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The Effect of Using the 5E Instructional Model on Students' Performance in and Motivation to Learn Sine Rule and its Applications

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Abstract

This study investigated the effect of using the 5E instructional model on Senior High School student's mathematical achievement in the application of the sine rule. A quasi-experimental, non-equivalent control group, pre- post-test research design was used in the study. Convenience sampling technique was used to select two intact class groups' representing a control and an experimental group. Trigonometry tests (pre-test & post-test) and questionnaires which generated quantitative and qualitative data were used to collect data. Descriptive, inferential and thematic analytical methods were used to analyze the data generated. The results showed that there was a significant difference between the mean performances of the experimental and control group. The average mean performances of each of the two groups showed that the experimental group performed better than the control group. Again, the results showed that the use of the 5E instructional model was fun, practical, interactive and interesting hence motivates students to learn trigonometry, specifically sine rule and it's application. The study recommended that Mathematics teachers should adapt the 5E instructional model in teaching trigonometric concepts to promote retention and transfer of knowledge.

Keywords: 5E Learning model, Motivation, Sine rule, Difficulties.

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Introduction

Mathematics education is central to the scientific development of a country. The more mathematically enlightened a society is, the better the chances of its citizens are getting employed, increasing their income opportunities, reducing their poverty levels and advancing in science and technology. Being aware of the role of mathematics in national development, the Ministry of Education have made provisions to provide her citizens equal access to quality mathematics education at all levels in the country. These provisions are captured in the Education Strategic Plan (2018 – 2030) of the Ministry of Education that has a strategic objective as to improve quality teaching and learning in Science, Technology, Engineering, Mathematics (STEM) education in all Senior High Schools in Ghana (National Development Planning Commission [NDPC], 2018).

STEM disciplines share the conceptual process of learners making sense what they learn as they individually or in a group, as they actively engage with the environment to explore, test, refine, develop, and use ideas together meaningfully (Li & Schoenfeld, 2019). STEM education aims at developing processes and skills for solving problems. The focus is on challenging learners to think critically and to come out with their own solutions novel problems and thereby making them innovators. STEM skills boost students' project management skills especially in mathematics and engineering courses. For example, building a simple robot, engine or computer involves many processes and management of resources. In the building process, Students acquire skills on how to manage resources in such projects. These skills assist students throughout their lifestyle.

The Senior High School mathematics teaching curriculum is structured to cover seven domains including algebra and trigonometry. Trigonometry is a branch of mathematics that deals with the understanding of triangular concepts and their applications (Rizkianto, Zulkardi, & Darmawijaya, 2013; Ahamad, et al. 2018). Trigonometry in the Ghanaian mathematics curriculum covers angles, measurement of angles, triangles and their relationships. It blends geometric, graphical, and algebraic reasoning to provide space for making sense in solving problems involving triangles, trigonometric expressions and graphs. Trigonometry in the Elective mathematics curriculum is taught in the second year (Form Two). In the Core mathematics curriculum, trigonometry is in two parts: Trigonometry I and Trigonometry II. Trigonometry I (Triangle Trigonometry) is taught in Form Two to enable students identify trigonometry ratios (sine, cosine and tangent) and their application to calculate distance and heights. Trigonometry II (Trigonometry function graph) is taught in Form Three to enable students draw the graphs of trigonometric functions and use them in solving problems. In addition to these objectives, teaching trigonometry in the elective mathematics curriculum is also to enable students convert angles into radians, state and use the sine and cosine rules, and apply them solving problems involving bearings equations (up to quadratic). Trigonometry is a product of algebraic techniques, geometrical realities and trigonometric relationships (Niranjan, 2013). Sound knowledge in trigonometry that is required to represent and solve problems in geometry and in daily life situations. 0ne of the most frequent trigonometry relation used in solving problems in geometry is the Sine rule. Teaching and learning of the sine law require a combination of approaches for effective formation of concepts and understanding.

In the SHS mathematics curriculum, the sine rule and its applications are taught at form two level This rule establishes a relationship between the angles and the side lengths of any given triangle. This rule state that given a triangle ABC with sides x, y, and z, as in

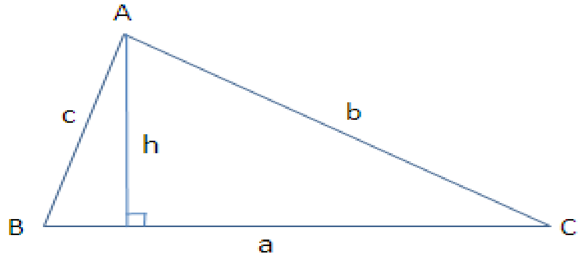

Fig. 1: Triangle ABC

Then, taking projection of both AB and AC on h gives:

c.sin $B = b.sinC$

Dividing through by sin B $and\ then\ sinC$

Therefore, $\frac{b}{SinB} = \frac{c}{SinC} = \frac{a}{SinA}$

Taking another projection of CA and CB on the height h *also gives*

a.sin $B = b.sinA$

Hence Sine Rule is stated as $\frac{\mathbf{a}}{\mathbf{SinA}} = \frac{\mathbf{b}}{\mathbf{SinB}} = \frac{\mathbf{c}}{\mathbf{SinC}}$

The curriculum does not explicitly explain how teachers teach and use the Sine Rule but there are problem situations that require its application for resolution. Besides, the relevance of learning Sine Rule cannot be overlooked as it has direct applications in Geography and used widely in other fields of Geometry, Cartography, Geology (Weber, 2005; Tuna, 2013) and flight engineering.

