Exploring Gender Disparity in Geometry Learning Using Van Hiele's Model: A Quasi-Experimental Study of Final Year Male and Female Students' Performance

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ABSTRACT

There are mixed findings and views about the gender gap in mathematics learning. While some studies have revealed that only men have the capacity to dominate in mathematics as compared to their female counterparts, other studies have found that women have the potential to even outperform their male counterparts in mathematics. There continues to be growing uncertainty regarding male and female students learning and performance in mathematics. This current study, however, was designed to explore the nexus between gender and geometry performance with respect to male and female students' geometry learning. The study employed a one-group quasi-experimental design with a population and sample size of 360 and 186, respectively. Stratified and random sampling processes were used to select the sample members. Data for the study were collected using a questionnaire (Google Form) and a Geometry Achievement Test (pretest and posttest). Data analysis was done using SPSS's descriptive procedures and a paired samples t-test. The study found that: 1) there was a significant difference between male and female students academic performance in geometry, p(<.000). 2) The study also found that the use of Van Hiele's geometry thinking model contributed to improved geometry learning and performance. The study therefore recommended that teachers should make use of Van Hiele's model in teaching geometry and give equal support or pay equal attention to both male and female students in the classroom during teaching and learning.

Keywords: Geometry, Gender, pretest, posttest, Test and quasi-experimental

INTRODUCTION

There have been persistent efforts by researchers and educators to investigate the causal factors for students' continuous poor performance, some in mathematical concepts and topics including geometry. For example, OpokuKumi, Karikari, AfiaAchiaa, and Adu (2020) conducted their research to investigate the reasons behind students' low academic performance in mathematics. Their study was conducted in Ghana's Western Region, specifically in the SefwiBonwire District. Their investigation showed that the main reason behind the students' low academic performance in mathematics was their study habits and attitudes. Chand, Chaudhary, Prasad, and Chand (2021) looked into low mathematics achievement using both quantitative and qualitative methods and found that students' attitudes toward mathematics were negative. Sparks-Wallace (2007) highlighted that it is believed men were intellectually superior to women in the past because of men's comparative advantage in academic performance. This idea frequently ignored the structural barriers and stereotypes that prevented women from achieving their full potential in the classroom, particularly in STEM. Recent studies have revealed a gender gap in academic achievement, with women outperforming men in practically every subject at all educational levels (see Grant and Behrman, 2010; Tshabalala and Ncube, 2016; Morita et al., 2016; Felkner Perez et al., 2012; Heyder and Workman, 2020). Workman and Heyder (2020) contended that men usually dominate in the natural sciences, historically, while women appear to perform better than men in language, the arts, and other subjects. You and Sharkey (2012) also pointed out that women's improved academic performance in elementary and higher education does not stem from their enrollment in simpler classes; rather, it is a reflection of their general competencies across all subject areas.

Mbugua, Kibet, Mungiria, George, and Nkonke (2012) investigated the reasons behind the low mathematics performance of Kenyan secondary school students. The authors cited a number of factors that affect students' and teachers' performance in mathematics classes, including staffing levels, insufficient teaching resources, low motivation, and unfavorable attitudes. One of the main variables that researchers have found affects students' performance and understanding of mathematics is gender. Many people think that gender matters when it comes to learning mathematics. For example, in an attempt to gain a deeper understanding of the effect of gender on students' academic performance in mathematics in public secondary schools, Risper (2009) conducted a causal comparative study, analyzing the data using both descriptive and inferential analysis techniques. The study's results, according to the author, suggested that students believed mathematics was primarily a male-dominated field, which could explain why women perform poorly in it. Kisigot, Ogula, and Munyua (2021) conducted a study in Kenyan public secondary schools to ascertain the effects of gender on students' academic performance. The authors' research design was an ex post facto causal comparative study with embedded mixed methods. The authors proposed, based on their analysis of the study data, that education stakeholders should embrace gender equity in order to improve academic performance for both males and females. These studies about gender and academic performance are largely carried out on the entire mathematics subject, as demonstrated in the background. This current study, however, was designed to explore the nexus between gender and geometry performance with respect to male and female students' geometry learning effectiveness using Van Hiele's model of teaching geometry.

