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The Effect of Constructivism on Students' Performance in Solving Mathematical Problems under Trigonometry

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Authors' contributions

This work was carried out in collaboration among all authors. Authors EA and RKG designed the study, wrote the protocols and wrote the first draft of the manuscript. Author FA and AKA managed the literature search and the intervention. Author EA and FA dealt with the data entry and analysis of the data. All authors read and approved the final manuscript.

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ABSTRACT

This paper is an action research which involves a sample of thirty five (35) second year students of Akontombra Senior High School comprising 24 males and 11 females. The study was aimed at using the constructivist approach to enhance students' competence in solving word problems under trigonometry. Prior to the study, it was observed that the students were not able to understand and solve word problems under trigonometry. The constructivist approach of teaching and learning was employed as the intervention strategy and series of activities was carried out. The pre – test and post – test scores obtained by the students were analyzed quantitatively based on the research questions of the study. Comparatively, the results obtained from the pre – test and post – test showed a significant improvement on the students' ability to solve word problems under trigonometry. It was then inferred from the results that the constructivist teaching and learning

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methodology employed during the intervention phases enhanced the academic achievements of the students. The constructivist approach to teaching encouraged students to participate in the process and environment of teaching and learning and to promote mathematics as a creative and meaningful activity that involves interpretation, effort and exploration.

Keywords: Constructivism; word problems; trigonometry; mathematics.

1. INTRODUCTION

Mathematics educations fundamental goal is to allow children to understand, reason and communicate mathematically and solve problems in their daily lives [1]. Asiedu-Addo & Yidana [2] indicated that mathematics research is therefore seen as a means of sharpening the intellect, shaping thinking skills, and improving the individual's personality to become a person in society who is more scientifically and technologically inclined. It is evident that those nations in the world that have taken the culture of mathematics and science seriously are leading, while those economies that have played little or no role in this culture are lagging behind and threatening their very existence [3]. That is why the study of a well-planned and effectively implemented mathematics education program has become the hallmark of most countries that are concerned about their scientific and technological development. Adetunde [4] emphasizes that the foundation of any solid education is mathematics. With this belief, mathematics serves as a vital filter for pupils or students seeking admission to secondary and tertiary institutions, as well as technical institutions such as the Colleges of Education and Polytechnics in Ghana [4].

Mathematics education has been highlighted as a very important subject, according to Eshun [5], because conceptual and computational methods of mathematics are applied in almost all fields of human knowledge. Mathematics education researchers are primarily concerned with the instruments, methods and approaches that facilitate practice. In Europe, research in mathematics education, known on the continent as didactics or mathematics pedagogy, has grown into a wide area of study with its own principles, theories, processes, national and international organisations, conferences and literature. It is therefore critical that the teaching and learning of mathematics as a subject in Ghana should also be transformed to meet the challenges demanded of it by the ever-changing environment [5]. Teachers in particular and educational planners in general are assumed to be tasked by society to devise practical teaching and learning methods that are relevant to the world of the learner and our everyday life circumstances [6] This is because, in general, it is assumed that children are generally interested in mathematics and come to school with an understanding of mathematical principles and different problem-solving techniques that they have discovered by studying the world in which they live [7]. Therefore, it is the core responsibility of mathematics educators to have experience that will help to inspire learners to understand and appreciate mathematics in order to increase their success as these fundamental practices are established.

It is in the light of the above reasons that the study of certain important topics like trigonometry in the senior high school curriculum cannot be ignored. Trigonometry has long been a standard part of the high school mathematics curriculum in all countries. Compared to other topics in mathematics, it is an area of mathematics that students think is especially difficult and abstract. With this perspective, trigonometry is one of the school topics that very few students like and succeed in, and with which most students hate and struggle with. Trigonometry has a dynamic existence. It incorporates numerous definitions and procedures that are algebraic, geometric, and graphical. For example, trigonometric functions vary from other types of functions in that some arithmetic formulas discovered by an algebraic formula cannot be calculated directly by performing them. It requires both geometric reasoning and algebraic reasoning to determine mathematical problems involving trigonometric functions. This diverse nature of the subject makes it difficult for students to grasp it conceptually. Mostly, the difficulties of students with trigonometric functions are due to a lack of understanding of related areas such as functions, angle measurement, and graphs (e.g. Orhun, [8]; Kang, [9]; Moore, [10]).

Unfortunately, many senior high school students are not accustomed to this type of reasoning in which students need to link diagrams of triangles to numerical relationships and manipulate the symbols involved in such relationships. Most of them turn to shy away and never want to meet it again in their cause of learning once the students experience some difficulties in the early stage of learning a subject. These have contributed to students raising mental barriers to mathematics and leading many science and mathematics students at higher education levels to drift massively towards the study of social sciences such as general arts [11]. Trigonometry is seen as a complex topic for many students and a deep understanding of it requires relations and transitions between similar concepts to be made. Gür [12] stressed that trigonometry and other similar concepts are abstract and non-intuitive, and teaching based on lecturing does not help students overcome their learning difficulties.

The understanding of trigonometry as a course is a pre-requisite for understanding areas in architecture, surveying, physics and many branches of engineering which play significant role in human existence. It is one of the earliest mathematics topics that links algebraic, geometric, and graphical reasoning. It can also act as an essential precursor to pre-calculus and calculus comprehension. In general, among several other methods, doing mathematics involves describing mathematical conditions in many ways, examining, formalizing patterns and regularities, generalizing and solving mathematical issues/problems.