Researchers (Brown, 2006; Weber, 2005; Presmeg, 2007 & Orhun, 2013) have examined students' misconceptions, errors, and related to learning complexities about simplification of trigonometric expressions, metaphors and students' understanding of the sine and cosine. These studies indicate that many students had an incomplete or fragmented conceptual understanding of the three major ways of visualising the sine and cosine namely: as coordinates of a point on the unit circle, as a horizontal and vertical distances that are graphical entailments of those coordinates, and as ratios of sides of a reference triangle. Research that examined the challenges in learning has shown that many students experience difficulties in learning geometry and trigonometry (Alex & Mammen, 2012; Abu & Abidin, 2013) and do not develop the concepts of trigonometry in solving trigonometry problems (Orhun, 2015). These situations that lead to student poor performance in problems involving trigonometry concepts.

In Ghana, Nabie, Akayuure, Bariham, and Sofo (2018) study of pre – service teacher's perceptions and knowledge of trigonometric concepts suggests that participants perceived trigonometry as abstract, difficult and boring to learn. They also had limited conceptual knowledge of basic trigonometrical concepts. Based on the findings, they recommended that teacher education must change their instructional practice and teach mathematics for understanding ~~if~~ to achieve the goal of quality mathematical education as emphasised in the curriculum. Teaching trigonometry for understanding requires the use of active techniques that enable learners to construct their own knowledge, reflect on what they doing and how their understanding is changing.

Theoretical Framework

This study is grounded on constructivism. This theory advocates active teaching techniques and is a widely touted theory of learning that encourage students to learn on their own. It's principles probe understanding on grounds that understanding can increase and change to higher level thinking based on experiences (Mvududu & Thiel-Burgess, 2012) The main idea of constructivism is that learners actively construct new knowledge on the foundation of pre-existing knowledge (McLead, 2019). The principles of the constructivism suggest that students can make sense of the materials they learn if they are actively involved and act based on their experiences. Teachers should consider what students know and allow them to put their knowledge into action. Such knowledge in action learning trigonometry enable the student to build new concepts that make sense to them. Through active classroom participation and interactions, students are able to participate in problem solving strategies, verbalize their thinking, explain or justify their solutions and ask for clarification. This enables the students to understand the concepts and extend their conceptual frame to accommodate alternative methods of solving trigonometry problems. In a constructivist learning environment, the teacher guides the students through problem-solving and inquiry-based learning activities with which students put their ideas together, draw conclusions and make inferences as a group and share their knowledge in a collaborative learning environment. Always guided by the teacher, students construct their knowledge actively rather than just mechanically ingesting knowledge from the teacher or the textbook. The task of the instructor is to translate information to be learned into a format appropriate to the learner's current state of understanding (Khalid & Azeem, 2012).

Constructivists view students as actively engaged in making of what they learn. Teaching trigonometry using the constructivist approach enables the teacher to assess what students can analyze, investigate, collaborate, share, build and generalise based on previous knowledge, rather than what facts, skills and processes they can produce. To do this effectively requires teachers to use innovative teaching methods that respond to emerging issues in mathematics education such as modeling. The 5E instructional model features all the characteristics epitomised in constructivism and provide opportunities for learner participation by engaging them in activities that enable them to construct their own understanding. In this way, teachers facilitate and guide students to make sense of what they learn.

The 5E instructional model, developed by a Biological Sciences Curriculum Study (BSCS) team (Bybee et al., 2006) within the constructivist frame, expands and deepens curriculum and instruction for improved student learning. It provides an instructional strategy that encourages a constructivist approach to education while introducing aspects of behaviorism and cognitivism (Jobrack, 2010). The model has five learning phases/stages all beginning with 'E' – Engagement, Exploration, Explanation, Elaboration, and Evaluation, and hence its name.

Engagement: This phase focus students' attention on the topic and attempts to capture their attention and interest. Consequently, activities focus students' attention on the learning situation, event, demonstration, or problem. Teacher asking questions, posing a problem, or presenting a discrepant event are strategies to engage learners to focus attention (Bybee, 2014). The engagement phase is student-centered and minds-on stage intended to create and develop learners' interest, and to occupy their minds on the topic and what lies ahead in the lesson.

Engagement should persuade and convince learners about the reason they should learn the topic (Dass, 2015). In this phase, past experiences are connected with actual classroom learning experiences. Students ask questions and try to find answers to them. For teachers, this phase provides opportunities for determining their students' misconceptions (Balci, 2005).

Exploration: At this stage, exploratory activities are designed for introducing and describing–exploratory experiences of concepts, practices and skills of the instructional sequence (Bybee, 2014). Students acquire experiences to formulate explanations, investigate phenomena, observe patterns, and develop their cognitive and physical abilities. The teachers' role in this phase is to introduce the activity, describe the appropriate background, provide adequate materials, and counter any inherent misconceptions. After this, the teacher assumes a passive role and paying attention to details, observing, directing students as they clarify their understanding and assisting them in the reconstructing concepts whiles developing their abilities.

Explanation: This is a teacher-centered phase in the model because teachers become active in correcting mistakes and completing the missing parts of students' work Duran (2004) described this phase as the "minds-on" phase that is more teacher-directed and guided based on students' prior experiences. Prior experiences are used as contexts of the explanation (Bybee, 2014) and methods are chosen to lead students to define their work or to explain their results. Supportive learning tools like videos, power-point presentations or role-plays (Mulder, 2019) may be used to help learners to clearly grasp the new concepts.-Formal mathematical definitions and explanations are provided by the teacher. The ultimate aim of the teacher is to cultivate in learners' the correct use of mathematical terms, develop their listening and oral skills in describing the observations in the exploration phase and providing answers and solutions to the lingering questions through interactive engagement (Dass, 2015).

Elaboration: In this phase, students practice their new knowledge, suggest solutions, create new problems and make decisions and/or introduce logical implications. This is achieved by presenting a new mathematical activity or by extending the activities done in the exploration phase (Wilder & Shuttleworth, 2005). The motive is to orchestrate the transfer of concepts and abilities to related, but new, situations (Bybee, 2014). Students are advised to inquire for understanding from their peers or to come up with new ideas or strategies based on the new skills they have learned. They present and explain their final situations and activities that are used as basis for evaluation (Dass, 2015).

