

THE EFFECT OF COOPERATIVE LEARNING THEORY ON THE TEACHING OF TRIGONOMETRY AT HIGH SCHOOLS**Richard Kyere Asomah¹ Gabriel Assamah² Millicent Narh-Kert³ Harriette Nusrat Manu⁴ Emmanuel Agyei⁵**^{1,3}Department of Teacher Education, University of Ghana, Legon, Accra, Ghana.^{2,4}Directorate of ICT Services, University of Cape Coast, Ghana.⁵Department of Mathematics, Illinois State university.Corresponding author: rkasomah@ug.edu.gh**TO CITE THIS ARTICLE:**Asomah, R. K., Assamah, G., Narh-Kert, M., Nusrat Manu, H., & Agyei, E. (2024). THE EFFECT OF COOPERATIVE LEARNING THEORY ON THE TEACHING OF TRIGONOMETRY AT HIGH SCHOOLS. *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, 15(2), 170–182. <https://doi.org/10.61841/turcomat.v15i2.14647>

ABSTRACT: The benefits of enacting lessons anchored on Cooperative learning (CL) in mathematics has been well documented. However, in particular, the effect of CL on the teaching of trigonometry is rare at the second cycled educational institutions. This study, therefore, is aimed at exploring the efficacy of CL in enhancing meaningful teaching and learning of trigonometry at some selected Senior High School (SHS) in Ghana. Mixed method research design was employed to collect data using a questionnaire with both close-ended and open-ended items, and Trigonometric Achievement Tests (TAT) with essay type questions. A stratified sampling technique was used to select 55 students as the participants in the study. Descriptive statistics, paired sample t-test and thematic coding were used in analysing the data. The findings showed that, there were significant improvement in the students' learning outcomes in trigonometry. Further, the study revealed improved performance in students' pre-test and post-test scores after participating in CL lessons. Finally, the students' overall positive dispositions towards the CL-lessons were reflected in high means scores on the subscales of CL: Positive interdependence, Individual accountability, Face-to-face promotive interaction, Social skills and Group processing, depicting favourable experiences with the CL-lessons. To this end, the authors argue that, to develop higher order thinking skills in students, the use of CL in the teaching and learning of trigonometry ought to be prioritised. It is recommended that; management of educational institution should consider conducting professional development training for educators who desire CL as a means of instruction. Implications for policy and further research are discussed.

KEYWORDS: Cooperative Learning, Positive Interdependence, Individual Accountability, Promotive, Face-to-Face Promotive Interaction, Social Skills, Group Processing

Introduction:

Trigonometry is an inseparable part of mathematics in high school. It is the product of arithmetic, algebraic techniques and geometrical realities (Gillman,1991). Although Trigonometry has been taught from elementary school level, it is one field of mathematics still regarded difficult by high school students (Gur, 2009; Asomah et al., 2023a). In particular, the use of improper equations, sequences of operations and misuse of sines and cosines, misinterpretations of languages, illogical inferences, distorted definitions, and technical error calculations have been identified as common slip-ups on the part of High School students in answering trigonometric questions (Tuna, 2013). Further, Ross et al. (2011) identified over-reliance on committing to memory as the short cut for learning trigonometric ratios of sine, cosine and tangent of angles as well as the deficiency in the use of text book definitions and mnemonics as an attributable function in the students' inability to understand the concept of trigonometry. Consequently, Jong and Brinkman (1997) indicate instructional and methodological problems as the bane of teachers in ensuring proper understanding of trigonometry. As a result, inappropriate teaching methods are employed to facilitate trigonometry in the learning environment. Thus, pitching students in a restricted situation that causes them to misrepresent basic concepts in trigonometry (Asomah et al., 2023b). To this end, the meaningful representation of concept of trigonometry is missed (Weber, 2005). Moreover, developing understanding based on trigonometric links is not easy for learners, and traditional ways of teaching trigonometry do not overcome students' difficulties (Demir, Sutton-Brown & Czermiak, 2012). For this reason, the medium of instruction employed to teach the concept of trigonometry is very important. Field-knowledge and pedagogical knowledge of teachers play important role in teaching (Cochran et al.,1993). Besides, mathematics education researchers have raised concern with regard to 'rote learning' of mathematics procedures (Kamii & Dominick, 1997), which limits opportunities to explore the nature of mathematics problems (Hiebert et al., 1996). Although, there have been fundamental changes in the nature of trigonometry in modern times, mathematic teachers, still, resort to traditional methodology of teaching. This is because, in the past, conventional method of teaching employed to manipulate trigonometric functions were regarded as critical in aiding students understanding in the classroom context (Asomah et al., 2023a). Thus, it could be argued that, there are problems with the method of teaching trigonometry. In this way, basic

concepts, thinking and creativeness which hitherto would have been acquired cognitively is lost in trigonometry. It is in response to these gaps that varied pedagogical strategies have been researched to have effect on the improvement of students learning in trigonometry (Asomah et al., 2023a; Delice & Roper, 2006; Kendal & Stacey, 2003). In developing students' ideas and skills, experience and reflection play a major part in modern approaches to teaching (Hammond et al., 2001). One of such teaching approaches is cooperative learning (CL). This is because characteristically, cooperative learning is practically oriented, collaboratively and participatorily inclined, reflexive in process, and purposefully constructed in bridging the loophole created in literature in relation to theory and practice in the classroom context (Trauth-Nare & Buck, 2011).