In almost every part of the world, the poor performance of students in mathematics and how students experience mathematics in schools over the years has therefore become a major concern. In some countries, these situations have led to restructuring and the introduction of a new school curriculum and teaching methods. It is suggested in the study of Thomasenia [13] that the new school curricula and strategies are structured to find ways to inspire students to learn mathematics using realistic and investigative approaches. Therefore, these findings require teachers of mathematics to look for ever changing strategies in mathematics teaching to make the topic more fun and interesting [14]. This is a teaching of mathematics in which the methodologies used emphasize the teaching of content in mathematics by processes experienced by students in real life circumstances. Mathematics educators, however, are mandated to provide students with mathematics activities to explore and make sense of mathematical patterns and relationships that will motivate and help them develop mathematical knowledge to solve problems and to explore new ideas in the classroom environment and the technological world.

The methods and strategies that teachers use in their instruction decide the effective learning of concepts and abilities in mathematics. The teaching strategy involving the promotion of independent student thought by teachers, the development of problem-centered lessons, and the facilitation of common meanings brings about good learning. A method of teaching that is advocated in the school curriculum is the problem-centered approach of teaching. It is accepted that students construct their own knowledge and thus try to establish individual and social processes in a problem-centered learning environment to monitor and enhance the nature and quality of those constructions. Teaching's through problem-centered approach chooses constructivism as the learning approach. This means the philosophy of constructivism is the framework for approaches to problem-centered teaching.

Constructivism is associated with constructive learning and facilitates contrast with previous experience of new concepts [15,16]. According to Slavin [17], "[The] view of cognitive development emphasizes the active role of learners in building their own understanding of reality" is defined as constructivist (p. 32). Teaching should allow learners to ask why, to question, to look for a solution and to overcome incongruities. The constructivist theory of learning typically implies that successful learning can take place only when students are given the opportunity to deal with challenges, focus on their response processes, and then verify the reasonableness of their outcomes.

Constructivism is a knowledge theory of psychology (Epistemology) which argues that from their experiences, people generate knowledge and meaning [18]. The theory of constructivism of learning is based on the idea that we develop our own understanding of the world around us by reflecting on our experiences. Learning is thus seen as the mechanism by which our conceptual models are updated to fit new experiences in our world. Each of us generates our own rules, minds and models in a constructivist approach to learning, which we use to make sense of our experiences. In the studies of Candy (1991) as cited in Richardson [19], Candy explained that Learning is therefore, seen as an adaptive and experiential process rather than a knowledge transference activity. Constructivist educators always think that knowledge must be actively built because the learner is an entity with previous experiences that must be regarded as being knowledgeable. Learning, therefore, depends on the way each individual learner looks at a particular situation and draws his/her own conclusions. In a constructivist approach to learning, students are allowed to determine their own knowledge based on their own way of processing information and according to their own beliefs and attitudes towards learning.

In confirmation, Brooks (2000) cited in Aka [20], outlined four guiding principles of constructivism. These are:

- Learning is a quest for meaning. Therefore, learning must begin with the problems that students are actively trying to create meaning around.
- Meaning requires both whole and part comprehension. And parts must be understood in the context of the whole. The learning process is therefore based on primary principles, not isolated evidence.
- We must consider the conceptual models that students use to interpret the world and the assumptions they make to support those models in order to teach well.
- The aim of learning is for an individual to construct his or her own meaning, not just to memorize the correct responses and regurgitate the meaning of someone else.

Nabie [21] argued, however, that the conventional 'talk and chalk' method of presenting mathematical facts does not allow learners to apply what they learn or solve problems in real life circumstances. Nabie also indicated that teachers must teach mathematics within the experiential realm of the students to allow learners to apply what they learn to real life situations. This should be the practice that the classrooms are concerned with.

1.1 Purpose of the Study

Promoting conceptual understanding is a growing focus in the teaching of mathematics. The main purpose of the study is to investigate the extent to which constructivist approach of teaching can help to develop students of Akontombra Senior High School understanding and enhance their performance in mathematical problems involving trigonometry.

1.2 Research Questions

The study is intended to provide answers to the following questions:

1. What difficulties do students encounter in understanding and solving mathematical problems in trigonometry?
2. To what extent will the use of the constructivist approach of teaching and learning help improve student's competence in solving mathematical problems under trigonometry?

2. METHODOLOGY

2.1 Research Design

The researcher employed action research as the preferred research design for this study because it deals with small scale intervention which is appropriate for a one classroom situation in the context of which this study was carried out. It was conclude, in the opinion of Baumgartner, Strong and Hensley [22] that action research allows teachers to be prepared with knowledge of the different techniques or strategies they can use to fit the children they teach. In addition, action research is mainly considered to be customized in classroom operations to address a problem [23]. In the context of pre-test, intervention and post-test, action research is designed to investigate how student success is enhanced using a constructivist teaching method. It allows the teacher, through observation, listening, evaluating, questioning and being interested in developing one's own knowledge, to determine the efficacy of his / her teaching.

2.2 Population and Sampling

The study was conducted at Akontombra Senior High School in the Akontombra District. The school has a population of eight hundred and twenty nine (829) students. Two hundred and ninety-six (296) of the students are in the SHS 2 (second year). Purposive sampling method was employed for the sample selection. The research was conducted in SHS 2 General Arts 2 class which has thirty-five (35) students comprising 24 males and 11 females. The average age of the class was seventeen (17) years and the students came from various regions in Ghana.

2.3 Instrumentation

Pre-test and post-test were used to gather information about the learners' achievements in tackling mathematics issues related to word problems involving trigonometric ratios. The instrument was well designed to assist with basic data collection, presentation, interpretation, and organization. In addition, the pre-test and post-tests were used to measure the students' success before and after the intervention.

