 IMTs and 37 students were also selected from school B. The majority, 87.5% (7), of the IMTs had BSc Mathematics in Education from the University of Education, Winneba, and the remaining 12.5% (1) had B. Ed Mathematics from the University of Cape Coast. BSc Mathematics and B.Ed Mathematics are courses mounted at the University of Education, Winneba, and the University of Cape Coast, respectively, to train mathematics teachers. The average age of in-service mathematics teachers was approximately 30 years (*SD* = 5.47), with a minimum age of 24 and a maximum of 39 years. The IMTs had an average teaching experience of approximately 4 years (*SD* = 2.05). This attested that the in-service mathematics teachers who participated in the study were familiar with the mathematics curriculum and had sufficient experience in teaching mathematics at the SHS level. More than half (56.3%) of the students were males, while 43.7% were females. The average age of students is approximately 17 years (*SD* = 1.62), with a minimum age of 12 years and a maximum age of 22 years. All the students 100% (87) were in SHS 2.

Professional Development Programme

The Professional Development Programme (PDP) for in-service mathematics teachers (IMTs) was designed to equip them with the theoretical knowledge and practical skills needed to develop, implement, and refine inquiry-based lessons in constructivist classrooms. Following the design-based research (DBR) approach, the training was conducted in iterative cycles, ensuring continuous improvement through enactment, reflection, and modification (Reeves, 2006). The PDP was structured into three key phases: training, lesson development, and enactment. In the initial phase, IMTs were introduced to the theoretical underpinnings of constructivism and inquiry-based learning, emphasising essential questions, student engagement, cooperative interaction, performance evaluation, and the use of diverse teaching resources (Herrington et al., 2014). They also explored the Van Hiele theory of geometric thinking to understand students' cognitive progression in geometry.

In the second phase, IMTs collaborated in teams to design inquiry-based lesson plans aligned with the Ghanaian Core Mathematics curriculum. Through guided PDP sessions, they developed structured lesson interventions focused on engaging students in active learning and problem-solving. The designed lessons were then tested in micro-teaching sessions among their peers, allowing for feedback collection and iterative refinements. The final phase involved the actual enactment of the refined inquiry-based lessons in senior high school classrooms. IMTs implemented their lessons while researchers observed and collected data through classroom observations, student feedback, and interviews. The iterative nature of the enactment process enabled IMTs to refine their instructional strategies, ensuring improved lesson effectiveness and alignment with inquiry-based teaching principles. Through this structured PDP, IMTs not only enhanced their pedagogical knowledge but also gained hands-on experience in implementing student-centred, inquiry-based teaching approaches. The training contributed significantly to fostering constructivist learning environments, leading to improved student engagement, geometric thinking levels, and overall performance in geometry (Mensah-Wonkyi & Adu, 2016).

Research instruments

The study adopted the van Hiele Geometry Test (VHGT), Geometry Achievement Test (GAT) and Geometry Attitude Scale (GAS) instruments to collect the data for the study.

Van Hiele Geometry Test (VHGT)

The VHGT is a multiple-choice survey of 25 items and is arranged sequentially into blocks of five items. Items 1-5 test students' understanding at level 1 (visualization), items 6-10 assess students' understanding at level 2 (analysis), items 11-15 measure students' understanding at level 3 (abstraction), items 16-20 measure students' understanding at level 4 (deduction), and items 21-25 measure student understanding at level 5 (rigour) (Armah, 2015). This test is used to measure the student's geometric thinking levels.

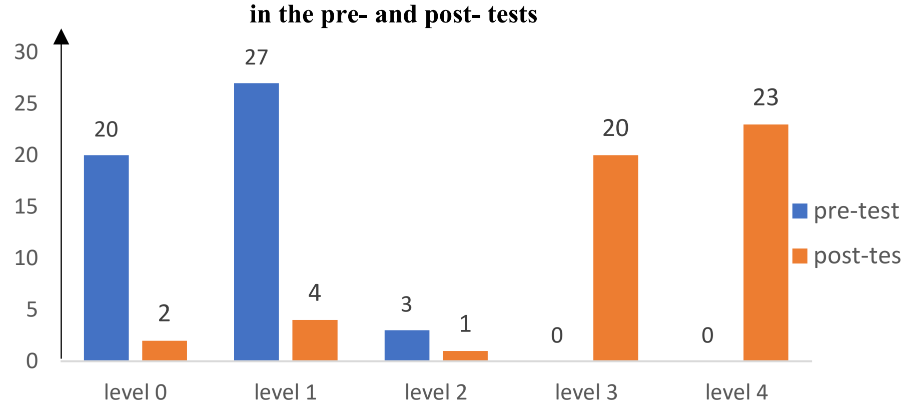
Geometry Attitude Scale (GAS)