Evaluation: This is the last phase of the model where the teacher involves students in experiences that are understandable and in lieu of those of prior phases and matching the explanations (Bybee, 2014). Assessment in this phase is in an inquiry-based procedure that is different from that in conventional lessons. The evaluation phase is important in determining whether or not concepts are learned correctly in the mathematical context. Evaluation which can be formal or informal (Wilder & Shuttleworth, 2005) are used for revealing students' constructed knowledge in their responses to oral questions, making short summaries, filling out empty maps, reading graph and evaluating tables. Evaluation is both a separate phase and an activity that applies throughout other phases in the learning cycle (Dass, 2015). A diagrammatic of the 5E learning model is presented in figure 1

Figure 2. Phases of 5E Learning Cycle Model (Tuna & Kacar, 2013, p. 76).

Motivation is a series of attempts to provide certain conditions, so that one wants and wants to do something, and if one does not like it, it will seek to nullify or circumvent those feelings of dislike (Creswell, 2012). Aminudin et al (2019) study on why students fail to think when solving problems on trigonometry revealed that motivation solve math problems in trigonometry was limited. He recommended teaching trigonometry based on Maslow's theory of need about self-actualization and self-esteem. The need for self-actualization is demonstrated in the 5E Instructional Model where students are allowed to construct their ideas through the full use of cognitive ability to solve a given mathematical problem.

Cazibe YİĞİT (2011) also investigated the motivation to improve writing skills among a group of students in three different classes which consisted 70 students at Trakya University, School of Foreign Languages through the 5E Model-based Writing Instruction. The students were given a pre-test before the implementation in order to determine how successful they were in writing skill and then they were given the same test at the end of the study as a post-test in order to find out how much they could improve their writing skill. Several studies have revealed that mathematics performance is highly affiliated to students' motivation towards mathematics achievement (Mullis, Martin, Foy & Arora, 2012; Pantziara & Philippou, 2013; Yu & Singh, 2016). According to Kurumeh, Achor, Akume and Mohammed (2012), many students are not interested in mathematics and what it can offer. In many cases, students tend to fear and dislike the subject since they are not motivated to learn. It is argued that this lack of motivation leads to large number of failures in mathematics examinations which in tend create a problem.

Statement of the Problem

Research studies (Moore, 2012; Cetin, 2015) revealed that students have difficulties in learning trigonometry. These difficulties emanate from a number of factors including lack of motivation, abstractness of trigonometric concepts, lack of understanding of fundamental concepts, and students' inability to connect concepts in trigonometry to their everyday life. In Ghana, Mensah (2017) study reported that students are generally susceptible to errors in solving problems in trigonometry. In addition, Nabie, Akayuure, Bariham, and Sofo (2018) study of pre – service teachers in Northern Region of Ghana suggest that trigonometry is perceived as abstract, difficult and boring to learn. They also had limited conceptual knowledge of basic trigonometrical concepts. Also, the SHS Examiners Reports consistently suggest that many students lack in-depth knowledge of trigonometric equations involving double angles and have difficulties in solving problems involving trigonometry concepts (WAEC Chief

Examiners' Reports, 2011; 2012; 2013; 2016; 2016; 2017). Specifically, the reports consistently indicate that many students have difficulties in solving problems involving (a) non - right angled triangles where one side of the triangle is given, (b) problems involving bearings and (c) angles of elevation and depression. If these problems are not resolved, it would continually affect students understanding in areas of bearings, other areas of physics and many branches of engineering

The 5E model learning cycle which have been used in teaching different scientific concepts (Akar, 2005; Ceylan, 2008) and mathematics concepts (Pulats 2009) is found to improve students' achievements and aids in the retention of new learnings (Tuna & kacar, 2013). However, there is limited knowledge on the effect of this model in addressing student's difficulties in trigonometric concepts. Generally, the literature on the use of this model in the Ghanaian mathematics classroom is limited. Hence, the need to investigate the efficacy of the 5E model on the sine rule, in the Ghanaian classroom.

The research was to investigate the effect of using 5E instructional model on Senior High School students' mathematical achievement in the use of the application of sine rule in problem solving. The study also explored students' common difficulties with use of the sine rule the effectiveness of the 5E instructional model in addressing student difficulties and motivating effect of the model on learning and applying the sine rule. In pursuance of the objectives, the study was designed to answer the following research questions:

1. What are the common difficulties of Senior High School students in applying the sine rules in solving problems?
2. What is the effect of using 5E instructional model on Senior High students' performance in applying the sine rule in problems involving?
3. How does the use of 5E instructional model motivates students to learn and use sine rule in solving problems?

Method

Design

The study employed the embedded mixed method approach with quasi-experimental group as a strategy of enquiry based on our understanding that no single data set is sufficient to answer all the research questions that are different in nature (Creswell, 2012). Non-equivalent control group pre-test--post-test design under quasi-experimental group was used. This design was used in order not to disrupt natural classes and the students are considered to share similar characteristics (Best & Kahn, 2006). A diagrammatic representation of the non-equivalent pre-test--post-test control group design is represented in figure 3:

The pre-test O1 was administered to both the experimental (A) and control (B) groups to determine the entry point of participants before treatment. The experimental group received 5E Instructional model lessons (X) while the control group underwent conventional instruction (C) after which a post-test (O2) was administered to both groups to measure the student achievement resulting from the different teaching methods (Creswell, 2012).This design enabled a control group to be compared with an experimental group in the application of the sine rule in solving problems. Both groups took a pre-test and post-test, however, only the experimental group received treatment on the 5E instructional model. The pre-test provided the researcher with some idea of how similar the control and experiment groups were before the treatment.