2.4 Intervention Process

To help address the problems students encountered in the pre-test, an intervention was carried out through the use of constructivist approach of learning. Constructivism is a theory of knowledge and learning that should inform practice but not prescribe practice. It is believed that constructivism is not a method [24], it emphasizes the importance of the teaching context, student prior knowledge, and active interaction between the learner and the content to be learned. The constructivist approach of teaching typically makes good and extensive use of cooperative learning. This way of learning emphasizes on active questioning and cooperative group activities that keep students with material they are learning. The students were made to group themselves into a group of five by the researcher in order to help each other solve the prepared set of questions.

At this stage of the intervention, the researcher took the students through various activities thoroughly. A lot of time and attentions was given to students understanding and meaning of some sentences and expressions in the questions. Emphasis was also based on helping students to understand and apply the trigonometry principles by translating them into mathematical expressions and subsequently solving the expression. The intervention period took three weeks of two mathematics sessions for an hour and thirty minutes (90 minutes per lesson). With the help of the researcher, the students were made to put themselves into groups in order to help each other solve the prepared set of questions at this stage.

1. Read the problem thoroughly to understand what you are solving. List all the unknowns in the problem, and assign a variable for each unknown. If there are two unknowns, you need two variables, such as a and b, for example.
2. Translate the problem into a diagrams and/or system of equations using the fundamental trigonometry principles and terms to describe the operations required. This helps the students in devising a plan to solve the problem to the extent of making diagrams and identifying possible trigonometry formulae to be use where necessary.
3. Solve the equations using the approved trigonometry methods and principles.
4. Apply the knowledge and skills gained to solve other mathematical problems.

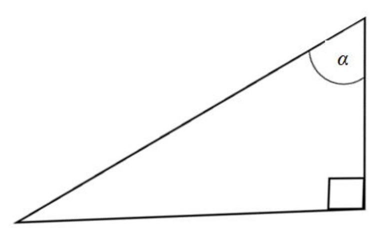
2.4.1 Activity one

Objectives: By the end of the 90 minutes lesson, students should be able to understand the mathematical problem given by identifying the clue for solution and listing all the unknowns and assign variables to each of them.

In the first week of the intervention, the researchers guided the students through how they will translate sentences and diagrams into mathematical statements and expressions. The researcher started by introducing the topic to the students through the use of various examples. To make this understandable to the students, the researcher guided the students through a list of instructions that need to be followed in order to arrive at their results. This involves the assignment of variables to all unknowns in the problem.

Here are examples that the researchers went through with the students in the first week.

1. Find the three trigonometric ratios of the angle α in the right-angled triangle below.



With this, the researchers asked the student to first of all try to recall the fundamental trigonometry ratios and understand the statements in them. I then ask them to freely represent the unknown sides of the right-angled triangle with any variable of their choice. Most students are familiar with x, y and z, and hence almost all of them agreed to represent hypotenuse, adjacent side and opposite side with *x*, *y* and *z* respectively. Hence, they agreed that the three trigonometry ratios for the diagram will be;

a) $\text{sine of} \propto = \sin \propto \text{(SOH)} = \frac{\text{side opposite} \propto}{\text{hypotenuse}} = \frac{z}{x}$

b) $\text{Cosine of } \propto = \cos \propto \text{(CAH)} = \frac{\text{side adjacent}\propto}{\text{hypotenuse}} = \frac{y}{x}$

c) $\text{Tangent of } \propto = \tan \propto \text{(TOA)} = \frac{\text{side opposite} \propto}{\text{side adjacent} \propto} = \frac{z}{y}$

I. If x is an acute angle such that $\cos x = \frac{w}{y}$, find $\sin x$ .The students groups together came out with their understanding as; there is a need to draw right-angled triangle to indicate within the diagram that $\cos x = \text{cosine of } x \text{ (CAH)} = \frac{\text{side adjacent } x}{\text{hypotenuse}}$. Then after that, $sinx$ can be calculated based on the diagram.
II. If $\tan x = 0.5673$ where $0° < x < 180°$. Find x .The students came out with the key word as $0° < x < 180°$, meaning the value of x must fall between zero and 180 degrees. The students group together came out with their understanding as; *x* is the inverse of tan of the number in the question.
III. The lesson continued with several examples of similar types. The researchers set out the objectives of the lesson to the students and the type of teamwork needed. The researcher served as a resource person, an instructor and a guide to the activities.

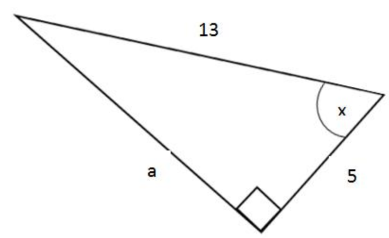
2.4.2 Activity two

Objectives: By the end of the 90 minutes lesson, students should be able to translate the mathematical problem into diagrams and devise a strategy or plan for finding solutions to mathematical problems.

In the second week, the learners were taken through a series of activities to develop the idea of coming up with a plan including drawing of diagrams and developing of trigonometry equations to solve problems involving trigonometry using constructivist approach of teaching and learning. This was followed by an explanation of the problems with the students after observing their answers.

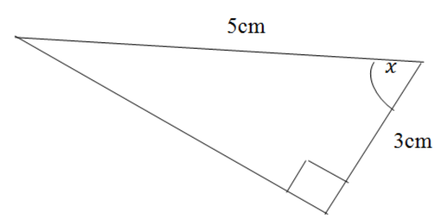
These are some of the examples that the researchers went through with the students. With each of them, they were asked to write a trigonometry expression (equation) and/or draw a diagram;

I. If x is an acute angle such that $\cos x = \frac{5}{13}$, find $\tan x$ .The researcher asked the students to analyse the question and come out with their sketches/diagrams and trigonometry equation for the solution of the question. With the aid of the researchers, the students came out with the diagram below based on the idea of cosine (CAH). They agreed to represent the opposite side with variable *a*;



Upon further discussion among the students themselves and a careful study of the diagram the students agreed that through the use of Pythagoras theorem, the unknown side which is represented with the variable a can be calculated. The students groups together came out with the appropriate formulae for finding solution to the question as: $tanx = \frac{a}{5}$.