The GAS instrument is used to measure students' attitudes toward learning geometry. This instrument was adapted from Asuman & Paksu (2007). This instrument has two constructs (motivation and self-confidence toward learning geometry) and contains 12 items. Per the original geometry attitude scale, the motivation construct has a reliability coefficient of 0.92, while the self-confidence construct has 0.87.

Geometry Achievement Test (GAT)

The researcher developed geometry achievement tests (GAT) based on the geometry topics taught by the participating in-service teachers. To ensure the content validity of the GAT, the researcher relied on the mathematics syllabus for SHS, approved textbooks for SHS, and the West African Senior Secondary Certificate Examination (WASSCE) questions on geometry. Also, the researcher gave GAT to two experts in assessment for approval. The feedback got was used to modify the GAT as a standardized geometry achievement test.

Figure 2 **School A students' van Hiele levels of geometric thinking in the pre- and post- tests**



Data Collection and Data Analysis Procedures

The data collection took place at the implementation stage of the PDP. During the enactment of the final refined intervention on the students in the normal classrooms by the IMTs, VHGT, and GAT were given to the students and timed on different occasions before the enactment of the lesson intervention. The GAT, VHGT and GAS were administered to the students before and after the study intervention. All the students were entreated to respond to each item on the GAT, VHGT, and GAS honestly. The data were analysed using frequency, percentages, mean, standard deviation and paired t-test.

Results and Discussion

The improvements in students' learning of concepts in geometry using the inquiry-based pedagogical approach can be understood and or explained from three perspectives: improved students' geometric thinking levels, improved performance in geometry, and a positive attitude toward learning geometry.

Improved Students' Geometric Thinking Levels

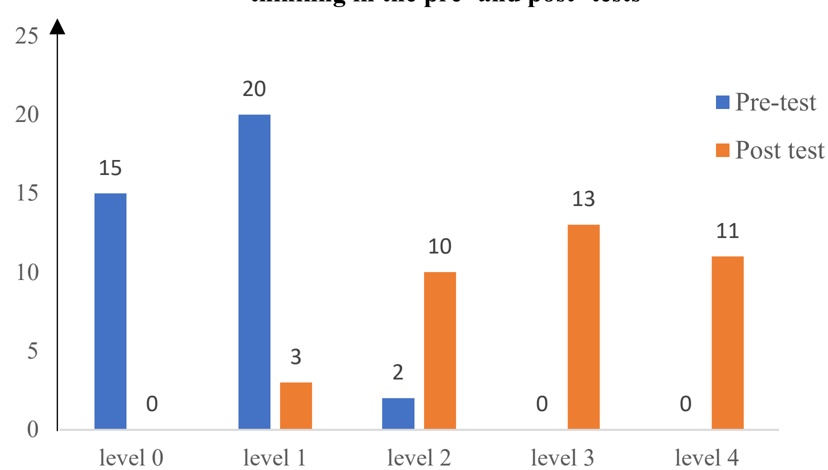
Figure 2 shows the number of students reaching each of the van Hiele levels of geometric thinking in the pre- and post- tests.

From Figure 2, the result showed that the students in School A attained higher van Hiele geometric thinking levels after the introduction of the intervention. In detail, the result revealed that in the pre-test, none of the students attained level 3 of the van Hiele geometric thinking level. Out of 50 students who took the pre-test, 20 (40%) of the students could not attain any of the van Hiele geometric thinking levels. This is referred to as level 0 (pre-visualization or pre-recognition level). The majority of the students 27 (54%) attained level 1 (visualization or recognition level) while only 3 (6%) attained level 2 (analysis or description level).

Moreover, only 2 (4%) of the students who took the post-test could not attain any of van Hiele's geometric thinking levels or level 0. This clearly showed that there was an improvement in the students' knowledge or geometric thinking level after the implementation of the inquiry-based geometry lessons. Four (8%) and 1 (2%) of the students in the post-test attained van Hiele geometric thinking levels 1 and 2, respectively. This also showed an increase in the students' geometric thinking levels 1 and 2. Again, the result revealed that 20 (40%) of the students in the post-test attained van Hiele geometric level 3 (abstraction or informal deduction), which none of the students attained in the pre-test. Significantly, 23 (46%) of the students in the post-test attained van Hiele level 4 as compared to 0% in the pre-test. This indicates a significant improvement in the geometric thinking Levels among students in the post-test.

