INVESTIGATING THE EFFECT OF USING GEOGEBRA AS AN INSTRUCTIONAL TOOL ON VAN HIELE'S GEOMETRIC THINKING LEVELS OF SENIOR HIGH TECHNICAL SCHOOL STUDENTS'

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ABSTRACT: *The study utilized mixed method approach involving one group pretest-posttest pre-experimental design to explore the effect of using GeoGebra on 80 second year Senoir High school students' effectiveness of the use of GeoGebra on their van Hiele level of geometric thinking. Inferential statistics of one-way ANOVA and paired sample T-test were used to test the hypotheses. Findings revealed that the use of GeoGebra on students van Hiele level of geometric thinking was effective because majority of the students obtained more than half of the marks allotted to the test. The hypotheses concluded that there was a statistically significant difference in students van Hiele geometric thinking levels (VHGTL) after GeoGebra instruction and also in their pre-VHGTL and post-VHGTL scores. Heads of senior high schools and other educational stakeholders' should organise in- service training for mathematics teachers to equip them with the required skills on how to utilise GeoGebra for effective teaching and learning of geometry and other lessons in mathematics.*

KEYWORDS: Senior High Students, Geometry, GeoGebra, Van Hiele geometric thinking level.

INTRODUCTION

The use of technology has been an essential tool for teaching and learning mathematics at all grade levels as it has the ability to improve the way mathematics should be taught in order to enhance students' comprehension of basic concepts. (Atteh, Assan-Donkoh, Ayiku, Nkansah, & Adam, 2020). NCTM (2008) underscores that, the use of technology in education is essential for teaching and learning of mathematics and therefore all schools should have necessary technological substructure and equipment for the active use of educational technologies in mathematics education. Integrating technology in classroom instruction guarantee greater motivation, improves good questioning skills, encourages initiatives and independent learning, develops problem solving capabilities increase focus time on task and improves social and communication skills.

In spite of the importance of educational technology and strong advocacy for the need to incorporate ICT in the teaching and learning of mathematics, classrooms in Ghana are still characterized by

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traditional method of teaching. The traditional method is the teaching approach characterised by lecture/oral exposition. This teaching approach is more of teacher-centred rather than learner centred. With the dominance of traditional methods in Mathematics instruction in Ghana coupled with students' learning difficulty in geometry, one probable approach for enhancing instruction and student learning could be implementing realistic instructional method such as the use of GeoGebra. GeoGebra is one of the educational technology tools used in mathematics instruction and other subjects. According to Bwalya (2019) GeoGebra is useful as a supportive tool in the teaching and learning of mathematics. GeoGebra shows positive impact on students' engagement; increase the amount of students' interactions with teachers; increase achievement in geometry, transformations and trigonometry; increase test scores; and benefit students who struggle with visualisation. In the mathematics classroom, the use of GeoGebra helps students and teachers to explore the mathematical ideas and concepts and the association of these ideas and concepts with real life examples, thus resulting in permanent and effective learning in mathematics and higher mathematics achievement (Mwingirwa, 2016).

While geometry is a crucial sub-discipline in the field of mathematics, most students have difficulties with school geometry (Ozkan & Oner, 2019). One of the explanations for these difficulties with learning geometry is the lack of instruction that is designed based on students' van Hiele (1999) levels of geometric thinking. The van Hiele (1999) model described five sequential levels of geometric thinking (visual, analysis, informal deduction, deduction, and rigor) that students go through when becoming proficient in geometry. Several studies in Ghana confirmed that the van Hiele levels of geometric thinking scheme were a valid indicator of the achievement in school geometry (for example Asemani, Asiedu-Addo & Oppong, 2017; Tay & Mensah-Wonkyi, 2018). Not only did the van Hieles focus on describing students' cognitive development regarding geometry but also suggested teaching strategies to support this development. Instruction that supports the development of the van Hiele levels of geometric thinking should consist of five learning phases, which are inquiry, direct orientation, explication, free orientation, and integration. Students can pass through one level to the next if instruction based on these phases is provided (Ozkan & Oner, 2019).