Statement

One major role played by academic performance is that it offers educational institutions the opportunity to assess the effectiveness of the school curriculum and its intended effect on students' learning and classroom instructional activities. For instance, Arshad, Zaidi, and Mahmood (2015) expressed the view that academic achievement provides a measure of how well educators and learners have met their intended learning objectives. However, the majority of senior high school students at the study's chosen school demonstrated poor geometry learning skills. These students go through stages of poor geometry learning and low academic performance relating to geometry problems or questions. The practical nature of geometry in senior high school core mathematics requires that every student be actively involved in the teaching and learning process so as to enhance understanding and learning outcomes. When students are taken through a learning process, they should acquire knowledge, skills, and attitudes that will enable them to act in a way that is consistent with the instruction they have received (Aiym et al., 2022, as cited in Suglo et al., 2023). One highly recommended method of geometry teaching is Van Hiele's Geometry Thinking Model. Oladosu (2014) supported the view that students would demonstrate a better conceptual understanding when they were taught geometry lessons using the Van Hiele instructional model. In the context of students' geometry thinking at Van Hiele's Level 4, Knight (2006) highlighted that students at Van Hiele's Level 4 are able to differentiate that it is adequate for a particular shape with four sides being a quadrilateral. Alex and

Mammen (2016) explained that students at Van Hiele's level 4 are able to create proofs and drive proofs on their own because they can comprehend the implications of induction at this level. Van Hiele's geometry thinking model has been highly recommended by researchers such as Howse and Howse (2015) and Alex and Mammen (2016) for teachers to implement in the teaching and learning of geometry so as to help improve students' geometry thinking and performance. When learners are taught geometry through route learning and textbooks for proofs and theorems, the majority of these students will be unable to recall geometric concepts, much less apply these concepts logically to solving similar problems (Van 2008). This current study, in an attempt to explore the nexus between gender and geometry performance, decided to use Van Hiele's Geometry Thinking Model as an instructional model to explore male and female students' geometry learning effectiveness and performance.

Objective of the study

Thisstudy aimed to;

1. Ascertain whether there was a significant difference between male and female students geometry performance in pre-intervention test scores.
2. Find out whether there is a significant difference in students' geometry learning and performance between male and female students in post-intervention test scores.
3. Survey the views of students regardinggender asa significant predictor of their academic performance in geometry.

Hypothesis of the study

The null hypothesis which guided the study held the idea that:

Thereisno significant difference between male and female students geometry performance in theirpretest scores.

There is no significant difference in students' geometry learning and performance between male and female students in theirposttest scores.

Research question

What are the views of students regarding gender as a significant predictor of their academic performance in geometry?

Significance of the study

The results of this study are extremely significant for education stakeholders such as teachers, parents, students, and researchers. Teachers will use the findings of this study to guide their lesson delivery to ensure that adequate attention is given to both male and female students during teaching and learning activities so as to carry both genders along. Parents will have their wards complete and graduate to their next level of education; hence, resources invested in these children will not be wasted. Researchers can build further studies on the limitations and findings of this study to emerge with either affirmative or divergent findings in the future.

EMPIRICAL REVIEW

Gender and academic performance

Erdoğan, Baloğlu, and Kesici (2011) conducted a study that aimed to examine gender differences in geometry course achievement, mathematics course achievement, and geometry self-efficacy. The authors had men's and women's genders as independent variables. The results of the study indicated that the dependent variable had a significant relationship with the gender variable in a multivariate way.

The academic performance of male and female students enrolled in STEM courses at the university level was compared to senior high school performance using a mixed-methods research design by Wrigley-Asante, Ackah, and Frimpong (2023). The authors looked at the variables that contribute to the gender gaps in academic achievement between the two rungs of the educational ladder. The findings indicated that, at the senior high school level, males outperformed females academically, but at the tertiary level, females' performance seemed to have improved in comparison to men's. Gender stereotypes played a significant role in explaining variations in high school academic achievement. However, female students' academic performance at the tertiary level improved, and the improvement was associated with factors such as teaching approaches and styles, parental encouragement and support, and advocacy campaigns for women's empowerment.