Figure 3 shows the number of students reaching each of the van Hiele levels of geometric thinking in the pre- and post- tests.

Figure 3 **School B students' van Hiele levels of geometric thinking in the pre- and post- tests**



In School B, out of 37 students who took the pre-test, 15 (41%) could not attain any of the van Hiele geometric thinking levels. In other words, 15 (41%) of the students attained level 0 or the pre-visualization level in the pre-test. Furthermore, 20 (54%) and 2 (5%) of the students attained levels 1 and 2 of van Hiele's geometric thinking levels, respectively, in the pre-test in the second phase of the study (school B). However, none of the students in school B could attain levels 3 and 4 of van Hiele's geometric thinking levels in the pre-test. This result revealed that the students in the second phase of the study were operating at the basic level of van Hiele's geometric thinking levels.

The post-test result shows an improvement in the students' geometric thinking levels. As indicated in Figure 2, none of the students remained in level 0 while 3 (8%) of the students remained in level 1 of the van Hiele geometric thinking levels. Comparing both pre-test and post-test results in the basic levels of geometric thinking, almost all the students (95%) in the pre-test operated at the basic level, while only 3 (8%) of the students in the post-test remained at the basic level. This showed a significant improvement in students' basic geometric thinking levels. Again, 10 (28%) of the students in the post-test attained level 2 as compared to 2 (5%) in the pre-test. Also, 13 (39%) and 11 (31%) of the students attained levels 3 and 4 in the post-test, respectively, which they could not attain in the pre-test. These results evidenced a much enhancement in the students' geometric thinking levels in all van Hiele's geometric thinking levels.

The post-test results in both the first and second phases of the study indicated enhancement in students' geometric thinking levels. That is, out of 87 students who were taught geometry with an inquiry-based teaching approach, 34 (39.1%) attained level 4 of the van Hiele levels, which means that they could answer geometry questions at the senior high level and pass. This enhancement was attributed to the implementation of inquiry-based geometry lessons. Therefore, the result revealed that the use of inquiry-based teaching and learning approaches promoted or enhanced students' geometric thinking levels.

Students' Improved Performance in Geometry

To ascertain whether or not the differences in performance observed are statistically significant, the data was subjected to further analysis using the independent t-test and the results are presented in Table 1.

Table 1 **Students' Performance in pre and post-test in School A**

Test	N	Mean	SD	Mean difference	t	df	Sig. (2-tailed)
Pre-test	50	6.28	2.176	23.22	31	49	0.000
Post-test	50	29.50	5.254				

p-value = 0.05

Table 1 shows the summarised independent sample paired t-test result of the students' performance in the pre- and post-test in school A. The mean score (M = 6.28) of the students in the pre-test indicated poor performance. However, after the intervention, the mean score of the students in the post-test (M = 29.50) showed an improvement in their performance. The result of the independent paired sample t-test showed that there was a significant mean difference in the student's performance in the pre-test (M = 6.28 and SD = 2.176) and post-test (M = 29.50, SD = 5.254), t (49) = 31, p = 0.000 < 0.05. Comparing the mean scores between the pre-test and post-test, the students in the post-test performed far better than in the pre-test. This was evidenced by the higher mean score (M = 29.50) of the students recorded in the post-test as compared to the pre-test (M = 6.28). The result recorded a high effect size of d = 6.25 and a mean gain of 23.22 which attested that the high performance of the students in the post-test was a result of the introduction of the lesson intervention (inquiry-based geometry lessons).

