Application of GeoGebra to Improve Academic Performance of Students in Geometry

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ABSTRACT
Students' performance in Geometry has been a source of worry to both teachers and students at the colleges of Education in Ghana. This is because the existing approach of teaching the afore-mentioned course has been chalk and talk (Traditional), which do not promote effective understanding. Thus, this study seeks to propose teaching according to Van Hiele theory of geometrical understanding using GeoGebra to address this gap. A sample of 390 level 100 students was selected purposively from a population of 490 level 100 students for the study. The main instrument for data collection was test. Data collected from the test were analyzed and presented by the independent sample t –test. Two tailed test was used in the descriptive statistics to test the null hypothesis. The reliability coefficient for the pre-test was 0.66 and that of the post-test was 0.65 indicating the instruments were accurate and reliable. The findings showed that there was significant difference between the mean score of students who were taught Geometry using GeoGebra and those taught without the use of GeoGebra in favor of the GeoGebra group. The study recommended among others that enough mathematics software especially GeoGebra should be provided in schools.

General Terms
Traditional Approach, Geometry

Keywords
Van Hiele Theory, GeoGebra, Geometry

1. INTRODUCTION
Students' performance in geometry has been a source of worry to both teachers and students at the Colleges of Education[1]. There have been a lot of studies in literature supporting this assertion[2],[3],[4]. For example, in the report presented by the University of Cape Coast in 2013, 2015 and 2017 academic year stated that students failed geometry and those who even passed the geometry paper in the Colleges of Education got weak passes. The report indicated that in 2013 academic year 38.8% of the 7,449 students who sat for the geometry paper either failed or got a grade D or D^+. Again in 2015 academic year 28.8% of the teacher trainees failed while 42.3% had D or D^+.

In 2017 academic year, 3,132 representing 23.2% out of the total 13,513 of the teacher trainees failed or obtained a grade of D or D^+ at the end of the semester examination, per the Institute of Education, professional board report, UCC- Ghana. The 2018/ 2019 academic year report on the students' performance in geometry was on the decline (UCC, Chief Examiner's Report for EBS 143: Geometry and Trigonometry, 2018). Although teachers of mathematics have been using the traditional approach (TA) which is predominantly talking and using chalk as means of illustrations[5]. The talk and chalk method (TCM) of instruction focuses on what the teacher says and what he or she writes on the board. The TCM of instruction deals with the teacher been an information giver instead of been a facilitator and the students been information recipient rather than negotiators of mathematical concepts. Meanwhile the focus of learning process has changed from teacher centered, direct instruction to student centered learning[6], [7]. One way to achieve studentcentred learning is the use of technology. When technological tools are used in mathematics, students are motivated and therefore perform better[8]. In this paper, a comparative study of the traditional approach and the use of GeoGebra software involving 390 level 100 students was conducted. The aim was to investigate the effect of the integration of GeoGebra into the teaching and learning of geometry on students' academic performance and how it can be improved. Thus, the following contributions were made:

- Conduct an extensive study on the two approaches, namely the traditional approach and the use of GeoGebra software.
- To find out if there is any significant difference in the post- test average scores of the control group and the experimental group at the Van Hiele's Geometric Levels.
- Make recommendations to stakeholders to decide on which of the two teaching approaches is appropriate for teaching geometry.

The remaining section of the paper is organized as follows: Section 2 presents related work in the domain of the study. This is followed by section 3 which discusses the theoretical framework of the study. Section 4 presents the methodology. Section 5 presents the findings and discussions of the study. The conclusion of the study is presented in section 6.