Group	Pre-test	Treatment	Post-test
A	O1	Y	O2
B	O1	C	O2

Time →

Fig. 3 Non-Equivalent Pre-Test--Post-Test Control Group Design

The population for the study was government assisted Senior High School students in Bekwai Municipality of the Ashanti Region of Ghana. These schools use the national mathematics curriculum and run the same academic calendar. The students admitted to these schools had passed their Basic Education Certificate Examination (BECE), and therefore have the ability to learn trigonometry in the mathematics teaching syllabus. The ages of Senior High School students in Ghana are between 15 and 20 years. Convenience sampling was applied to select 80 (57 males; 23 females) General Science students from one out of the two mixed assisted government SHSs in the Bekwai Municipality. Convenient sampling technique was used for the sample on the basis of the accessibility. Two intact third year, classes 3E and 3F, were used as the Control and Experimental groups respectively for the study. The control group of 40 students was made up of 29 males and 11 females while the experimental group 40 students comprised of 27 males and 13 females. Students from all the selected classes grades in their second semester, form two Elective Mathematics subjects ranges from AI to C6.

Two instruments: Trigonometry Achievement Tests (pre-test and post-test) and a Questionnaire (closed ended and open ended) were used to collect data for the study. The Trigonometry Achievement Test was comprised the Pre-test and Post-test. The pre-test was made up of eight (8) items on problems to be solved by the use of sine rule. The first four items centered on the identification of sine rule to solve problems of lengths and angles of triangles. The last four items involved applications of sine rule in solving problems on bearings, angle of elevation and depression, designed by the lead author to collect data for research one (1). The post-test, also made up eight (8) similar items on sine rule, was developed to collect data to measure the learning outcomes of the students' ability to apply sine rule in solving problems. The post-test was designed to answer research two (2). The pre- test items were different from the post-test to avoid providing clues to the latter. All the items were drawn from SHS mathematics curriculum materials especially the teaching syllabus. In all 8 items each for pre-test and post-test were used to measure the profile dimensions: knowledge, Understanding and Applications.

The questionnaire was a five-point Likert scale type items based on 5E learning model. It was used to collect data on student's reactions, attitudes, motivation, interest and perceptions in learning trigonometry taught through the model. The questionnaire was in three sections: A, B and C. Section A of the questionnaire was made up of three items designed to collect demographic information of participants. Section B made up of ten closed-ended items explored participants perceptions, interests, attitudes and motivation to learn trigonometry questions. Section C consisted of (2) opened-ended questions constructed to elicit information on how the 5E Model motivates students after experiencing it in lessons on sine rule and its application.

Validity and Reliability of the Instrument

The tests were validated by having colleague teachers review the items with respect to course objectives stated in the syllabus. This was followed by consultation with experts in the field of mathematics education including three lecturers at the department of Mathematics Education of the University of Education, Winneba (UEW). Furthermore, the tests were piloted on 48 students selected from a similar school in the district mainly to detect lack of clarity in the phrasing of the questions, and to give indication for the appropriateness of time needed for its completion.

Reliability on the other hand means dependability or consistency of results on many occasions. It refers to the extent to which a measuring instrument; a questionnaire, a test yields the same results on repeated applications (Williams, 2014). It means the degree of dependability of a measuring instrument. In this study, the split-half method was used to check the reliability of the instruments. The spilt-half method requires the construction of a single test consisting of a number of items. These items were then divided or split into two parallel halves (usually, making use of the even-odd item criterion). According to Gay and Airasian (2003), for a cognitive test in which the questions are not scored dichotomously the reliability can be calculated by using the Spearman Brown formula $R = 2r/(1+r)$, where r is the correlation coefficient between split half test results, or between test and the re-test results, or between two equivalent randomly assigned groups. The results in this study showed significant correlation coefficient of 0.59 given R as 0.748.

The pre-test and post-test were both administered under same conditions before and after treatment respectively. The pre-test lasted for 40 minutes on Monday, 18th of March 2019 in the second semester of the 2018/2019 SHS academic calendar. The pre-test was marked and scored on the following day where data was retrieved. The experiment followed the pre-test on Monday, 25th of March 2019. Post-test was conducted on Tuesday,2nd April, 2019 after the treatment which lasted for 40 minutes. Data was compiled from the post-test scores after marking The Trigonometry Achievement Tests (TAT) were meant to be written by all participants in the study. Time to complete each test was forty (40) minutes. Marking schemes were prepared separately for the two tests and all participants' answer sheets from TAT was marked and scored by the researcher. Both the pre-test and the post-test were scored out of fifty (50) marks. Hence a participant can obtain a minimum of zero and a maximum of fifty marks. Each item carried a different mark for both pre-test and post-test.
After the treatment, questionnaires were administered to students in the experimental group at their usual classroom. Participants completed the questionnaires on the spot within 30 minutes and turned them in resulting in a return rate of 100%.

A total of three periods (one period for 60 minutes) amounting to 120 minutes of mathematics lesson was used to implement the experiment which involved the five phases of the 5E instructional model. The intervention took three days to complete. During the treatment, the experimental class was taken through lessons on the sine rule by employing the 5E instructional model while the control group was taken through the same lessons using the traditional approach. In the control group, the students were taught the same topics (as in the experimental group) but with traditional approaches such as the lecture method in which the learners strictly follow the instruction the researcher gives and active participations was not promoted. The students were not given any hands-on activities to help them explore sine rule under trigonometry concepts and form their own knowledge. The sine law was given to students without any explanation. In other words, trigonometry instruction was not in line with the 5E Learning Model but mainly in lecture format and therefore instruction was teacher-centered. The 40 students in the control group were not put into groups. Their lesson was taught in the same week as in the experimental group in second semester.