In Ghana, however, literature on the use of CL as a pedagogical approach to teaching trigonometry in the SHS classroom context have been rare. Even though, there have been several studies conducted in mathematics with particular focus on CL in Ghana and elsewhere (e.g., Asomah et al., 2023a; Asomah et al., 2023b; Rohrbeck et al., 2003; Slavin, 2014). Nevertheless, the studies of (Assan-Donkoh et al., 2019; Edekor & Agbornu, 2020; Bosson-Amedenu, et al., 2021) using the CL focussed on the teaching and learning of circle theorem at the SHS and a topic in mathematics at the Junior High School (JHS) and College of Education respectively. Thus, providing a limited scope in literature on the prospects of the efficacy of CL on the teaching and learning of mathematics at the SHS level and in particular, trigonometry as a concept. In view of the abysmal performance of Ghanaian students in trigonometry as reflected in how they performed poorly in the WAEC examinations (WAEC, 2023), the current study focusses on the effect of CL in the teaching and learning of trigonometry. This is because CL environments are more relaxed and enjoyable in comparison with traditional methods of teaching (Roger, Olsen, & Kagan, 1992). The choice of this instructional approach is appropriate since previous studies affirmed the difficulties accompanying the methods of instructions used to teach trigonometry as well as student's misunderstanding in learning (Slavin, 2014). Therefore, this study is aimed at determining the efficacy of CL in aiding students to overcome the conceptual difficulty in learning trigonometry.

The context of the study

Trigonometry as a course of study, takes an unparalleled place in mathematics curriculum in different learning institutions in many countries. Although various nomenclatures attributed to it differ from one country to the other (Delice & Roper, 2006). In the Ghanaian SHS mathematics curriculum however, trigonometry encapsulates seven general objectives, to be specific, the units 2.11 and 3.40 of the second and third year aspects of the mathematics syllabus are structured with eight content sections sequenced as: "tangent, sine and cosine of acute angles; the three main ratios in trigonometry in respect of 30° , 45° and 60° ; the use of calculators to read sine, cosine and tangent of angles between 0° and 360° ; inverse of trigonometric ratios; angles in respect of their elevation and depression in a given right angled triangle; application of the concept of ratios of trigonometry; graphs of trigonometric equations" (MOE, 2010, pp. 43-53). The problems associated with the teaching of concepts in trigonometry as identified in literature cannot be different in the Ghanaian context. This is because it continues to be major highlighted as a weakness in the Chief Examiner's report of West African Examination Council (WAEC), a body charged with the responsibility of an oversight administration of examinations in the West African Sub-region (WAEC, 2011; 2012; 2023). The WAEC Chief Examiners' Report on mathematics has incessantly acknowledged the concept of trigonometry as part of the difficult topics for most learners. For instance, in 2023, the report decried the poor performance of candidates in answering question on trigonometry. Thus, the student's inability to conceptualize and apply their understanding of the various concepts (topics) under trigonometry to answer questions posed to them at the end of their two-year learning of trigonometry at the SHS level. Again, in 2011, the Chief Examiner's Report delineated the pedagogical problems in teaching trigonometry as a result of which almost all the candidates who attempted the trigonometric question got it wrong:

" Given that $\sin x = 0.6$ and $0^\circ \leq x \leq 90^\circ$, find $1 - \tan x$, leaving your answer in the form $\frac{a}{b}$ where 'a' and 'b' are integers. In (a) candidates were to find $1 - \tan x$ in form $\frac{a}{b}$ where a and b are integers given that $\sin x = 0.6$ and $0^\circ \leq x \leq 90^\circ$ "

Similarly, in 2012, the Chief Examiner's Report indicated students' inability to diagrammatically represent the trigonometric questions in right-angled triangle and thereby failed to apply the appropriate trigonometric ratios of sine, cosine and tangent of an angle in solving the question. As such, the question was left unanswered by most candidates and those who attempted it. In view of the limited literature on the teaching methods that enhances the learning experiences of students in the concept of trigonometry especially at the SHS level (Asomah et al., 2023a), it could be argued that, trigonometry is one of the mathematics topics which has become the bane to many students such that they have to strive to obtain a pass (Usman & Muhammed, 2017). Further, the teaching and learning of trigonometry is compulsory for all SHS students (its taught both as a common core course and an elective) (MOE, 2010). Thus, students at the SHS are forced to grind it with other courses. In light of this, the current study seeks to explore the effectiveness of CL as a teaching method to overcome the difficulty students face in learning trigonometry conceptually. This is because, student's errors are unique and reflect their understanding of concept, problem or a procedure ((Sarwadi & Shahrill, 2014) as expressed in the WAEC Chief examiners Report (WAEC,