Results of a great deal of studies have shown that GeoGebra has significant effect on Van Hiele geometry understanding level of students. For example, a study conducted by Kutluca (2013) revealed that GeoGebra instruction employed on the experimental group was better on increasing Van Hiele geometry thinking levels of students than traditional approach of teaching circle. He further pointed out that GeoGebra helped students in creating their own geometric shapes, testing and constructing their own knowledge. GeoGebra, as both teaching and learning tool, also helped the teachers to change their classroom to an investigative environment whereby students were actively involved in the instructional process. Again, Kutluca, (2013) was of the view that students learning under such environment were able to contribute their thoughts at ease, argue the results with colleagues and make their individual understanding about Geometry. Bhagat and Chang (2015) used quasi-experimental research design to survey "the effect of using GeoGebra, on student's Mathematics attainment in learning Geometry" among fifty students divided into an experimental and a control group. The experimental group was taught using GeoGebra while students in the

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control group were instructed through traditional teaching approach. They observed difference in the mean achievement scores of students taught with GeoGebra and that of students taught with traditional method. GeoGebra facilitated the learners in the demonstration of mathematical ideas in diverse ways, which can influence students to learn Mathematics. It is evident from the study of Bhagat and Chang (2015) that teaching and learning Geometry with GeoGebra, helped students to improve their reasoning, visualization skills and representation of mathematical concepts in various ways but this is not the case in Ghana. According to Tay & Mensah-Wonkyi (2018), most senior high school students are unable to construct, visualize and justify geometrical concepts due to traditional approach of teaching and learning process in Ghanaian classrooms. This method of teaching, according to Tay & Mensah-Wonkyi, (2018), makes students' passive learners and deficient in geometrical analysis and reasoning. For this reason, students are not encouraged to discuss, interact with each other and to explore the content collaboratively, and repeatedly fail to build the exploration and visualization skills demanded for geometrical ideas, geometry reasoning and problem-solving skills. Therefore, this study aims at delving into the effect of using GeoGebra on Van Hiele geometric thinking levels (VHGTLs) of senior high technical school students in Ghana so as address the gaps identified above. In order to fill these gaps, two hypotheses were formulated to guide the study:

H_{01}: There is no statistically significant difference in senior high technical school students (VHGTLs) after GeoGebra instruction.
H_{02} : There is no statistically significant difference between the pre-(VHGTLs) and post-(VHGTLs) scores of senior high technical school students.

METHODOLOGY

The target population for the study was all students in the senior high technical school in the Central region of Ghana. The accessible population of the study was form two senior high technical school students in Abura Asebu Kwamankese district in the Central region of Ghana. The population is made up of 546 males and 64 females. Simple random sampling procedure was used to select a sample size of 80 (50 males and 30 females) second - year senior high technical school students. The second year students were considered due to their relatively long period of stay in the school and as such must have experienced some technology usage in learning mathematics as compared to the first year students.

In this study, one group pretest-posttest pre-experimental design was employed where participants were exposed to treatment and measured afterwards to see if there were any effects (Baumgartner, Strong & Hensley, 2002). Van Hieles' Geometry Tests (VHGT) was used to collect data on the effectiveness of using GeoGebra on students VHGTLs. The VHGT was conducted before students were taught using GeoGebra on VHGTLs and students taught after using GeoGebra on VHGTLs. Then both of students' score were compared to find out if there is a significant difference. There were four independent groups regarding students VHGTLs such as level 1, level 2, level 3 and level 4. Therefore, the means of these independent groups were compared in order to find out whether

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any differences existed between these independent groups on students VHGTLs after GeoGebra instruction.