II. Calculate, correct to the nearest degree, the value of x in the triangle below.



The students were given ample time to discuss the solution plan or process among themselves in a group. The researchers explained to them that they should always try as much as possible to follow what the problem demands before they write their respective expressions. Upon a careful study of the diagram the students came out with the appropriate formulae for finding solution to the question as:

$$\cos x = \frac{3}{5}$$

Some of the students suggested the use of Pythagoras theorem to solve the unknown side and further explain that, with the solution to the unknown side the other trigonometry ratios apart from cosine could be used to find the value of x.

III. If $\cos x = \sin 39°$, $0° < x < 90°$, find x.

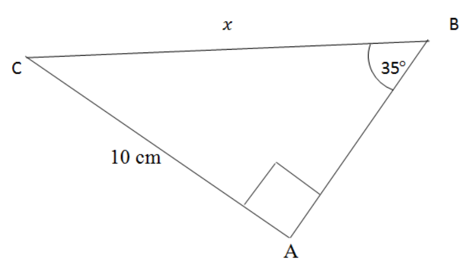
The students were asked by the researchers to analyse the question and come out with their formulae for solving the question. Based on the idea from the previous lessons, the students group together responded to the question above as;

From complementary angles

$$\sin 39° = \cos(90° - 39) = \cos 51°$$
$$\rightarrow \sin 39° = \cos 51^{\circ}$$

The students further suggested that the value of x lies between $0^{\circ} and\ 90^{\circ}$

IV. Find the lengths of the sides marked x



In this question, most of the students were found wanting. They found it difficult in writing the correct trigonometry expression. Majority of the students started using the wrong trigonometry ratios. The researchers tried to construct the expression from the problem with the students. The researchers asked the students to identify the known sides of the diagram (right-angled triangle). They gave the respond as the hypotenuse (10 cm) and the side opposite to the angle (x). The researcher then asked the students to write a trigonometry ratio for the question based on the identified sides of the diagram. The researcher then asked them to write a trigonometry expression for the problem. They all gave the answer as;

$$\cos 35^{\circ} = \frac{|AC|}{|BC|} = \frac{10}{x}$$

After going through activity two, the researcher realized that some students were still having various degrees of challenges in modeling the trigonometry expressions. With this at hand, I carried another routine activity with the said students, i.e the third activity, to help them in their search for better understanding.

2.4.3 Activity three

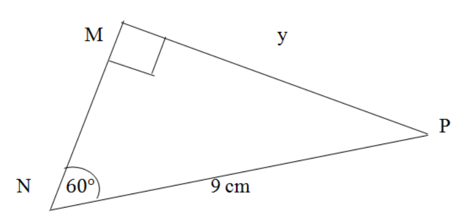
Objectives: By the end of the 90 minutes lesson, students should be able to use various diagrams and strategies or plans or formulae in finding solutions to mathematical problems.

In this routine activity, the researcher groups the students in four separate groups which were evenly distributed. Each grouped had students who had developed their interest and competence in the topic. The idea behind this was that, the students will cooperatively help each other, especially for those who were still having problems. The constructivist approach of teaching and learning emphatically make extensive use of cooperative learning. With this, students will be more comfortable and easily discover and comprehend difficult concepts if they communicate with each other about the problem at hand.

The objective of the third lesson of the intervention was to guide students on how to use various strategies or plans in finding solutions to mathematical problems. The activity three was organized purposely to teach students how to solve mathematical problems step by step through the use of appropriate problem solving strategy like sketches or diagrams, formulas and patterns. This was followed by an explanation of the problems with the students after observing their answers where necessary.

During the cause of solving the questions, the researchers went round helping the groups that were encountering difficulties. The students' responds to the selected problems for the activity are as shown below;

I. Find the value of *y* in the diagram below.



The students agreed to use Sine as the trigonometry ratio for the question at hand.

Therefore;

$$sin60^{\circ} = \frac{|MP|}{|NP|}$$

But $|MP| = y \; and \; |NP| = 9 \; cm$. Substituting into the main equation we get

$$sin60^{\circ} = \frac{y}{9}$$

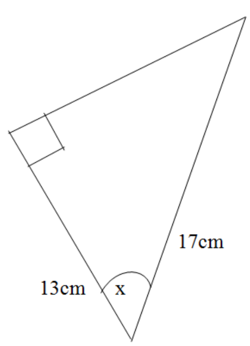
Multiplying through the equation by 9, gives

$$y = 9 \times sin60^{\circ}$$
$$= 9 \times 0.866$$
$$= 7.794$$
$$\therefore y = 7.79 \; cm$$

Therefore the value of y In diagram above is $7.79cm$

All the students participated in solving this question and I then asked them to check the answer.

II.



Calculate, correct to the nearest degree, the value of x in the triangle above.

It was agreed among the student groups that Cosine is the trigonometry ratio to be used in the solution of the question above.