2011; 2012; 2023). To this end, since errors committed by students are symptomatic of misunderstanding in trigonometry (Lai, 2006), the deployment of CL as pedagogical tool in the SHS mathematics classroom context, could bridge the loophole created in literature in relation to theory and practice.

Theoretical underpinning of the study

Constructivism is ‘an approach to learning that holds that people actively construct or make their own knowledge and that reality is determined by the experiences of the learner’ (Elliot, Kratochwill, Cook, & Travers, 2000, p. 256). Scaffolding is an important feature of the theory of constructivism, it ensures an effective teaching, where the grown-up incessantly fine-tunes the level of his or her assistance in response to the beginner's level of performance. In the classroom context, scaffolding entails modelling a skill, providing hints or cues, and adapting material or activity (Coppie & Bredekamp, 2009). Thus, constructivism recognizes the individual student’s active participation in the learning environment as a means of constructing one’s own knowledge and the realization that the knowledge created will vary in its degree of validity as a true reflection of reality. Characteristically, constructivism is a theory in continuum and depending on one’s perspective, it is categorised into three main types: Cognitive constructivism, social constructivism and radical constructivism. In particular, the social aspect of the theory of constructivism was defined as” learning is a collaborative process, and knowledge develops from individuals' interactions with their culture and society” (Lev Vygotsky, 1978, p. 57). This assertion therefore suggests that, the development of the cultural function of every child seems to occur twice: first, from the child’s social level and, later on, at the level of the individual; first, between people (inter-psychological) and then inside the child (intra-psychological). The tenants of social constructivist theory are achieved through Cooperative, collaborative and participatory forms of teaching and learning. Nonetheless, the current study focusses on cooperative learning as a means of achieving constructivist oriented pedagogical approach to teach trigonometry.

According to the Johnson & Johnson model (1998), cooperative learning is an instruction that involves student working in teams to accomplish a common goal, conditioned on the inclusion of the constructs: Positive interdependence, Individual accountability, Face-to-face promotive interaction, Appropriate use of collaborative skills and Group processing. Again, Slavin and Karweit (1981) averred that cooperative learning can be referenced as pedagogical approach where students conduct their work in small groups or teams purposed to master academic materials and consequently are rewarded for doing well in their groups. Hence, the concept of cooperative learning cannot be a substitute to a situation where students are merely allocated in group for the purposes of working in activity. CL is reliably recognized for its efficiency in improving social, motivational and cognitive outcomes of students (Rohrbeck et al., 2003; Slavin, 2014). Johnson and Johnson (1998) contended that lessons that are cooperative based are characteristic of five main variables: positive interdependence, face to face promotive interaction, social skills, individual accountability and group processing.

Positive Interdependence lends credence to the effect that, the student in the learning environment is successful if such students is reliant on the ideas, involvement, and accomplishment of the others in the group (Johnson, Johnson, & Smith, 1991). Individual accountability ensures that students learn together, but perform alone (Johnson et al., 1998). According to Johnson et al. (2014) promotive face-to-face interaction occurs in the learning environments where students are afforded the opportunity (time in class) to discuss, ask questions and offer the needed support to each other in the completion of the task assigned to the group. Moreover, group processing, affords students, an opportunity to reflect upon the correctness or otherwise of the work done by a group. This aids in the determination of the quality of work as executed by the group in respect of the successfulness or otherwise of cooperative learning teams (Johnson et al., 1991). Lastly on the tenant of social skills, Johnson et al., (1998) recognizes the need for students in the cooperative learning environment to exhibit some competencies for cooperative learning to be effective. Finally, this study was anchored on the social aspect of the theory of constructivism as an approach to teaching. CL, as an instructional approach is one of the means through which the theory of constructivism is achieved. In reviewing literature therefore, it is established that a learning environment is said to be cooperative learning-based if and only if such pedagogical technique is anchored on the five main variables (Johnson & Johnson, 1998). Thus, positive interdependence, face to face promotive interaction, social skills, individual accountability and group processing.

Research question

In evaluating the efficacy of CL as a pedagogical approach aimed at improving students learning outcome in trigonometry, the question: “How effective is the CL in improving students learning outcome of concepts in trigonometry?” guided the conduct of this study.