ANALYSIS AND DISCUSSION

A pre-test was administered to the selected sample comprising of 80 students. Twenty items were used to assess the students' levels with each item allotted with one mark. Table 6 shows the general performance of students in the 20 pre-test items.

Table 1: Total scores obtained by students in Pre-VHGT by cumulative frequency

Score	Number of students (F)	Cumulative (F)	Percentage (%)	Cumulative Percentage (%)
5	10	10	12.5%	12.5%
6	15	25	18.8%	31.3%
7	10	35	12.5%	43.8%
8	14	49	17.5%	61.3%
9	16	65	20.0%	81.3%
10	5	70	6.3%	87.5%
11	3	73	3.8%	91.3%
12	4	77	5.0%	96.3%
13	3	80	3.8%	100.0%

Results in Table 1 shows that 81.3% (F = 65) of the students obtained less than half of the total score, 6.3% of the students (F = 5) scored half of the total marks allotted to the test while 12.5% (F = 10) obtained more than half of the total marks allotted to the test. In spite of the low performance of the students in at the pre-test, no student scored zero with only ten of the students obtaining the minimum mark of 5. Interestingly, the highest mark scored in the test was 13 out of the 20 and three students obtained that. Moreover, no students could score marks above 14. This indicates that the general performance of the SHS 2 students in the pre-VHGT Item test was very weak.

Levels reached by students' in the van Hiele Geometry Pre-Test

Table 2 shows the van Hiele levels of geometric thinking attained by the students after the van Hiele Geometry pre-test.

Table 2: Students van Hiele levels attained in the pre-VHGT

Levels	Number of students (F)	Percentage (%)
0	10	12.5
1	24	30
2	36	45
3	10	12.5
4	0	0
Total	**80**	**100**

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Table 2 indicate that, 12.5% (n = 10) of the students could not reach any of the levels, 30% (n = 24) of the students reached the Visualization (level 1), while 45% (n = 36) reached the Analysis (level 2) of the VHGTLs. Furthermore, 12.5% (n = 10) reached the Ordering (level 3),with None of the students reaching the level 4 of the VHGTLs as 0% (n = 0). Students who did not reach any of the levels means that the students could not meet the criteria for attaining VHGTLs, that is the student could not answer three (3) questions correctly from the items 1 to 5. Again, it can be seen that 12.5% (n = 10), students reached the Ordering stage (level 3); this is an indication that out of 80 students only ten (10) of the students could reach the levels 1, 2 and 3. This means that only ten (10) students could perform in level 3, where students can logically order the properties of shapes. Finally, none (n = 0) of the students reached the Deduction stage (level 4) of the VHGTLs. This indicates that none of the students was able to meet the criteria 3 of 5 correct in all the levels, that means no students could answer 3 items correctly in questions items; 1 to 5, 6 to 10, 11 to 15, 16 to 20. It shows that, at this level a student understands the significance of deduction. Even though Van Hiele's level 3 criterion was met by student at the pre-test, they cannot be placed in Van Hieles' level 3 because the student failed to answer correctly at least three of second level questions. Hence, the van Hiele Levels of geometric thinking attained by the students after the van Hiele Geometry pre-test was level 2. In the post-test twenty items were used to assess the students' levels with each item allotted with one mark. Table 3 shows the general performance of students in the 20 pre-test items.

Table 3: Total scores obtained by students in post-VHGT by cumulative frequency

Score	Number of students (F)	Cumulative (F)	Percentage (%)	Cumulative Percentage (%)
12	11	11	13.8%	13.8%
13	10	21	12.5%	26.3%
14	10	31	12.5%	38.8%
15	10	41	12.5%	51.3%
16	12	53	15.0%	66.3%
17	10	63	12.5%	78.8%
18	7	70	8.8%	87.5%
19	6	76	7.5%	95.0%
20	4	80	5.0%	100.0%

Results in Table 3 show a minimum mark of 12 and maximum mark of 20. Majority of the students 95.0% (F = 76) obtained more than half of the marks allotted to the test, while 5.0% (F = 4) had the total marks allotted to the test. This indicates that the general performance of the SHS 2 students in the post-VHGT Item test was very impressive hence above average remarks.