Efa and Frimpong (2023) examined how senior high school students in the Cape Coast Metropolis differed by gender in their perspectives and performance in core mathematics. The authors used a mixed-methods approach to a sequential explanation design. The authors selected 393 senior high school students—212 males and 181 females—using purposeful, practical, straightforward, and stratified sampling techniques. Math Perception Questionnaires, interview techniques, and a math test were used to collect data. The study's findings showed a significant gender gap in students' mathematics proficiency, with female students reporting more parental and teacher support for the subject than did their male counterparts.

Adigun, Onihunwa, Irunokhai, Sada, and Adesina (2015) examined the relationship between gender and academic achievement. The study employed a questionnaire instrument consisting of thirty multiple-choice questions that were extracted from prior Senior School Certificate Examination questions. The questionnaire was distributed to 275 students in the study area who attended both public and private schools. An independent t-test was employed to examine the data following the grading and annotation of the students' responses. The results of the study showed that although there was a slight performance advantage over female students, there was a discernible improvement in performance at the private school, which was found to have the best male brains in the research area.

Fehintola and Yahya (2019) investigated the impact of a student's gender on their secondary school academic achievement. In their study, a non-equivalent pretest-posttest control group research design was employed. The population of the study consisted of 77 male and female senior secondary school students in Oyo town who were studying economics. The results of the study ($t = 0.27$, $\rho > 0.05$ for male students and $t = 0.25$, $\rho > 0.05$ for female students) showed no appreciable difference in the performance or retention of male and female students. The study found no evidence of a significant relationship between gender and secondary school students' retention and performance.

METHODS AND DESIGN

The study employed a one-group quasi-experimental pretest-posttest design. The rationale for implementing this design was that the study aimed at establishing a cause-and-effect relationship between the independent and dependent variables. The one-group quasi-experimental pretest-posttest design gave the study the opportunity to administer a pretest, intervention activities, and a posttest. McCaleb, Andersen, and Hueston (2015) employed a one-group pretest-posttest experimental design to study pre-service teachers' perceptions of school violence. The results showed that following the completion of the treatment, respondents' opinions regarding school violence changed. Kongkaew, Scholfield, Supapaan, Mann, Mongkhon, and Chanunun (2020) carried out a one-group pre- and post-testing experimental study and discovered that the

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posttest results determined students' level of knowledge. The one-group pretest-posttest quasi-experimental design has been used in many research studies because it produces reliable results.

Fig 1: Showing one-group pretest-posttest quasi-experimental design

Measurement: Dependent variable		Treatment: Quasi-independent variables		Measurement: Dependent variable
Assess students' geometry performance using achievement test	→	Students receive 4 weeks of teaching using van Hiele's model	→	Assess students' geometry performance using achievement test

Source: Adapted from McCaleb, Andersen, and Hueston, (2015).

The experiment intervention was implemented using Van Hiele's method of geometry instruction. The study chose to implement the Van Hiele geometry thinking model for the intervention instruction due to its widespread endorsement by various scholars for geometry teaching and learning. For instance, Demircioglu and Hatip (2023) examined the students' levels of reasoning, proofreading, and justification skills using the Van Hiele geometry method. Their study found after the data analysis that there was a linear relationship between the students' proofreading and writing abilities and their Van Hiele thinking levels. Abdullah and Zakaria (2013) also evaluated the extent to which students had grasped the different levels of geometry and the efficacy of Van Hiele's phases of geometry learning. Two student groups participated in a quasi-experiment as part of their investigation. The findings demonstrated that most students in both groups finished their foundational geometric reasoning courses at the first Van Hiele levels.