As indicated in Table 2, the mean score of the students in the pre-test (M = 14.86) out of a total score of 40. This indicated a poor performance in the geometry test. However, the mean score (M = 32.24) of the students after the implementation of the intervention revealed an improvement in the students' performance. Also, the result of the student's performance indicated that there was a significant difference in the mean scores of the pre-test (M = 14.86 and SD = 8.125) and post-test (M = 32.24 and SD = 7.410), t (36) = 12.760, p 0.000 < 0.05. The students' performance in the post-test, as evidenced in Table 2, was better than their performance in the pre-test. This was because the students' mean score on the post-test (M = 32.24) was higher than that of the pre-test (M = 14.86). The result recorded a high effect size of d = 6.06 and a mean gain of 17.38 that confirmed the students' high performance in the post-test was a result of the implementation of the inquiry-based geometry lessons. The use of inquiry-based teaching

Table 2 **Students' Performance in pre and post-test in School B**

Test	N	Mean	SD	Mean difference	t	df	Sig. (2-tailed)
Pre-test	37	14.86	8.125	17.38	12.760	36	0.000
Post-test	37	32.24	7.410				

p-value = 0.05

and learning approaches in the teaching of geometry in normal classroom teaching has promoted or enhanced students' understanding of the concepts, hence, reflected in their high performance in the first and second phases of the study.

Students' Attitudes Toward Learning Geometry

Per the data collected, Cronbach's Alpha reliability coefficient of the motivation scale is 0.72, and that of self-confidence is 0.71. The descriptive statistics and the independent t-test of the results obtained on the affective outcomes are presented in Table 3.

Table 3 **Students' Attitudes toward learning geometric concepts in school A (n = 50)**

Outcome	Test	Mean[1]	SD	Mean difference	T	df	Sig. (2-tailed)
Motivation	Pre-test	2.62	0.414	0.967	-10.757	49	0.000
	Post-test	3.59	0.308				
Self-confidence	Pre-test	2.87	1.042	1.25	-6.442	49	0.000
	Post-test	4.12	0.815				

[1]Mean < 3.5 → poor attitude, and ≥ 3.5 → positive attitude.

Table 4 **Students' Attitudes toward learning geometric concepts in school B (n = 37)**

Outcome	Test	Mean[1]	SD	Mean difference	T	df	Sig. (2-tailed)
Motivation	Pre-test	1.87	0.513	2.396	-22.281	36	0.000
	Post-test	4.27	0.519				
Self-confidence	Pre-test	1.74	0.707	2.103	-11.320	36	0.000
	Post-test	3.85	0.908				

[1]Mean < 3.5 → poor attitude, and ≥ 3.5 → positive attitude.

In Table 3, the result shows that students in school A had a poor attitude ($M = 2.62$, $SD = 0.414$) toward the learning of geometric concepts before they were exposed to the intervention lessons. However, the students lack much self-confidence to learn geometric concepts as revealed by the mean score ($M = 2.87$, $SD = 1.042$) which is less than 3.5. Moreover, after the students were exposed to inquiry-based geometry lessons, their attitudes improved. They developed a positive motivation and self-confidence to learn geometric concepts as indicated by the mean score ($M = 3.59$, $SD = 0.308$) and ($M = 4.12$ $SD = 0.815$), respectively, after being exposed to the inquiry-based geometry lesson intervention. Furthermore, the result indicated that there is a significant mean difference between the students' levels of motivation toward the learning of geometric concepts before ($M = 2.62$, $SD = 0.414$) and after ($M = 3.59$, $SD = 0.308$) the implementation of the inquiry-based geometry lessons, $t(49) = -10.757$, $p = 0.000 < 0.05$ and the mean difference of 0.967. Again, the result shows that there is a significant mean difference between the students' self-confidence levels toward the learning of geometric concepts before ($M = 2.87$, $SD = 1.042$) and after ($M = 4.12$, $SD = 0.815$) the implementation of the inquiry-based geometry lessons, $t(49) = -6.442$, $p = 0.000 < 0.05$ and the mean difference of 1.25. The result of the study suggests that the use of inquiry-based geometry lessons through an inquiry-based teaching and learning approach has improved significantly the motivation and self-confidence of students toward the learning of geometric concepts in the first phase of the study.

The result from school B in the second phase of the study indicated the students lacked motivation (M = 1.87, SD = 0.513) and self-confidence (M = 1.74, SD = 0.707), hence poor attitude to learning geometric concepts before they were exposed to the inquiry-based geometry lessons as shown in Table 4.