Levels reached by students in the van Hiele geometry post-test

Table 4 shows the van Hiele levels of geometric thinking attained by the students after the van Hiele Geometry post-test.

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Table 4: Students van Hiele levels attained in the post-VHGT

Levels	Number of students (F)	Percentage (%)
0	0	0
1	14	17.5
2	23	28.75
3	40	50
4	3	3.75
Total	**80**	**100**

Table 4 indicate that, 0% (n = 0) of the students could not reach any of the levels, 17.5% (n = 14) of the students reached the Visualization (level 1), while 28.75% (n = 23) reached the Analysis (level 2) of the VHGTLs. Furthermore, 50% (n = 40) reached the Ordering (level 3). 3.75% (n = 3) of the students reaching the level 4 of the VHGTLs. Students who did not reach any of the levels of Van Hiele Geometric thinking means that the students could not meet the criteria for attaining VHGTLs, that is the students could not answer three (3) questions correctly from the items 1 to 5. Again, it can be seen that 50% (n = 40) students reached the Ordering stage (level 3); this is an indication that out of 80 students only fourteen (14) of the students could reach the levels 1, 2 and 3. This means that fourteen (14) students could perform in level 3, where students can logically order the properties of shapes. Finally, 3.75% (n = 3) of the students reached the Deduction stage (level 4) of the VHGTLs. This indicates three (3) out of 80 students were able to meet the criteria 3 of 5 correct in all the levels, that means three of the students could answer at least 3 items correctly in questions items; 1 to 5, 6 to 10, 11 to 15, 16 to 20. It shows that, at this level a student understands the significance of deduction and the role of postulates, axioms, theorems and proofs. These are important geometric knowledge which students need to study in geometry related courses at the tertiary level. This shows the sequential order of Van Hiele's level 3 criterion because the students were able to answer correctly at least three of second level questions. Hence, the van Hiele Levels of geometric thinking attained by the students after the van Hiele Geometry post-test was level 3 and 4.

Analyses of hypotheses

Hypothesis 1

H_0 : There is no statistically significant difference in senior high technical school students VHGTLs after GeoGebra instruction.

H_1 : There is statistically significant difference in senior high technical school students VHGTLs after GeoGebra instruction.

The first research hypothesis sought to find out whether or not there was a statistically significant difference in senior high technical school students VHGTLs after GeoGebra instruction in Senior High Technical School. One-Way Analysis of Variance (ANOVA) was used in the analysis. With regards to this study, there were four independent groups regarding students van Hiele geometric thinking levels which are level 1, level 2, level 3 and level 4. Therefore, the means of these independent groups were compared in order to find out whether any differences existed among these

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independent groups on students van Hiele geometric thinking levels after GeoGebra instruction. Result is illustrated in Table 5.

Table 5: One-way ANOVA analysis of students VHGTLs after GeoGebra instruction

Significant @ 0.05 level

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	2975.468	1	2975.468	14.079	.001
Within Groups	7608.111	36	211.336		
Total	**10583.579**	**37**			

Results in Table 5 shows that the statistical test is the *F* ratio and it can be seen that the *F* ratio is 14.078 and the *p* value of the *F* ratio is .001. Since, the *p* value of .001 is less than the alpha level of .05; it implies that there is a statistically significant difference among the level means of students van Hiele geometric thinking levels after GeoGebra instruction.

Hypothesis 2

H_0 : There is no statistically significant difference between the pre-VHGT and post-VHGT scores of senior high technical school students.

H_1 : There is statistically significant difference between the pre-VHGT and post-VHGT scores of senior high technical school students.