Population of the study

Shukla 2020, as cited by Enoch (2024), defined a research population as an assemblage of all the units that have the variable characteristic under investigation in common and for which the study's conclusions can be broadly generalized. The students, originally from their first year, had been assigned to thirteen classrooms based on their various electives. The various classes are ranged as follows: 3A1–3A2, 3B1–3B5, 3C1–3C2, 3D1–3D2, and 3E1. The target population, therefore, comprised the students in the various classes. The entire accessible population was divided into strata one and two. The strata one was made up of 52% male students', and the strata two was made up of 48% female students. The total accessible population that was ready and available for data collection was 360 students. Students who were eligible but could not participate in the study were exempt. These included students who were sick, those who were on leave, and chronic absentees.

Sample and sampling technique

Krejcie and Morgan (1970) as cited by Suglo et al. (2023)sample determination table is widely used and accepted in the determination of sample size. This current study sample size was determined using the table Krejcie and Morgan (1970) sample determinationtable. Krejcie and Morgan (1970) showed in their table that the sample size (S = 186) is optimal for a population (N = 360). Using a simple random sampling method, 4 out of the 13 classrooms were selected to constitute the sample members for the study. The entire accessible population was divided into two strata, defined as male students and female students. Strata one was made up of 52% male students', and strata two was made up of 48% female students. The study used the stratified random sampling technique to ensure that the sample was representative of the population in terms of gender. The stratified sampling was also useful because the study intended to evaluate and compare the mean difference of both the male and female group's information. By using stratified random sampling, the study multiplied the percentages for the male and female students by the total sample size to determine the number of male and female students to include in the study sample. Hence, 0.52 (186) produced 97 male students included in the study sample. 0.48 produced 89 female students included in the study sample. Lastly, sample members from each stratum were selected through a random procedure.

Data collection instrument

The study data were collected using two instruments, which included a questionnaire and a geometry achievement test (GAT), herein described as a pretest and a posttest. The questionnaire was designed using a Google Form, which collected data on the views of students' regarding gender and academic performance. The Google form gave students the opportunity to select one of four options: strongly disagree (SD), disagree (D), agree (A), or strongly agree (SA) against each statement in the questionnaire. The GAT was designed with 25 multiple-choice questions for a total score of 50 marks. The GAT was administered to the students both before and after the intervention activities. The 25 multiple-choice questions on the Geometry Achievement Test were taken from WASSCE past questions. After each exam, students' scripts were collected, marked, recorded, and analyzed.

Data collection procedure

Observing professional guidelines and data collection codes of conduct was imperative to the study. Thus, permission and consent from both the participants and the school administration were obtained. The study started by first obtaining permission from the participants' school academic board head. The study followed up with an orientation for the participants on the purpose and objectives of the study. After the orientation, the students took the pretest, which was followed up by a 4-week teaching intervention using Van Hiele's method of geometry teaching. The intervention phase was immediately followed by the posttest and the filling out of the Google form.

Data analysis tool

The study analyzed the pretest and posttest data using the Paired Samples T-test tool. Also, data from the Google form was analyzed using descriptive statistics and frequency procedures, and the outcome was represented in a frequency table. The data was gathered from the respondents, and the study used a basic linear regression model. The paired sample t-test was used to help the study determine whether there was a significant difference between the pretest and posttest scores.

RESULTS AND DISCUSSIONS

This aspect of the study presents the analysis results in statistical tables, followed by appropriate interpretations. The aspect captures Table 1, which presents data on the demographic characteristics; Table 2, which presents the pretest paired sample statistics; Table 3, which presents the pretest paired sample test; Table 4, which captures descriptive statistics on students' views; and finally, Table 5, which presents the paired sample test for the students' posttest scores.

Demographic characteristics for the study population

Table 1: Showing demographic characteristics of the study population in terms of gender

Class	Male	Female	Total
3A1	23	6	29

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3A2	14	10	24
3B1	18	18	36
3B2	24	16	40
3B3	21	15	36
3B4	21	20	41
3B5	20	12	32
3C1	4	33	37
3C2	1	21	22
3D1	18	11	29
3D2	17	9	26
3E1	6	6	12
Total	**187**	**173**	**360**

Source: field data, 2024.