Data Analysis

Data collected involved both quantitative and qualitative data. Quantitative data collected from the scores of pre-test and post-test were analyzed by employing and descriptive and inferential statistics respectively using Statistical Package for Social Sciences (SPSS) version 21.0. Measures of central tendencies and measures of dispersion were employed to understand how one score compares with another while independent samples t-test were run to compare for any significant difference in the scores of the experimental and control groups at 95% confidence level. Again, descriptive statistics was also used to analyze the closed- ended part of the questionnaire in the form of simple percentages. For the qualitative data, the process of data analysis involved was thematic, where research findings were interpreted with reference to data gotten from open-ended questionnaires. Data collected were analyzed by themes that run through the responses of the open-ended data from the questionnaires after the researcher had read the and identified categories of responses that answered the research question.

Results

The results were presented based on the research questions that guided the study. The quantitative data generated from the pre-test, post-test and closed ended questionnaire were analyzed using both descriptive and inferential statistics. The qualitative data generated from open- ended questionnaire was analyzed using thematic analysis.

Quantitative Data

Research Question One

Research question one focused common difficulties of Senior High School students in the application of the sine rule in solving problems. To answer research question one, students' answers to pre-test questions were scored item by item and the results presented in Tables 1 and 2.

Table 1. Item by Item Comparison of Pre-Test Results of The Experimental Group

Item	Correct (%)	Partially Correct (%)	Wrong (%)	No Attempt (%)	Total (%)
Q. 1	12 (30%)	5 (12.5%)	23 (57.5%)	0 (0%)	40 (100%)
Q. 2	20 (50%)	5 (12.5%)	13 (32.5%)	2 (5%)	40 (100%)
Q. 3	15 (37.5%)	3 (7.5%)	24 (60%)	8 (20%)	40 (100%)
Q. 4	4 (10%)	3 (7.5%)	15 (37.5%)	18 (45%)	40 (100%)
Q. 5	2 (5%)	9 (22.5%)	9 (22.5%)	20 (50%)	40 (100%)
Q. 6	0 (0%)	2 (5%)	14 (35%)	24 (60%)	40 (100%)
Q. 7	2 (5%)	0 (0%)	7 (17.5%)	31 (77.5)	40 (100%)
Q. 8	1 (2.5%)	5 (12.5%)	7 (17.5%)	27 67.5%)	40 (100%)

Table 2. Item by Item Comparison of Pre-Test Results of The Control Group

Item	Correct (%)	Partially Correct (%)	Wrong (%)	No Attempt (%)	Total (%)
Q. 1	17 (42.5%)	7 (17.5%)	16 (40%)	0 (0%)	40 (100%)
Q. 2	27 (67.5%)	5 (12.5%)	5 (12.5%)	3 (7.5%)	40 (100%)
Q. 3	10 (25%)	10 (25%)	20 (50%)	0 (0%)	40 (100%)
Q. 4	13 (32.5%)	5 (12.5%)	12 (30%)	10 (25%)	40 (100%)
Q. 5	5 (12.5%)	9 (22.5%)	11 (27.5%)	15 (37.5%)	40 (100%)
Q. 6	0 (0%)	6 (15%)	5 (12.5%)	29 (72.5%)	40 (100%)
Q. 7	0 (0%)	4 (10%)	8 (20%)	28 (70%)	40 (100%)
Q. 8	1 (2.5%)	3 (7.5%)	10 (25%)	26 (65%)	40 (100%)

From Table 1, it would be realized that, apart from question two, only 30%, 37.5%, 10%, 5% of participants in the experimental group answered correctly questions one, three, four and five respectively. Similarly, from Table 2 it would be realized that, apart from question two, only 42.5%, 25%, 32.5%, 12.5% of participants in the control group answered questions one, three, four and five respectively correctly. These results indicated poor understanding of basic trigonometry concept in sine rule. It was therefore not surprising that about 45% and 50% in the experimental group (see Table 3) did not attempt questions four and five respectively while 25% and 37.5% in the control group did not attempt questions four and five respectively. Also, it would be realized that most of the students who attempted questions (1, 3, 4 and 5) either had them wrong or partially answered them correctly.

The results from Table 1 also revealed that most students answered question two correctly. Twenty (20) participants representing 50% in the experimental group and (27) participants representing 67.5% in the control group answered question two correctly. A careful analysis of students' answer scripts showed that the students performed better in question two as a result of using other rules such as Pythagoras' theorem and trigonometry ratios instead of sine rule to solve the right-angled triangle. However, a whopping 32.5% and 12.5% from the experimental and control groups still answered this question wrongly. These results showed that majority of the students did not have basic conceptual understanding of trigonometry especially Sine rule.

Results from Table 1 indicated that only two students representing 5% of the participants from the experimental group answered question seven correctly while one student each representing 2.5% from both groups answered question eight correctly. It is surprising to note from Table 1 and 2 that, no student from both groups answered question six correctly. The results also revealed that majority of the participants ranging from 65% to 72.5% in the control group and 60% to 77.5% in the experimental group did not even attempt these questions while most of those who attempted had them wrong (12.5% to 25% in the control group and 17.5 to 35% in the experimental group) and few had them partially correct (17.5% to 15% in the control group and 0% to 12.5% in the experimental group). A further investigation of participants' responses indicated that most of the students who attempted these questions could not translate the word problems into accurate diagrams in order to apply the required trigonometric rules. This result is troubling as over 60% of the participants from both groups did not attempt these application questions.

To determine the difficulties students' encounter in trigonometry questions, the self-constructed responses to the pre-test were assessed using as assessment rubrics as follows: poor conceptual knowledge of basic trigonometry, inability to view sine rule as ratios of sides of a reference triangle, limited conceptual knowledge in geometry and inability to apply knowledge in trigonometry to solve practical questions. The results of the assessment were presented in Table (3).