Therefore;

$$\cos x = \frac{13}{17}$$

They further applied the trigonometry principle, which gives;

$$x = \cos^{-1}\left(\frac{13}{17}\right)$$

$$x = \cos^{-1}(0.7647)$$
$$x = 40.12$$

Therefore; $x \approx 40^{\circ}$

III. If $\cos\beta = \sin 43°$, $0° < x < 90°$, find β.

The students groups together presented the solution process below;

$$\cos\beta = \sin 43^{\circ}$$

But from complementary angles;

$$\sin 43^{\circ} = \cos(90^{\circ} - 43^{\circ}) = \cos 47^{\circ}$$

This suggests that

$$\sin 43^{\circ} = \cos 47^{\circ}$$

Substituting $\cos 47^{\circ}$ gives as;

$$\cos\beta = \cos 47^{\circ}$$

Therefore, on comparing,

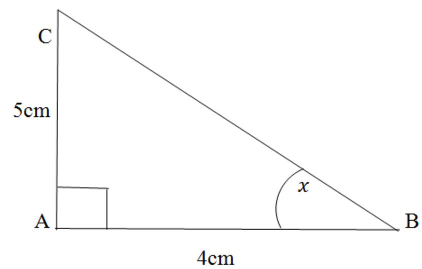
$$\beta = 47^{\circ}$$

IV. If $\cos x = 0.8$, find the value of $\cos^2 x - \sin^2 x$

Upon further discussion among the members of each group, the students agreed on the solution processes elaborated below;

$$\cos x = 0.8 \Longrightarrow \frac{4}{5}$$

Base on the expansion of the expression above, the diagram below was drawn



From Pythagoras theorem principle,

$$|BC|^2 = |AB|^2 + |AC|^2$$

$$|AC|^2 = |BC|^2 - |AB|^2$$

$|AC|^2 = 5^2 - 4^2$

$|AC|^2 = 9$

$|AC| = \sqrt{9}$

$|AC| = 3$

Therefore;

$\sin x = \frac{3}{5}$

But $\cos^2 x = \left(\frac{4}{5}\right)^2$ *and* $\sin^2 x = \left(\frac{3}{5}\right)^2$, therefore substituting it will give as,

$\cos^2 x - \sin^2 x$

$\left(\frac{4}{5}\right)^2 - \left(\frac{3}{5}\right)^2$

$\frac{16}{25} - \frac{9}{25}$

Therefore, the answer is,

$\frac{7}{25}$

All the students participated in solving this question and I then asked them to check the answer.

2.4.4 Activity four

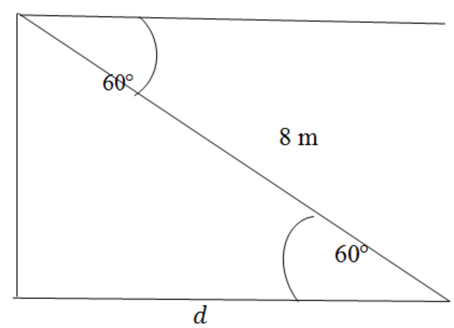
Objectives: By the end of the 90 minutes lesson, students should be able to apply knowledge and skills gained to solve mathematical problems in other areas.

Activity four preceded the post-test, and in this, students were guided through some interventional processes involving the application of knowledge acquired under trigonometry in different areas of mathematics. At this point, most of the students were abreast with the requisite concept and knowledge in modeling trigonometry expression into equations and solving the equations. This activity four was organized purposely to teach students how to apply knowledge gain appropriately in solving problems through the use of strategies like sketches or diagrams, formulas and patterns on finding solution to mathematical problems. These are some of the examples that the researchers went through with the students during this activity four.

I. A ladder 8 m long leans against a vertical wall. The angle of depression from the top of the ladder is $60°$. How far is the foot of the ladder from the wall?

The students were task to read the question carefully and come out with a diagram or pattern or formulae to solve the problem base on their experience in the previous lesson. This was their response;

Let *d* be the distance between the foot of the ladder and the wall, and they also together agreed on the sketch of a diagram as indicated below



They therefore agreed on the trigonometry expression below;

$$cos60^\circ = \frac{d}{8}$$
$$d = 8 \times cos60^\circ$$
$$d = 4m$$

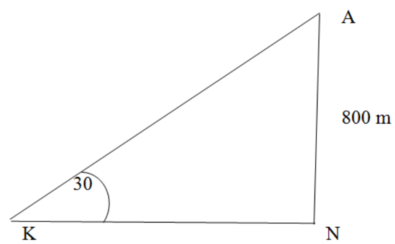
Therefore the distance between the foot of the ladder and the wall is $4m$

II. The angle of elevation of an aircraft from a point K on the horizontal ground is 30°. If the aircraft is 800 m above the ground, how far is it from K.

The students were task to read the question carefully and come out with a diagram or pattern or formulae to solve the problem base on their experience in the previous lesson. These were their responses;

Let *A and N* represents the position of the aircraft and the ground respectively and they also together agreed on the sketch of a diagram as indicated below;

They therefore agreed on the trigonometry expression below;

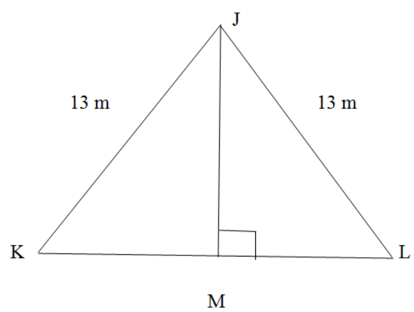


$$sin30^{\circ} = \frac{800}{|KA|}$$
$$|KA| = \frac{800}{sin30^{\circ}}$$
$$|KA| = \frac{800}{0.5}$$

Therefore; $|KA| = 1600\ m$

Therefore the distance between the aircraft at A and the point K is $1600\ m$

III



In the above diagram, $|JK| = |JL| = 13\ cm$ and $|K\ L| = 24\ cm$. Find $\sin < JKL$

The students were task to analyse the question carefully and come out with a pattern or formulae to solve the problem base on their experience in the previous lesson. The student groups together gave the following responses;

$$sin < JKL = \frac{|JM|}{|JK|}$$

But $|JK| = 13cm\ and\ |JM| = ?$. To get $|JM|$ we based on Pythagoras theorem to get;

$$13^2 = 12^2 + |JM|^2$$
$$|JM|^2 = 13^2 - 12^2$$
$$|JM|^2 = 25$$
$$|JM| = \sqrt{25}$$
$$|JM| = 5$$

Therefore, substituting $|JK| = 13\ and\ |JM| = 5$ into the expression gives us;

$$sin < JKL = \frac{|JM|}{|JK|} = \frac{5}{13}$$

After these examples, students were given both group and individual assignments to try on their own. This was to measure the level of students understanding pertaining to the concept of word problems under applications of trigonometry ratios.