2. RELATED WORK
This section of the study present existing literature on the use of GeoGebra to improve academic performance of students in the colleges of education in Ghana. Ampiah et al[9] attributed students' poor performance in mathematics and geometry in particular to the traditional method use in teaching mathematics. This teaching method according to them is more of teacher–centered rather than student–centered and do not promote conceptual understanding by students. According to them, this way of teaching has resulted in general detest for mathematics by students and poor mathematics achievement in schools and colleges. In another study, Acquah and Alhassan[10] conducted a study to assess the challenges of Ghanaian pre-service teachers in the learning of geometric transformation concepts and perception of factors inhibiting the development of their mathematical knowledge for teaching in selected Col-

leges of Education in the Eastern Region of Ghana. Findings from the study shown challenges of pre-service teachers were as a result of factors such as lecture approaches (talk and chalk method) adopted by mathematics teachers in the teaching of geometric transformations, inadequate exercises in geometric transformation concepts taught to consolidate students understanding and poor nature of assessment task given on geometric transformation. A comparative study on the teaching effectiveness of chalk and talk versus ICT tool was a study by Tarpan, Megha and Hiral[11],[12]. According to the study, teaching using the ICT tool was better than the talk and chalk method as teaching aid.Abdoleza, Suraya and Kamariah [13]conducted a study entitled comparison of new mathematics teaching methods with traditional method. Data were collected using observation and semi-structured interviews with seven teachers, who were selected by snow ball method in two secondary schools at different States of Malasia. According to the participants (sampled teachers), the traditional method is ineffective in teaching mathematics in the selected secondary schools and therefore recommended discovery and the use of ICT tools in teaching and learning of mathematics. They suggested that teachers should emphasis on teaching methods which include less lecture, more students directed classes and more discussion. Noreen and Rana[14] compared activity based method and that of the traditional method of teaching mathematics at elementary level. The study was an experimental one involving a sample of 60 students selected randomly from class seven Government Girls school in Kasur District in Pakistan. The study concludes that the traditional method does not promote knowledge, understanding and application of knowledge as compared to the activity-based teaching method. Yazlik[15] also conducted a study to investigate whether geometry instruction using Cabri Geometry Plus II software had any impact on seventh grade students' learning outcomes in geometry. At the end of the study, it was found that using the dynamic geometry software program Cabri in teaching geometry increased the success level of the students in the experimental group as compared to students in the control group who were instructed using talk and chalk method of instruction. From all the aforementioned studies factors such as traditional teaching methods, lecture approach, lack of dynamic teaching, lack of ICT integration and the lack of activity-based approaches are the major contributing factors of students' poor performance in geometry. Thus, the application of GeoGebra to address students' performance in geometry is limited. Hence, there is a dire need to find alternate teaching and learning method that incorporate technology, since studies have shown that technology application has positive effect on students' mathematical performance[16, 17].

Integrating technology software, such as GeoGebra in the teaching and learning of mathematics is supported by the theory of experiential learning and learner-centered education[18].

3. THEORETICAL FRAMEWORK

3.1 Van Hiele's theory of geometrical understanding

The study adopted the Van Hiele's theory of geometrical understanding which describes the development of geometrical reasoning as its theoretical framework[19]. It is a pedagogical theory which describes geometrical understanding levels of students by focusing on problems students face when they learn geometry. According to Van Hiele theory, students' progress through five levels of development when learning geometry, namely visualization, analysis, abstraction, deduction and rigor.

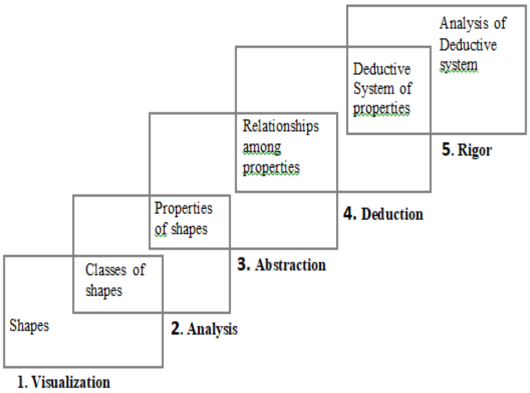

Fig 1: The Van Hiele's theory

3.1.1Visualization

Van Hiele postulated that at these level students recognizes a figure by appearance alone, often by comparing them to a known prototype. The properties of a figure are perceived. Students recognize triangles, squares, circles, parallelogram, trapezium, kite and other shapes, but do not identify correctly the properties of these figures.