Table 3. Students Difficulties in Solving Problems Involving the Sine Rule

Common Difficulty	Control **f (%)**	Experimental **f (%)**
Poor conceptual knowledge of basic trigonometry	35 (87.5%)	38 (95%)
Inability to view sine rule as ratios of sides of a reference triangle	35 (87.5%)	38 (95%)
Limited conceptual knowledge in trigonometry	39 (97.5%)	39 (97.5%)
Inability to apply knowledge in trigonometry to solve practical questions	40 (100%)	40 (100%)

From Table 3 shows that students generally had difficulties in solving trigonometric problems as over 85% of students in both control and experimental groups have challenges in the domains assessed. All the participants in both the control and experimental groups (100%) were unable to apply trigonometry in solving practical problems, 97.7% in both groups had limited conceptual knowledge of geometry. Equal proportions of participants (87.5%) in the control group had poor conceptual knowledge trigonometry and lack the ability to view the sine rule as a ratio of the sides of the sides a triangle and so is the proportions of participants in the experimental group (95%)

Research Question Two

Research question one focused on the effectiveness of using 5E instructional model on Senior High students' performance in problems involving sine rule teaching and learning in contrast to conventional instruction on students' achievement in sine rule. The pre-tests of both the control and experimental groups were compared using independence samples t-test at 95% confidence interval to ascertain whether there was significance difference in the achievement of the control and experimental groups before the treatment. The descriptive statistics (see Table 4) of the pre-treatment achievement scores of the two groups is presented below.

Table 4. Descriptive Statistics of Pre-test Scores of Control and Experimental Groups

	N	Minimum	Maximum	Mean	Std. Deviation
Control group	40	4	40	17.48	8.12
Experimental group	40	0	33	10.18	8.23

From Table 4, the results showed a mean score of 10.18 and 17.88 respectively for the experimental and control groups with a mean difference of 7.30. The minimum score for the experimental group was 0 while that of the control group was 4. Also, the experimental and control groups scored a maximum mark of 33 and 40 respectively. To test whether the difference in the mean scores was statistically significant, independent samples t-test (see Table 5) was performed at 95% confidence interval.

To test whether there was statistically any significant difference in the pre-test scores of the two groups, an independent samples t-test was performed at 0.05 significance level. The results of the independence samples t-test in Table 5

Table 5. Independence Samples T-test of the Pre-test of Control and Experimental Groups

Groups	N	Mean	Std. Dev.	t-value	df	p-value	Eta Squared
Experimental	40	17.48	8.12	3.995	78	0.000	0.046
Control	40	10.18	8.23				

Table 5 revealed that there was statistically significant difference between the control group $(M = 17.48,\ SD = 8.12)$ and experimental group $(M = 10.18,\ SD = 8.23)$ conditions; $t\,(78) = 3.995, p = 0.000 < 0.05$. The results suggest that the experimental and control groups were not at the same level of achievement before intervention. The mean score of 17.48 by the control group as compared to 10.18 obtained by the experimental group suggests that the control group outperformed the experimental group in the pre-test. The effect size (eta squared value) was calculated and was found to be 0.046 (see Table 5). This eta squared value indicates a small effect size which implies that 4.6% of the variance in the pre-test scores is elucidated by the independent variable. This result indicates that even though the control group outperformed the experimental group in the pre-test, the extent of the difference between the achievement on the pre-test was small.

Post-test Results for Control and Experimental Groups

Table 6. Descriptive Statistics of Post-test Scores of Control and Experimental Groups

	N	Minimum	Maximum	Mean	Std. Deviation
Control group	40	6	43	20.95	9.995
Experimental group	40	10	50	31.43	9.421

From Table 6, the minimum scores on the post-test were 6 and 10 respectively for the control and experimental groups. Also, the control group had a maximum score of 43 while the experimental group had a maximum score of 50. This result indicates an improvement in the post-test scores for both groups compared to their pre-test scores. Furthermore, Table 10 depicts a mean score of 20.95 and a standard deviation of 9.995 for the control group compared to a mean score of 31.43 and a standard deviation of 9.421 for the experimental group. The results from Table 6 suggests that the experimental group performed better on the post-test than the control group. To ascertain whether the difference in the scores was statistically significant, the following hypothesis was formulated:

Hypothesis Testing

Ho: There is no statistically significant difference in the mean performances of the experimental and control groups post-test scores in sine rule under trigonometry.

H1: There is statistically significant difference in the mean performances of the experimental and control groups' post-test scores in sine rule under trigonometry.

To test the hypothesis, an independent samples t-test was performed at 95% confidence interval to verify if there was statistically significant difference in the post-test scores of the two groups. The results from the independence samples t-test is shown in Table 7.

Table 7. Independence Samples T-test of the Post-test of Control and Experimental Groups

Groups	N	Mean	Std. Dev.	t-value	df	p-value	Eta Squared
Experimental	40	20.95	9.995	4.823	78	0.000	0.206
Control	40	31.43	9.421				

From Table 7, the independent samples t-test performed on the post-test scores of the control and experimental groups revealed statistically significant difference between the control group $(M = 20.95,\ SD = 9.995)$ and experimental group $(M = 31.43, SD = 9.421)$ conditions; $t\,(78) = 4.823, p = 0.000 < 0.05$. The results suggests that the experimental group outperformed the control group on the post-test conducted after experiment. The mean difference of 10.48 between the experimental and the control group suggests that the experimental group outperformed the control group in the post-test. This difference in achievement between the two groups might be as a result of the 5E instructional model employed on the experimental group during the experiment and the traditional method employed on the control group.