As can be seen in Table 1, there were 12 classes in total for the year-three students who constituted the study population in the school. These classes included: 3A1–3A2, 3B1–3B5, 3C1–3C2, 3D1–3D2, and 3E1. Due to the focus of the study, the entire accessible population was divided into two strata, defined as male students and female students. The entire accessible population consisted of 360, comprising 187 (52%) male students and 173 (48%) female students. The study used a stratified random sampling technique to ensure that the sample was representative of the population in terms of gender.

Evaluation of the study objectives

In this aspect of the study, data collected in respect to the various objectives were represented in statistical tables followed by interpretation and explanation.

Ascertain whether there was a significant difference between male and female students geometry performance in their pre-intervention test scores.

The study objective 1 was to ascertain whether there was a significant difference between male and female students geometry performance in the pretest scores. The study employed descriptive statistics and paired sample t-test analysis procedures for the analysis of the data. The results of the analysis for the paired sample statistics are shown in Table 2.

Table 2: Showing paired samples statistics for the students' pre test scores.

	Mean	**N**	**Std. Deviation**	**Std. Error Mean**
Male students' GAT test scores	19.30	186	4.422	.324
Female students' GAT scores	15.56	186	4.074	.299

Source: Primary data, 2024

The results in Table 2 revealed that the male students obtained a mean score of M(19.30) while their female counterparts had a mean score of M(15.56). The results clearly showed that thereexists a mean difference of 3.74 between the male and female students' scores in the pretest. The results presented in Table 2 are well explained by the output in Table 3, which indicates the significant level of the test.

There is no significant difference in students' geometry learning and performance between male and female students in the Builsa South District.

This hypothesis was aimed at ascertaining whether there was a significant difference between male and female students geometry performance in the pretest scores. The study employed a paired sample t-test analysis procedure. The results of the analysis are presented in Table 3.

Table 3: Showing a paired samples test for the male and female students' pretest scores.

	N	t	df	Sig. (2-tailed)
Male & Female students' test scores	186	15.302	185	.000

Source: Primary data, 2024

As shown in Table 3, the study found that there was a significant difference between the male and female students pretest scores, t(N=186) =15.302, p(<.001). In fact, the results in Table 2 revealed a significantmean difference of 3.74 between the male and female' students' scores in the pretest. This result led to a rejection of the null hypothesis that there was no significant difference in the students' geometry learningand performance between male and female students in the pre-intervention test scores. The results in Table 2 showed that the male students' performance in the pretest was 3.74 better or higher than their female counterparts.

Table 4: Showing a paired samples test for the male and female students' posttest scores

	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Male-female test	4.729	.347	2.000	185	.047

Source: Primary data, 2024

The output in Table 4 showed a marginally significant difference between the male and female students performance in the posttest, t(N=186) = 2.000, p(.047) at an alpha level of 0.05. The posttest results also showed that there was still a significant difference in performance between the male and female students, even though it was of marginal significance. This finding led to the rejection of the null hypothesis that there was no significant difference in students' geometry learning and performance between male and female students in the posttest scores.

Survey the views of students regarding gender as a significant predictor of their academic performance in geometry.

This objective of the study is intended to explore the views of students regarding the influence of their gender on their learning and academic performance in geometry. A Google Form survey was designed, and students were guided to fill it out. Their responses were then collected, analyzed, and represented in Table 5.

Table 5: Showing statistics of students' views regarding gender and geometry learning

4-points rating scales with codes	Frequency	Percent
1. Geometry in mathematics is not difficult and I can learn and achieve better performance in it		
Strongly Disagree [1]	39	21.0
Disagree[2]	74	39.8
Agree[3]	55	29.6