3.1.2 Analysis

Analysis is a process of identifying and examining each element of an object or features on it in detail in order to understand it. A student operating at this level is able to identify each element of a geometric object in terms of its properties in isolation. At this level, students see figures as collections of properties. They can recognize and name the properties of a figure, but they do not see any relationships between the properties.

3.1.3 Abstraction

Abstraction is the process of formulating generalized concepts of common properties by disregarding the differences between numbers in a particular instance. Students operating at this level are able to perceive relationship between properties and figures and create meaningful definitions and give informal arguments to justify their reasoning.

3.1.4 Deduction

Deduction is the reasoning process by which an individual concludes something from facts or circumstances. Students at this level can construct proofs, and understand the role of axioms and definitions, and know the meaningof necessary and sufficient conditions. At this level students at the Colleges of Education level should be able to construct proofs as those encountered in the secondary schools[20].

3.1.5Rigor

The last level by Van Hiele is the rigor. Students at this level understand the formal aspects of deductive reasoning, such as establishing the similarities and differences between mathematical concepts. They can also perform indirect proof and proof by contra- positive methods as well as non- Euclidean systems[21].

3.2 Conceptual Framework

The study sought to investigate the effect of integration of GeoGebra into the teaching and learning of geometry on students' academic performance at the Colleges of Education in

Ghana. The study employed two different teaching methods, i.e., the traditional teaching method and the GeoGebra teaching method. The GeoGebra teaching method was applied to the experimental group while the traditional teaching method was also applied to the control group. The Van Hiele theory of geometrical understanding was adopted as a theoretical framework to analyses the learners' levels and/stages that they go through when engaged in geometry (especially circle geometry) problem-solving skills.

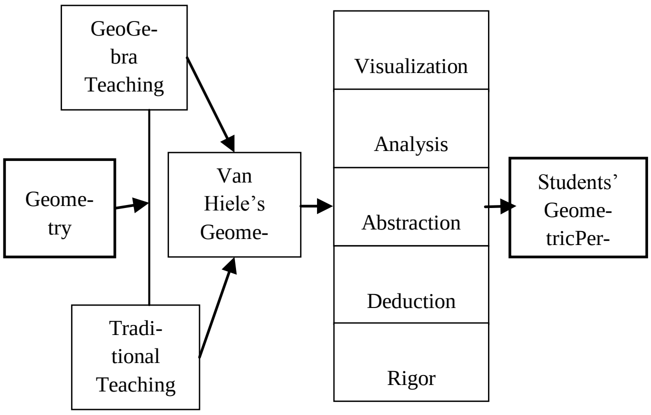

Fig 2:Conceptualized Framework of the Study

4. METHODOLOGY

4.1 Design

This quantitative study employed a quasi- experimental research design, specifically pretest posttest control group design. The experimental group was taught using the GeoGebra approach, while the control group was taught using the traditional approach. The quasi- experimental research design was used because intact classes of unequal number of students were involved and also it enabled the researchers to estimate the causal impact of the intervention on its target population[22].

4.2 Participants in the study

The participants for this study comprised 390 level 100 students drawn from six (6) mixed ability Colleges of Education in Ghana using simple random sampling. The number consisted of 200 males and 190 females. A simple random sampling technique was again employed to select the intact classes into either control or experimental group. In all, the control and the experimental group had three classes each. The total number of students in the experimental groups was 220 made up of 120 males and 100 females, while 170 students made up of 90 males and 80 females constituted the control group. The difference in the group was as a result of uneven distribution of students in the various programs.