3. RESULTS AND DATA ANALYSIS

Students were first given a set of questions to solve as the pre – test and they were then taken through a series of intervention activities after which they were given a post – test. The pre – test was conducted based on the students' previous knowledge on the mathematical concepts they have learnt in trigonometry. The students were asked to freely; choose any method of their choice to solve the questions. The pre – test consisted of seven (7) questions which were marked over thirty five (35) and was conducted for the thirty five (35) students in a period of 45 minutes. Table 1 show the marks obtained out of 35 by the students in the pre – test. To give a clear picture of this scenario, the researchers added a frequency distribution in percentages of the scores obtained in the pre – test by the students. This was intended to give the break downs of how the scores obtained by the students were collected.

Table 1. Frequency distribution of pre–test scores in percentage

Scores	Frequency	Percentage (%)
1 – 5	9	25.7
6 - 10	14	40.0
11 – 15	7	20.0
16 – 20	4	11.4
21 – 25	1	2.9
26 – 30	0	0
31 - 35	0	0
Total	35	100

After the administration of the pre – test, generally, the authors observed very uninspiring performance after marking the student's scripts with most of them scoring marks which was below the average score. After a careful observation of their pre-test scripts, there was an indication that the students lack the understanding of the basic concepts of word problems under trigonometry and therefore they were not able to use appropriate strategies and principles in finding solution to the mathematical problems.

To address these challenges of the students, a series of intervention activities, using the constructivist approach of teaching and learning were organized by the researchers for the students on trigonometry and a post–test was administered to them. This was aimed at ascertaining whether the intervention had gone down well with them.

The post – test on the other hand was conducted to see how the intervention activities helped the students to improve upon their competences and skills as well as acquiring new concepts and methods to solve trigonometry problems. The total number of students who were involved in the post – test was the same as that of the pre – test. Table 2 shows the scores obtained by the 35 students out of 35 marks for the post – test in the same period of 45 minutes.

The post- test scores from Table 2 showed a tremendous improvement in the performance of the students in relation to the solving of the questions administered to them and this was an evidence of the good use of the constructivist approach of teaching and learning through numerous activities that they were taken through. After the administering of the post – test, the researchers observed that the students had not employed a guess and check method in solving the questions given to them. This shows that the intervention process had helped the students to now understand the trigonometry concepts and that they will not rely on memorization procedures in solving trigonometry questions in the future.

Table 2. Frequency distribution of post–test scores in percentage

Scores	Frequency	Percentage (%)
1 – 5	0	0
6 - 10	2	5.7
11 – 15	3	8.6
16 – 20	9	25.7
21 – 25	12	34.3
26 – 30	6	17.1
31 - 35	3	8.6
Total	35	100

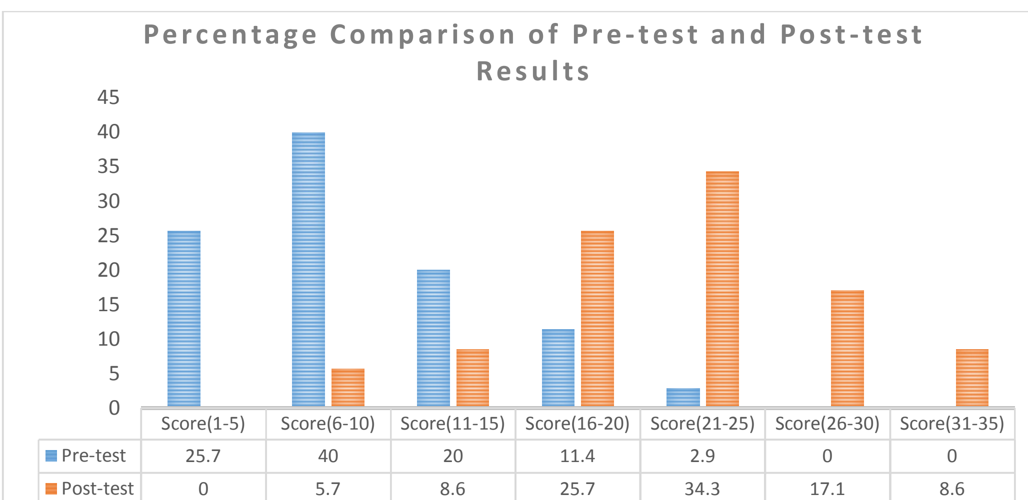


Fig. 1. Percentages of students' pre-test and post-test performance comparison

Table 3. Descriptive statistics of pre–test and post–test

Paired Samples Statistics					
		Mean	**N**	**Std. Deviation**	**Std. Error Mean**
Pair 1	Pretest	9.2571	35	5.20375	.87959
	Posttest	21.7714	35	6.14092	1.03801

The researchers undertook inferential analysis of the pre–test and post–test, and the data used for this analysis were the scores obtained by the students in both tests. Statistical Package for Social Scientist (SPSS) was employed by the researchers to obtain the results of the analysis. Table 3 indicates the mean, standard deviation and standard error mean of the paired samples.