From table 7, the eta squared value was found to be 0.206. This eta squared value showed a large effect size indicating that 20.6% of the variance of the post-test scores were improved by using the 5E instructional model as the experiment. By this eta squared value (0.206), it implies that the difference in achievement on the post-test between the experimental group, where 5E instructional model was used, and the control group, where the traditional approach was used, was large

Research Question 3

Research question three sought to determine how effective the 5E model impart on students' motivation towards the study of sine rule. To answer this research question, a questionnaire was administered to the experimental group where they were taught using the 5E model during the treatment. The questionnaire consisted of three sections, section A, B and C. For section B, the respondents were required to indicate on a five-point Likert scale ranging from strongly agree (1) to strongly disagree (5) their views on the effectiveness of the use of 5E model as an instructional approach. For section C, the respondents were expected to provide written responses to the three opened-ended questions on the effects of 5E instructional model on their motivation to learn.

Analysis of Participants' Responses to Section B Of the Questionnaire

Students' responses to items in the section B of the questionnaire where respondents were required to indicate on a five-point Likert scale ranging from strongly agree (1) to strongly disagree (5) their views on the effectiveness of the use of 5E model as an instructional approach were analyzed. The percentage presentation of the results is shown in Table 8.

From Table 10, it would be realized that apart from 5% of the students who were undecided, the rest (95%) either agree or strongly agree that the use 5E instructional model enhanced their understanding in sine rule under trigonometry. Also, 100% of the respondents either agree or strongly agree that 5E model made them solve sine rule application questions without too much difficulty, increased their motivation in solving problems involving trigonometry, has increased their interest in studying sine rule under trigonometry and is friendly in learning.

Furthermore, 75% of the respondents were of the view that 5E model is the best practical approach in learning sine rule under trigonometry while 20% were undecided and 5% disagree 5E model is the best practical approach. Similarly, 82.5% were of the view that their motivation in learning sine rule was positive and encouraging while 12.5% were undecided and 5% disagree.

Finally, 90% of the respondents agreed that the use of 5E model was effective and has built them a strong background in solving problems relating to bearing, angles of elevation and depression while 7.5% and 2.5% were undecided and disagreed respectively.

Table 8. Percentage Presentation of Respondents' Perception about the Use of 5E Model

		SA (%)	A (%)	U (%)	D (%)	SD (%)
1.	5E model enhances my understanding in sine rule under trigonometry	37.5	57.5	5	0	0
2.	5E model makes me to solve sine rule applications without too much difficulty.	25	75	0	0	0
3.	Learning sine rule in Trigonometry through 5E model is the best practical method	25	50	20	5	0
4.	My attitudes towards sine rule in trigonometry was positive and encouraging	47.5	35	12.5	5	0
5.	The use of 5E model to teach sine rule under trigonometry is highly very effective	35	55	7.5	2.5	0
6.	Learning through 5E model in sine rule increased my motivation in solving problems	25	75	0	0	0
7.	5E model is friendly in learning	25	75	0	0	0
8.	Deducing sine rule formulae is easy after learning through 5E model	35	45	15	2.5	2.5
9.	Interest in sine rule and its application has increased due to 5E model.	55	45	0	0	0
10.	5E model has built me a strong background for sine rule in solving problems relating to bearing, angles of elevation and depression.	45	45	7.5	2.5	0

Key: SA = Strongly Agree, A = Agree, U = Undecided, D = Disagree, SD = Strongly Disagree

Qualitative Data

The written responses of participants to the opened-ended questions in section C of the questionnaire were analyzed based on the themes that run through them.

Most of the students were of the view that the 5E instructional model has helped them understand sine rule and its applications better and see the method as very effective approach. When asked to comment on how they find the use of the 5E instructional model in learning sine rule and its application in the questionnaire, one of the respondents wrote that "*the lesson was very interesting and I understood everything you taught us in the class*". Responding to the same question, another respondent noted:

> *I see the 5E instructional model as a very simple way of teaching sine rule for students to understand and solve questions correctly without finding it difficult.*

In another response, the respondent stated that "*I find this trigonometry lesson interesting and free from fear and confusing because I am free to ask questions from group members and the teacher*". Continuing, the respondent wrote that "*during the group activities, my friends explain certain things I don't understand to me*".

The responses of the participants suggest that they enjoyed the lessons taught by the use of the 5E instructional model and were of the view that 5E instructional model is an effective approach of teaching trigonometry. This is in line with Praveen and Leong (2013) who found out that social interaction between pupils help to develop knowledge.

Also, participants' responses to the question on how they were motivated to study trigonometry by the use of the 5E model indicated that, the 5E instructional model provide an atmosphere for engagement, discussions, fun and practical activities. These attributes of the 5E model, in the view of the students, motivated them throughout the intervention stage. When asked how the use of the 5E model motivated him to study sine rule, one respondent stated that:

> *Ever since you started teaching us with this method, I always wanted to come to class for trigonometry lessons. Also when I go to the dormitory, l always solve questions from my textbook on trigonometry.*

A second respondent, stated that "*this method of teaching trigonometry has made me to like the topic unlike first that I don't like trigonometry at all*" some of the respondents stated that the use of the 5E instructional model has led to an increase in their study time because of its motivational attributes. According to them, their personal study time for mathematics has increased because the 5E model made the lesson interesting and practical hence making them want to study more mathematics. When responding to the question on how the use of the 5E model motivated him to study mathematics, one respondent was of the view that "this method has made learning of trigonometry so fun that my study time for mathematics has increased from twice in a week to four times in a week". Another respondent was in support of this view when he stated that

> "*yes I have really enjoyed the lessons we had with this method because it was full of practical activities in a friendly atmosphere. Because of this, now I study mathematics more than previously".*

Furthermore, the participants stated that the use of the 5E model has improved their application of sine rule in solving questions involving angles of elevation and depression. This improvement was observed in their post-test scores where most of the participants attempted application questions unlike the pre-test where majority did not attempt application questions. Commenting on how the use of the 5E model improved the way he solved application questions, a participant stated that:

> *In the pre-test, I did not even attempt any application question but after you took us through the lesson using this method, 5E model, I attempted all the application questions in the post-test and I know I will get them correct.*

In his response, another participant stated that "*for the first test we did, I did not solve any application question but the second test I solved two out of the three application questions*". Another respondent was of the view that the use of the 5E model made her understanding of the concept better when she stated "*In fact, for the first time, I understand these concepts better and learning has been made easier because now I don't need to do "chew and pour" as I used to do*"

Adopting engaging tools in the classroom, teachers may be able to transform feelings about learning and Mathematics by changing the focus from teaching facts and skills to building positive relationships between learners and Mathematics. From the above responses, it was concluded that the respondents were of the view that the use of the 5E instructional model was fun, practical, interactive and interesting hence they were motivated to study trigonometry, specifically sine rule.