4.3 Instrument

The main research instrument that was used in the study was Geometry Learning Assessment Test (GLAT). The GLAT comprised pretest and posttest. The items on the pretest were different from that of the posttest on geometry. The reason for the pretest was to determine the initial entry points and to compare differences between experimental and control group before treatment. The pretest consisted of twenty (20) multiple choice questions which were based on students' SHS core mathematics syllabus (Ministry of Education, 2013). The pretest lasted for one hour. Also, a posttest consisting of eleven (11) multiple choice and ten (10) essay type questions were conducted. The posttest questions were based on Colleges of Education Geometry course outline (4-year Bachelor of Education Curriculum for Colleges of Education in Ghana, 2016). The reason for the posttest was to determine the treatmentimpacts and effects on students' academic performance The validity of the instruments was ascertained by giving the instruments to four (4) experts in Mathematics Education for content and face validity. Two reliability tests were calculated, Kuder-Richardson 20 (KR 20) for the pretest and Cronbach's Spearman-Brown for the posttest. The reliability coefficient of the pretest was 0.66 and that of the posttestwas 0.65 indicating the instruments were accurate and reliable.

5. FINDINGS AND DISCUSSIONS

The main purpose of this study was to investigate the effect of integration of GeoGebra into the teaching and learning of geometry on students' performance at the Colleges of Education in Ghana. Two main research questions were raised, namely; (1) Is there any significant difference between the performances of students taught using GeoGebra as compared to students taught without GeoGebra in geometry? (2) Is there any significant difference in the post-test average score of the control and the experimental group at the Van Hiele's levels? The data collected were organized and presented using descriptive statistics to test the null hypotheses.

5.1 Pre –Test Results

A pre–test was administered to both groups (control group and experimental group) one week before the interventions in order to check if the two groups were of comparable geometric abilities before the intervention. Table 1 shows the descriptive statistics for the pre–test results for the two groups.

Table 1: Pre-test results

	Groups	N	Mean	Std. Dev-ia-tion	Std. Error Mean
Pre test	Experimental Group	220	10.5364	1.68895	.11387
	Control Group	170	10.5471	1.76776	.13558

The mean for the experimental group was 10.54 and the standard deviation was 1.69 which was lower than that of the control group with mean 10.55 and standard deviation 1.77. The mean score difference between the two groups was 0.01. To check whether the difference in performance between the experimental and the control group were statistically significant, an independent sample t–test was conducted. The following hypothesis were tested at 95% confidence interval:

H_o: There is no significant difference in geometric performance between the experimental and control group in the pre-test.

H_1: There is significance difference in geometric performance between the experimental and control group in the pre-test.

Table 2. Independent samples t-test for posttest

t-test for Equality of Means						
T	df	Sig. (2 tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
					Lower	Upper
-.061	388	.952	-.01070	.17602	-.35677	.33538

Table 2 shows that there was no statistically significance difference between the control and the experimental group although the mean of the control group (M = 10.55, SD = 1.77) was higher than that of the experimental group (M = 10.54, SD = 1.69). According to the t-test conducted, t(388) = -.061 and the p–value = 0.952. Since $0.952 > 0.05$, it means the difference in mean of the two groups is not statistically significant. Therefore any difference in geometric performance after treatment could be attributed to the treatment

5.1 Research question 1

Is there any significant difference between the performances of students taught with GeoGebra as compared to students taught without GeoGebra in geometry?

To answer the research question 1, the post-test descriptive statistics were run for both the control and the experimental group. Table 3 gives the details of the results obtained.

Table 3. Post-test results

	Groups	N	Mean	Std. Deviation	Std. Error Mean
Post-test	Experimental Group	220	38.7773	5.20629	.35101
	Control Group	170	30.0706	5.49187	.42121

In the post-test, the average score (M = 38.77; SD = 5.21) of the experimental group was higher than the control group's average score (M = 30.07; SD = 5.49). To check if the difference between the performances of the groups were statistically significant, independent samples t-test was computed to check whether there was significant difference between the two groups' geometric performance. The following hypotheses were tested at 95% confidence interval.

H_o: There is no significant difference in geometric performance of the experimental group as compared to the control group after treatment.

H_1: There is significant difference in geometric performance of the experimental group as compared to the control group after treatment. The results are shown in Table 3.