The second research hypothesis sought to find out whether or not there was a statistically significant difference in Van Hiele Geometry Tests (VHGT) scores of senior high technical school students. The paired samples t-test was used to test the null hypothesis that there was no significant difference in the two tests. The results obtained for the t-test analysis is presented in in Table 12.

Table 6: Paired sample T-test of pre and post VHGT scores of students

TEST	N	Mean	Std. Dev.	Mean Difference	t-value	Df	Sig. (2-tailed)
Post-Test	80	15.43	2.375	7.48	-16.654	79	.000
Pre-Test	80	7.95	2.140				

Significant @ 0.05 level

Results in Table 6 shows the paired samples t-test results in Table 12 shows that the pre-test mean score (M=7.95; SD=2.140) and post-test mean score (M=15.43; SD=2.375) were found to be statistically significant at t= -116.654; df=79; p<0.05. Therefore, the null hypothesis that there is no statistical significant difference between the pre-VHGT and post-VHGT scores of senior high technical school students was rejected.

DISCUSSION

The study sought to find out how effective is the use of GeoGebra on senior high technical school students' van Hiele level of geometric thinking. The result in table 1 indicates that most students

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did not perform well in the pre-VHGT item test and therefore could not solve the Levels 3 and 4 items as compared to the post-VHGT Item test. Students who attempted the questions used incorrect working procedures in their effort to solve the items in the pre-VHGT Item test. This resulted in some students arriving at various answers. Furthermore, students inability to solve the Ordering and Deductive levels questions agree with the findings of Atebe and Schafer (2010); Baffoe and Mereku (2010) who stated that students 'weaknesses had obstructed the progress of mapping the steps appropriately to finding the solution. After the treatment period (the use of GeoGebra), it was observes that students were able to solve the ordering and Deductive level questions as presented in table 4. This coincides with Bwalya (2019) who concludes that GeoGebra is one sure solution to the poor performance in questions involving geometric concepts as it enhances understanding which is the key ingredient to good mathematics learning and hence improved performance in the area of geometry at secondary school level.

Also the analysis of levels reached by students on the VHGTLs showed that, majority of the students had not reach any level or reached the first and second levels of the VHGTLs, that is the Visualization and Analysis level in the pre-test in table 2 as compared to table 4 in the post-test. The number of students who reached levels 3 and 4, that is ordering and deductive levels shows that most students were not able to categorize and generalize by attributes and develop proofs using axioms and definitions in the pre-test as compared to the post-test. The findings in the study showed that students who reached the Ordering and Deductive levels could classify and generalize by attributes and develop proofs using axioms and definitions.

The table 5 which shows the results of the One–Way ANOVA indicates that there is a statistically significant difference among the level means of students VHGTLs after GeoGebra instruction. This is in line with the study of Ahmad and Rohani (2010) which discovered that the independent-t test comparing the post-test results of the two groups showed that there was a significant difference between mean performance scores of the control group compared to GeoGebra group. This finding indicated that students who had learned Coordinate Geometry using GeoGebra were significantly better in their performance compared to students who did not.

CONCLUSION AND RECOMMENDATION

The findings from the effectiveness of using GeoGebra on students' van Hiele level of geometric thinking indicated that, most of the students did not perform well in the pre-VHGT Item test and therefore could not solve the Levels 3 and 4 items as compared to the post-VHGT Item test. Students who attempted the questions used wrong working processes in their attempt to solve the items in the pre-VHGT Item test. After the treatment period (the use of GeoGebra), it was observes that students were able to solve the ordering and Deductive level questions. The Van Hiele Levels of geometric thinking attained by the students after the use of GeoGebra was level 3 and 4. Thus, the use of GeoGebra on students van Hiele level of geometric thinking was effective. It is recommended among others that Heads of senior high schools and other educational stakeholders should organise in- service training for mathematics teachers to equip them with the required skills on how to utilise GeoGebra for effective teaching and learning of geometry and other lessons in mathematics.

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