Furthermore, after the implementation of the inquiry-based geometry lessons in school B, the results showed that the student's motivation (M = 4.27, SD = 0.519) toward learning geometric concepts improved. Also, the student's self-confidence level (M = 3.85, SD = 0.908) has increased toward learning geometric concepts. Moreover, the result indicated that there was a significant mean difference between the students' levels of motivation toward the learning of geometric concepts before (M = 1.87, SD = 0.513) and after (M = 4.27, SD = 0.519) the implementation of the inquiry-based geometry lessons, $t(36) = -22.281$, $p = 0.000 < 0.05$ and the mean difference of 2.396. Again, the result showed a significant mean difference between the students' self-confidence levels toward the learning of geometric concepts before (M = 1.76, SD = 0.707) and after (M = 3.85, SD = 0.908) the implementation of the inquiry-based geometry lessons, $t(36) = -11.320$, $p = 0.000 < 0.05$ and the mean difference of 2.103. Therefore, the result of the study suggests that the use of inquiry-based geometry lessons through inquiry-based teaching and learning approach has improved significantly the motivation and self-confidence of students toward the learning of geometric concepts in school B in the second phase of the study hence a positive attitude.

Discussion

This study investigated the extent to which the inquiry-based pedagogical approach enhances students' learning of geometry concepts. The findings were explored from three distinct perspectives: (1) improved students' geometric thinking level, (2) enhanced students' performance, and (3) a positive attitude towards the learning of geometric concepts.

The finding of the study revealed that in the pre-test, none of the students attained levels 3 and 4 of the van Hiele geometric thinking. Also, the majority of the students (54%) were at level 1 while only 5.7% managed to attain level 2. However, 40.2% of the students could not attain any of the van Hiele levels (level 0). The post-test results indicated an enhancement in students' geometric thinking levels. The finding indicated that 39.1% of the students had attained level 4 of the van Hiele levels which means that they could answer geometry questions at the senior high level and pass. In addition, 37.9% were at level 3 while only a few students 8% and 12.6% remained in levels 1 and 2, respectively. This finding aligns with several findings of studies conducted to measure SHS students' geometric thinking levels which indicated that most of the students could not attain levels 3 and 4 of the van Hiele geometric thinking levels (Bashiru & Nyarko, 2019; Asemani et al., 2017; Armah et al., 2017; Abdullah & Zakaria, 2013; Baffoe & Mereku, 2010).

Again, the study revealed that after the introduction of the intervention, there was an improvement in the students' performance in geometry. The poor performance of the students in the pre-test supports the poor performance of the students in the WASSCE (Abreh et al., 2018), poor performance in the TIMSS 2003 and 2007 (Mereku & Anumel, 2011; Anamuah-Mensah & Mereku, 2005), and students underachieved less than the NMS pass mark (Mills & Mereku, 2016).

Furthermore, the findings of the study from the two phases indicated that the initial attitude of the students toward the learning of geometry was poor. However, after the implementation of the intervention, the students developed positive attitudes in terms of improved self-confidence and motivation toward learning geometry. This finding supports the findings of the studies conducted by Sakiz et al. (2012); Yang (2013); Joseph, (2013); Blazar & Kraft (2017) that stated that students developed a positive attitude toward mathematics (geometry) if they were taught using appropriate instructional methods and using instructional materials, and also, the personality and content knowledge of the teachers. A similar finding was reported by Syyeda (2016) that students learn Mathematics willingly when Mathematics becomes interesting and enjoyable through the teaching approach. Mata et al. (2012) also stated that the students in the second cycle have positive attitudes toward Mathematics. However, Joseph (2013) revealed that 55% of secondary school students in Tanzania have a generally negative attitude toward Mathematics.

Conclusion and Recommendation

This study established that integrating an inquiry-based teaching and learning approach into constructivist classrooms significantly improved students' geometric thinking levels, performance, and attitudes toward learning geometry. The findings align with the study's conceptual framework, which was grounded in constructivism, inquiry-based learning, and the van Hiele theory of geometric thinking. By engaging students in active exploration, cooperative interaction, and structured inquiry, the inquiry-based intervention facilitated deeper conceptual understanding and enhanced problem-solving skills. The study's results demonstrated that students exposed to inquiry-based lessons showed notable progress in their geometric thinking levels, transitioning from lower van Hiele levels to more advanced deductive reasoning stages. Additionally, students exhibited improved performance in geometry and a more positive attitude toward learning, characterized by increased motivation and self-confidence. These outcomes affirm that when mathematics teachers effectively implement inquiry-based teaching strategies in constructivist settings, students become more engaged, leading to meaningful learning experiences.

Based on these findings, the study recommends that mathematics educators adopt inquiry-based instructional methods to enhance student-centred learning and improve overall academic achievement in geometry. Future research could explore the long-term impact of inquiry-based teaching on students' retention of geometric concepts and its applicability across other mathematical domains.

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