Table 4. Independent samples t-test for post-test

t-test for Equality of Means						
T	df	Sig. (2 tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
					Lower	Upper
15.989	388	.000	8.70668	.54454	7.63606	9.77731

Table 4 shows that there is a statistically significant difference in post-test scores of experimental groups (M = 38.78; SD = 5.21) and control group (M =30.07; SD = 5.49); t (388) = 15.898; p = 0.00). This finding illustrated that the students in the experimental group performed better using GeoGebra than the control group that used the traditional learning method.

5.1.1 Discussion

In this study, the effect of using GeoGebra on students' mathematics performance in learning geometry was examined using quasi-experimental design. With the current exponential development in information and communication technology in the field of education, the present study attempted to examine the effectiveness of using GeoGebra as a tool in teaching and learning geometry. The results of the study indicated that there was a significant difference between the performance of the control group, which underwent the traditional method of teaching, and the experimental group, which was taught utilizingGeoGebra. This result indicated that students taught geometry with GeoGebra performed better than students taught without GeoGebra. The result is consistent with the studies by Saha et al[23], which showed a positive effect of using mathematical learning software's, thus motivating the students towards geometry learning[24].

5.2 Research question 2

Is there any significant difference in the post–test mean scores of the control and experimental group at the Van Hiele's levels?

Table 5. Group's post-test descriptive statistics at Van Hiele levels

	Marks	N		Std. Deviation	Td. Error Mean
Visualization	Experimental Group	220	2.9409	.23633	.01593
	Control Group	170	2.7706	.42170	.03234
Analysis	Experimental Group	220	6.8909	.35360	.02384
	Control Group	170	6.2176	.82472	.06325
Abstraction	Experimental Group	220	12.0273	1.78762	.12052
	Control Group	170	9.9824	2.07114	.15885

Deduction	Experimental Group	220	9.1182	1.52143	.10257
	Control Group	170	6.9059	1.73801	.13330
Rigor	Experimental Group	220	7.7955	2.53541	.17094
	Control Group	170	4.1824	2.09726	.16085

Table 5 shows the descriptive statistics of both groups (control and experimental group) at the various Van Hiele levels. The results show that the average of the experimental group was higher than the average of the control group at all the Van Hiele levels of geometric understanding. The averages for the various Van Hiele levels for both groups were: visualization – (experimental group; M =2.94, SD = 0.24) which was higher than that of the control group's average of M = 2.77, SD = 0.42, analysis – (experimental group; M = 6.89, SD = 0.35) again higher than the control group's average of M = 6.22, SD = 0.82. The averages at the abstraction, deduction and rigor levels for the experimental group were respectively M =12.03, SD = 1.79, M = 9.12, SD = 1.52 and M= 7.80, SD = 2.54 which were respectively higher than that of the control group of M = 9.98, SD =2.07, M = 6.91, SD = 1.74, M = 4.18, SD = 2.10 respectively. To check whether the difference between the averages of the groups (experimental and control group) at the various Van Hiele levels were statistically significant, independent samples t-test was conducted at 95% confidence interval to test the hypothesis:

H_o: There is no significant difference in the post–test mean scores of the control and experimental group at the Van Hiele's levels.

H_1: There is a significant difference in the post–test mean scores of the control and experimental group at the Van Hiele's levels.

Table 6. Independent sample t-test for the group's performance at each of the Van Hiele Levels

t-test for Equality of Means							
	T	**Df**	**Sig. (2 tailed)**	**Mean Difference**	**Std. Error Difference**	**95% Confidence Interval of the Difference**	
						Lower	**Upper**
Visualization	5.502	388	.000	.17032	.03371	.10404	.23660
Analysis	10.886	388	.000	.6726	.06185	.55166	.79486
Abstraction	10.450	388	.000	2.04492	.19568	1.66019	2.42965
Deduction	13.379	388	.000	2.21230	.16536	1.88719	2.53741
Rigor	15.027	388	.000	3.61310	.24044	3.14036	4.08584

Table 6 shows that at Van Hiele visualization level, there was a statistically significant difference between average marks of the experimental group (M = 2.94, SD = 0.24) and the control group (M = 2.77, SD = 0.42); t (388) = 5.05, p = 0) in favor of the experimental group. Similarly, there is a statistically significant difference between the average post–test marks of the experimental group (M = 6.89, SD = 0.35) and control group (M = 6.22, SD =0.82); t (388) = 10.89; p = 0) at the analysis level of geometric understanding in favor of the experimental group.