The results therefore indicated that there is a significant difference between the pre–test scores and that of the post–test which is in favor of the post–test. And this was attributed to the intervention processes the researchers took the students through.

4. DISCUSSION OF RESULTS

Considering the scores obtained by the students in the pre – test and post – test, as shown in Tables 1 and 2, it can be deduced that the performance of the students before the intervention was very poor. The respective frequency distribution tables of the pre – test and post – test (Tables 1 and 2) clearly showed the difference in the scores obtained by the students. In the pre – test for instance, 30 out the 35 students scored less than half of the 35 marks for the test, which represented 85.7% of the total number of students. This poor performance by the students in the pre – test was due to the teaching strategy previously used in teaching the students and it took the lecture – form of teaching.

With this teaching strategy, the students did not have the chance of using their experience to create their own understanding, but rather lessons were delivered to them in an organized form. This was also an indication that the students lacked the right competencies and approach in solving the questions. Some of them also lacked the pre requisite mathematical concepts in understanding the questions that was administered to them. The students also lacked cooperative learning and hence the average students could not help their low performing classmates.

Results from the post – test scores by the students, as shown in Table 2, indicated that the students performed much better as compared to the pre – test. This is an indication that students had difficulties in solving mathematical problems using the rote (traditional) method before the intervention. From the frequency distribution of the post – test scores (Table 2), out the 35 students who took part in the test, 30 of them obtained either half or more than half of the total mark of 35 for the test, representing 85.7% of the total students' number. The results indicated an upwards trend in the post – test scores, which showed that the Intervention activities were effective in assisting the students to overcome their problems and helping them in their learning.

The improvement in the performance of the students, which was evident in the post – test scores they obtained, was through the constructivist teaching strategy that the researchers employed during the intervention activities. With the constructivist approach, the researchers designed a well–planned intervention activity in the lessons with the students. The constructivist approach of teaching enabled the students to participate actively in the lessons and also encouraged cooperative learning among the students. And in effect, each student in a group was not only responsible for learning what was being taught alone, but also helped group mates who were still having challenges and thus created a conducive learning atmosphere. This is in line with Boadi *et al*. [25] study which suggested that, the adoption of constructivist approach of teaching and learning in the mathematics classroom will enable students to participate actively in the lessons and also encouraged cooperative learning among the students.

The constructivist approach of teaching used in this research study enabled the students to comprehend the conceptual knowledge and the procedural understanding of trigonometry problems which the students were able to solve them successfully. A study conducted by Andam *et al*., [26], Boadi *et al*. [25] and Eggen & Kauchak [27] suggested that constructivist approach of teaching and learning do assists students to constantly create new knowledge based on previously acquired knowledge in conjunction with new experiences thereby improving their understanding and performance. In the event of all these, the researcher found out that the students were motivated and inspired by the way the lessons were systematically delivered.

Therefore, it is clear that after the intervention, the evidence gathered suggests that employing the intervention tool (Constructivist Approach of Teaching) into mathematics classroom for teaching trigonometry had a positive effect on the performance of the students as a whole. This confirms that it is important that teachers should actively involve learners in their teaching to enable the students to construct their own knowledge [28].

5. CONCLUSION AND RECOMMENDATIONS

This aspect focused on the results from the pre – test and the post – test based on the research questions. The analysis of the results enables the researchers to find out the level of improvement of students' performance in relation to trigonometry problems through the use of constructivist approach of teaching.

The answer to research question 1: What difficulties do students encounter in understanding and solving mathematical problems in trigonometry?

From the findings in the research, the study showed that the students performed poorly in the pre-test indicating the lack of understanding in the topic trigonometry.

It became obvious that they were not able to understand trigonometry problems involving the word problems. They could not analyze and interpret the key words involved in the word problems statement and this was evident in the pre –test scores they obtained. The students were not able to translate the given problems into trigonometry equations. The errors students made in the pre-test were categorized as follows:

1. Students were unable to understand the questions. They were not able to identify the unknowns in the mathematical problems given.
2. Students were not able to come up with a plan or diagram and/or formulae to find solution to the mathematical problems.
3. Students were unable to apply the required principles and methods in solving the mathematical problems given.

For example, students encountered problems with words like 'SOH', 'CAH', 'TOA' of various acute angles. In addition to this, words such as 'angle of elevation', and 'angle of depression' were a problem to the students.

The answer to research Question 2: To what extent will the use of constructivist approach of teaching help students improve their competence in solving mathematical problems under trigonometry?

According to Table 3, the results of the intervention by the comparison between the pre – test scores of the individual students with their respective post test scores showed some level of significance improvement in terms of their performance. There was a significant improvement in students' performance after the use of the constructivist approach of teaching in teaching the topic trigonometry. The post – test mean score of 21.7714 (Standard deviation of 6.14092) is significantly higher than the pre – test mean score of 9.2571 (Standard deviation of 5.20375). This indicates that the use of constructivist approach in teaching and learning in solving mathematical problems under trigonometry brought about a tremendous improvement in students' conceptual understanding and performance. From the intervention, students were able to use their own experience to create their own understanding. Through that they were able to gain the right competencies and approaches in solving the questions. With this, they also acquired the basic requisite trigonometry concepts in their understanding of the problems and it also paved the way for the average students to help their low performing classmates through cooperation. Additionally, the students discovered during the intervention activities that there are often several correct techniques and methods of finding solutions to mathematical problems. Surely, there is certain time at which teachers need to tell and show students what and how to do something

It is recommended that, teaching of concepts in mathematics should always involve the use of constructivist approach of teaching and learning to make it more practicable as possible. It will promote the doing of Mathematics as a creative and sense making activity that entails interpretation, effort, and exploration. Additionally, students must be encouraged to perform more activities in which they can associate the experiences they gain to their day by day activities. Therefore, mathematics teaching should be practical and activity oriented.