Discussion

The findings to the first research question indicated that SHS students encounter some difficulties in solving questions involving trigonometry specifically, the sine rule. These difficulties include; poor conceptual knowledge of basic trigonometry, inability to view sine rule as ratios of sides of a reference triangle, limited conceptual knowledge in geometry and inability to apply knowledge in trigonometry to solve practical questions. Statistics from the pre-test responses of participants revealed that students were not able to write accurate sine rules for reference triangles and could not solve application questions involving trigonometry. These findings resonate strongly with the study by Brown (2006), which found that many students had an incomplete or fragmented understanding of ways to view sin e as ratios of sides of a reference triangle. Also, the results are in line with the findings from a study by Nabie, Akayuure, Bariham, and Sofo (2018), which found among other things pre – service teachers, who were admitted directly from the SHS level, perceived trigonometry as abstract, difficult and boring to learn and had limited conceptual knowledge of basic trigonometrical concepts. Furthermore, the results resonate with the study by Orhun (2015), who studied the difficulties faced by students in using trigonometry for solving problems.

Also, the findings from the independence samples t-test performed on the pre-test scores of control and experimental group revealed a significant difference in the mean scores, where the control group was on a higher achievement level in trigonometry than the experimental group. However, results from the independence samples t-test performed on the post-test scores of the two groups indicated that the experimental group outperformed the control group after intervention. These findings showed that the use of the 5E model applied to the experimental group during intervention improved their performance significantly to have outperformed the control group who were on higher achievement level in the pre-test. This finding is in line with the study by Tuna and Kacar (2013) who found that the use of 5E instructional model improves students' achievement and assists them retain new learning in trigonometry.

Finally, statistics from questionnaires administered to the experimental group after intervention revealed that the use of the 5E model made them develop positive attitudes towards the study of trigonometry. thus about 83% of the respondents agreed that they had positive attitudes towards trigonometry after the use of the 5E model. This positive attitude reflected in their performance in the post-test. This was alluded to by Addae and Agyei (2018) when they revealed that students' attitudes determine the effort they put in in learning a subject and encourage mathematics teachers to strive to sustain students' positive attitudes towards mathematics for good performance. The responses suggest that the way learners feel about Mathematics profoundly influences what they do with it and how they reflect on it, which in turn influences how knowledge grows and connects. The responses resonate strongly with that of M. Aminudin et al (2019) that motivation connect deeply with learner's passions and interests in learning trigonometry. 5E model was also found to be very practical, develop confidence in students, friendly and increase students' interest in trigonometry as alluded to in the responses of the participants. These findings also resonate strongly with the study conducted by Tabi and Boadi (2014), who found that teachers'' teaching approach affect student's interest and attitudes in teaching mathematics.

Conclusion

This research study investigated the effects of the 5E instructional model on SHS students' achievement and motivation to the study of Trigonometry in relation to sine rule. The study also explored the difficulties that SHS students face in the study of Trigonometry. In this study, participants in the experimental group were taught lessons in trigonometry, specifically the sine rule, by using the principles of the 5E instructional model which their counterparts in the control group were taught lessons using the traditional approach. Students' responses to the pre-test revealed some difficulties they have in answering questions involving the sine rule. These difficulties were revealed from the responses of participants in both experimental and control groups to the pre-test and observation made during intervention. These difficulties include; poor conceptual knowledge of basic trigonometry, Inability to view sine rule as ratios of sides of a reference triangle, limited conceptual knowledge in geometry and Inability to apply knowledge in trigonometry to solve practical questions. Another major finding in this research study was that the pre-test results showed that participants in the control group performed better than those in the experimental group. However, the post-test results revealed the opposite, where the experimental group out-performed the control group after experiment was performed. That is, it can be claimed that the use of the 5E instructional model in teaching trigonometry has a positive impact on the academic achievement of SHS students in trigonometry. The practicality of lessons provided by the 5E instructional model may have contributed to the high academic performance of students taught by this approach. Also, findings from participants' responses to questionnaire items revealed that the use of 5E instructional model has improved their motivation, attitudes and interest towards the study of trigonometry. From students' responses, 5E instructional model was also found to be very practical, develop confidence in students and increase students' interest in trigonometry, specifically sine rule.

Recommendations

Based on the findings of this study, the following recommendations are made:

1. Mathematics teachers should adapt the 5E instructional model in teaching trigonometric concepts, especially the foundation concepts in sine rule, to promote retention and transfer of knowledge. This recommendation is made because it was found that students had limited conceptual understanding of basic trigonometric concepts which affected their performance in the pre-test.
2. Appropriate training and in-service training should be provided to mathematics teachers to use and eliminate the difficulties of application of the 5E instructional model in teaching trigonometric concepts. This would provide practical approach to learning, enhance students' engagement and enhance active learning.

Since this teaching method was found to be efficient and led to the improvement of students' performance and motivation in mathematics, curriculum developers should consider emphasizing this teaching and learning approach in the curriculum.

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