Similarly, there are statistically significant differences in geometric performance between the experimental and control group at all levels of Van Hiele geometrical understanding in favor of the experimental group.The average post–test marks for abstraction, deduction and rigor for the experimental group are: M = 12.03, SD = 1.79; M = 9.12, SD = 1.52; M = 7.80, SD = 2.54 respectively while that of the control group are: M = 9.98, SD = 2.07; M = 6.91, SD = 1.74; M = 4.18, SD = 2.10 respectively. The analysis of the result show that, the experimental group who were taught with the use of GeoGebra performed better in circle theorem than the control group who were taught using the traditional approach. There were statistically significant differences in geometric performances between the experimental and control group at all levels of Van Hiele geometrical understanding in favor of the experimental group. The analysis of the result show that, the experimental group who were taught with the use of GeoGebra performed better in geometry than the control group who were taught using the traditional approach at all the levels of Van Hiele geometric understanding. The possible reasons for these findings could be attributed to the fact that GeoGebra as an instructional tool enabled students in the experimental group to check the accuracy of their work and correctness of their methods. Because GeoGebra is a dynamic teaching and learning tool and simple to use, students in the experimental group had the opportunity of re-examining their work, while those in the control group only memorized concepts and applied them with little or no understanding as to how the concepts came by. Again, in the control group, teaching was limited to few examples while the experimental group had the chance to explore the concept further using the GeoGebra software. This result is consistent with the findings of Venkataraman (2012), who found that students taught with GeoGebra made progress towards mathematical explanations which provide a foundation for further deductive reasoning in mathematics (levels 1 and 2).

6.2 Summary of the study

This study was aimed at investigating the effect of integration of GeoGebra into the teaching and learning of geometry at the Colleges of Education. This became necessary due to the poor performance of college students in geometry over the years. After the analysis of data collected, the following summary were made.

- If students at the Colleges of Education are taught geometry using GeoGebra software as an instructional tool, their performance would be better than when they are taught using the traditional method of teaching.
- GeoGebra makes lesson more practical, easy to understand, interesting and also enhances students' visualization instead of memorization of theorems.
- Students taught geometry with GeoGebra perform better than students taught without GeoGebra.
- When students are taught using GeoGebra approach they perform better at all the Van Hiele levels.
- Teaching using the traditional method do not promote conceptual understanding by students.

6. CONCLUSION

The study concludes that GeoGebra as a mathematical tool can aid the improvement of the poor performance of students in questions involving geometry and that it enhances students' understanding which is key to good mathematics learning and therefore its use in mathematics classrooms should be encouraged.

6.1 Recommendations of the study

Based on the research findings, the following recommendations are considered appropriate:

1 Teachers should use technologically enhanced methods in teaching geometry.

2 Seminars/workshops should be organized for Colleges of Education Mathematics tutors on the use of appropriate technological tools such as GeoGebra in the teaching and learning of mathematical concepts by technological experts. This is because the application of GeoGebra in teaching and learning requires skills on the part of teachers.

3 Ghana Tertiary Education Commission (GTEC), Ghana Education Service (GES), Mathematics Teachers' Association of Ghana (MAG) should organize professional development workshops for all teachers to learn Van Hiele model for teaching geometry.

4 The traditional method of teaching mathematics does not promote conceptual understanding in the colleges of Education and therefore college tutors should find alternative/or supplementary ways of teaching mathematics in general and geometry in particular.

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