CONSENT AND ETHICAL APPROVAL

As per international standard or university standard guideline participant consent and ethical approval has been collected and preserved by the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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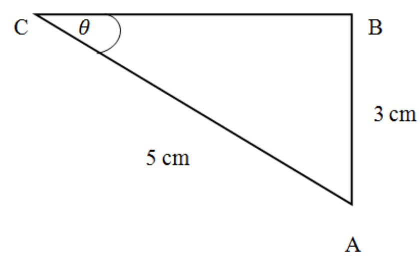
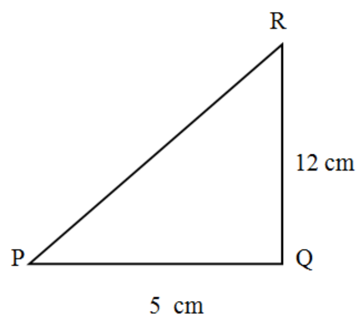
APPENDIX A

Pre- Test Questions

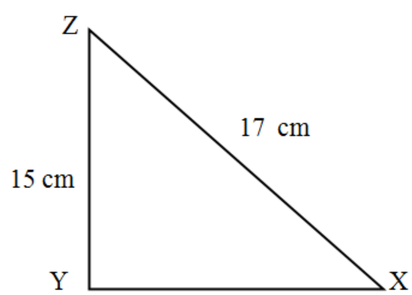
1. Find θ from the diagram below.



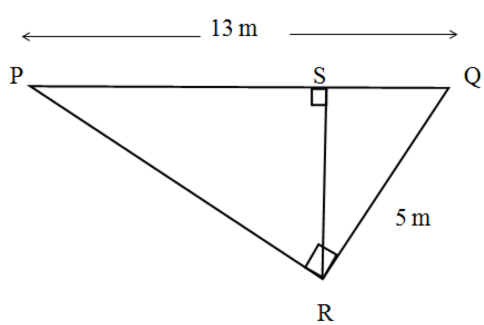
2. Calculate $\angle QPR$ from the diagram below.



3. Calculate ∠ XZY from the diagram below.



4. Find $|SR|$, correct to two decimal places.



5. A ladder 8 m long leans against vertical wall. If the foot of the ladder is 3 m away from the wall. Find the angle the ladder makes with the wall correct to the nearest whole number.

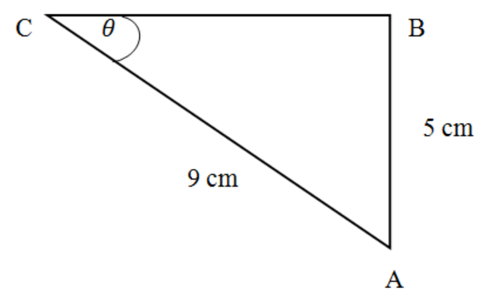
6. From the top of a building 15m high, the angle of depression of a football lying on the horizontal ground is 69°. Calculate, correct to one decimal place, the distance of the football from the foot of the building.

7. The angle of elevation of the top of a tree 39 m away from a point on the ground is 30°. Find the distance between the top of the tree and the point of elevation on the ground

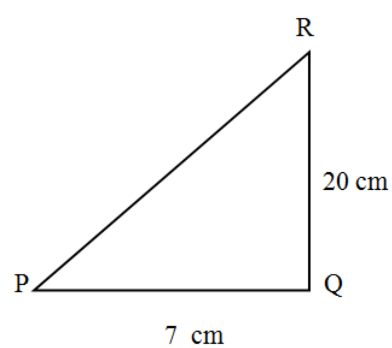
APPENDIX B

Post-Test Questions

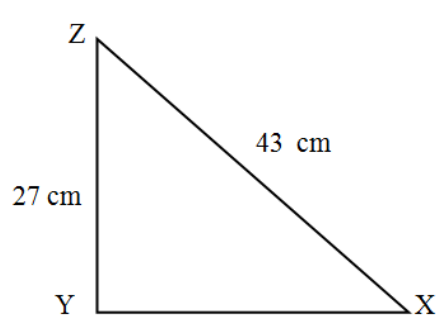
1. Find θ from the diagram below.



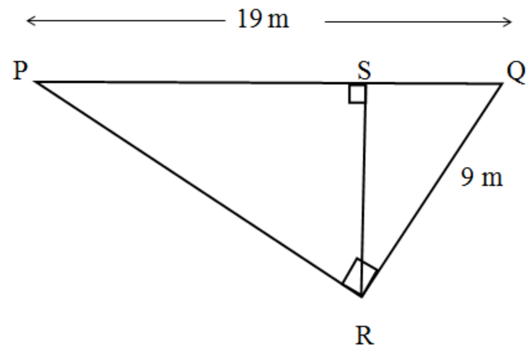
2. Calculate $\angle QPR$ from the diagram below.



3. Calculate ∠ XZY from the diagram below.



4. Find $|SR|$, correct to two decimal places.



5. A ladder 16m long leans against vertical wall. If the foot of the ladder is 5m away from the wall. Find the angle the ladder makes with the wall correct to the nearest whole number.

6. From the top of a building 9 m high, the angle of depression of a football lying on the horizontal ground is 54°. Calculate, correct to one decimal place, the distance of the football from the foot of the building.

7. The angle of elevation of the top of a tree 55 m away from a point on the ground is 42°. Find the distance between the top of the tree and the point of elevation on the ground.

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