Strongly Agree[4]	18	9.7
2. I believe that both males and females have the ability to learn and perform well in Geometry in mathematics		
Strongly Disagree [1]	41	22.0
Disagree [2]	53	28.5
Agree [3]	64	34.4
Strongly Agree [4]	28	15.1
3. Teachers when teaching geometry in mathematics pay equal attention to both males and females		
Strongly Disagree [1]	50	26.9
Disagree [2]	53	28.5
Agree [3]	53	28.5
Strongly Agree [4]	30	16.1
4. I believe that any student can perform well in Geometry in mathematics no matter the gender		
Strongly Disagree [1]	39	21.0
Disagree [2]	58	31.2
Agree [3]	71	38.2
Strongly Agree [4]	18	9.7
5. I think female Students can actually learn geometry in Mathematics better just as their male counterparts.		
Strongly Disagree [1]	40	21.5
Disagree [2]	63	33.9
Agree [3]	73	39.2
Strongly Agree [4]	10	5.4

Source: Primary data, 2024.

Discussion of Findings

The results of this study shed light on the academic performance and gender dynamics among students, particularly in the context of STEM education. Tables 3 and 4 presented significant differences in performance between male and female students, with male students consistently achieving higher scores in both pretest and posttest assessments. These findings align with previous research by Wrigley-Asante, Ackah, and Frimpong (2023), highlighting a trend where male students outperform females at the senior high school level, but this trend seems to reverse at the tertiary level.

Furthermore, the study's results resonate with the work of Adigun, Onihunwa, Irunokhai, Sada, and Adesina (2015), which also observed a performance gap favoring male students. Notably, the study emphasized improvements in female performance at the tertiary level compared to their male counterparts. In contrast, findings from Fehintola and Yahya (2019) diverged, showing no significant difference in academic achievement between male and female secondary school students studying economics.

In exploring gender dynamics within the classroom environment, Table 5 revealed that a majority of students disagreed with the statement that teachers provide equal attention to both male and female students during geometry instruction. This finding echoes a similar sentiment expressed in a study by Efa and Frimpong (2023), indicating a gender gap in mathematics proficiency with female students perceiving more support from parents and teachers compared to males.

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Overall, these results underscore the importance of addressing gender disparities in academic performance and classroom dynamics, highlighting the need for targeted interventions to promote equitable learning environments for all students.

CONCLUSION

The study conducted revealed a noteworthy dissimilarity in the pretest scores between male and female students. This disparity suggests that there may be inherent variations in academic performance based on gender within the sample population. These conclusions were made based on key findings from the study:

1. The existence of a significant difference between the male and female students' academic performance in the geometry pretest and posttest indicates that both male and female students learn geometry differently. It also suggests that teachers pay unequal attention to both male and female students during the teaching and learning of geometry, which has resulted in the significant difference that was found by the study. This view has been endorsed by 103 (55.4%) of the students who disagreed with the statement that teachers pay equal attention to both genders during teaching and learning.
2. The results of the study also revealed a significant improvement in the students posttest compared to their pretest. The significant improvement observed between pretest and posttest scores endorses the efficacy of Van Hiele's model in enhancing students' geometry learning and performance. The substantial improvement indicates that students benefited from the instructional intervention, which increased their mastery of the geometry concepts and problem-solving skills.

RECOMMENDATION OF THE STUDY

1. Further investigation into the underlying factors contributing to this contrast could provide valuable insights for educators and policymakers aiming to address gender-based disparities in educational outcomes. Additionally, implementing targeted interventions tailored to the specific needs of male and female students could potentially help bridge this gap and promote more equitable academic achievement across genders
2. The study also recommends that teachers should pay equal attention to both male and female students during the teaching and learning of geometry. Giving equal attention and support to both male and female students will help address gender gaps in the teaching and learning process.
3. The study recommends that teachers should employ Van Hiele's geometry thinking model in their teaching and learning of geometry concepts so as to enhance students' geometry learning and performance. The use of this model as an instructional intervention will help improve students' mastery of geometry concepts and problem-solving skills.

DECLARATIONS

Ethical clearance: The study was given ethical clearance by the FumSec School Ethical Review Academic Headmaster/Board Chair.

Competing interest: I, the author of this paper declare that there is known competing financial interest or personal relationships that could have appeared to influence the outcome of this study.

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