Research design

A mixed method research design that entailed the quantitative and qualitative data collection was employed in this study. The rationale was to obtain different but complementary data on the effectiveness of CL in improving students

learning outcome of concepts in trigonometry (Morse, 1991). The quantitative and qualitative data were used in complementing the findings of the study (Creswell & Tashakkori, 2007). Thus, through triangulation of the data, a deeper understanding of the students' meaningful experiences of CL was accounted for in the study (Cresswell, 2020).

Sample and participants

Cape Coast is the only Metropolis out of Twenty-three (23) districts in the Central Region of Ghana. The Metropolis is bounded to the South by the Gulf of Guinea. It hosts eleven (11) SHS (GES, Cape Coast Metropolitan Office, 2024). These schools constitute the population of the study. The availability of the different categories of SHS informed the choice of this Metropolis as most suitable for the conduct of this study. Constructs such as the school's infrastructure, enrolment (numerical strength of teachers and students in the school), readily available teaching and learning resources (state of the art laboratories and equipment) and academic excellence (Computerised School Selection and Placement System [CSSPS], 2023) informed the placement of the 11 SHS into two strata (Tier A and B). A school from each of the two strata was selected based on stratified and simple random sampling techniques. Further, in determining numerical values of participants in the study, a probability proportional to size (PPS) sampling approach was used. This technique eliminated biases and allowed an intact class to be selected on an equal basis. Thus, a total of 55 (Tier A=29 and Tier B =26) students were engaged as the study's sample. Subsequently, these intact classes from the two-tier schools (Tier A and B) were instructed on the concepts of sine, cosine and tangent of angles using the CL as the medium of instructions. Data was taken before and after instruction with the CL lessons. With regards to the qualitative aspect, responses from six (6) participants were selected randomly on stratified method of approach. Thus, Stud_10, Stud_11 Stud_12 Stud_13, Stud_14, Stud_15 (Stud-Student from Tier A and B). Hence, positioned the authors to attribute specific statements made to their corresponding authors in the respective schools. Participants inclusion or exclusion was by consent. Further, anonymity and confidentiality of the participants were guaranteed. The gender distribution of the students in the study is shown in Table 1.

Table 1: Gender Distribution of Respondents (Students)

Gender	Frequency	Percentage (%)
Male	45	81.8
Female	10	18.2
Total	55	100.0

The Table shows that more than half of the respondents were males, representing 81.8% of the total sample size. The average age of students in this study was 17 years ($SD = 1.50$). The minimum age was observed to be 15 years while the maximum age was 24 years. From the test of frequencies and percentages, all 55 (100%) of the respondents were SHS 2 students. This is because the teaching and learning of trigonometry excludes first year SHS students (MOE, 2010).

Instrument

Two sets of instruments constructed in this study, were grounded on the loopholes and growing themes identified in literature. The questionnaire was adapted from instruments previously developed by Agyei et al., (2013) and employed by Asomah et al., (2022). In particular, a questionnaire with open-ended and closed ended items as well as Trigonometric Achievement Test (TAT- a 30-item multiple choice question with an essay type question) were administered in the study. The questionnaire consisted of 3 parts. The demographic information (e.g. sex, age, course of study etc.), close-ended items relating to students' experiences of CL Lessons constituted the first and second parts of the questionnaires. Students disposition towards the experiences of the CL Lessons were characterised by the extent to which they agree or disagree to each item on a 5-point Likert scale. To this end, negative and positive observations were assigned and interpreted as 1=lowest score and 5=highest score respectively. The last part of the questionnaire, afforded the respondents an opportunity to express their satisfaction or otherwise of the CL lessons introduced in the class. The instruments were piloted with a smaller sample of students with similar characteristics in some selected schools before administering it to the participants in this study. The two instruments were administered personally by the first author in all the selected schools. Both instruments were in the English language since it's the medium of instruction used in senior high schools in Ghana. The inputs received at the pilot stage were used in modifying the instrument in relation to its validity and reliability. Further, the reliability of the subscales of CL as established were determined using Cronbach Alpha coefficients. Specifically, this questionnaire (closed ended items) comprised 20 items grouped under the subscales of positive interdependence, promotive face to face interaction, individual accountability, group processing and social skills. The Cronbach's alpha reliability estimates for all the subscales: individual accountability (3 items, $\alpha = .72$), positive interdependence (5 items, $\alpha = .80$),

promotive face to face interaction (4 items, $\alpha = .75$), group processing (3 items, $\alpha = .73$) and social skills (5 items, $\alpha = .83$) were considered to be reliable according to Hinton, et al., (2014) for the conduct of a study. In addition to the questionnaire, TAT was in the form of pre-test and repeated as post-test in the area of trigonometry was employed. The questions were first constructed using the WAEC (2023) standardized questions on trigonometry. Subsequently, an informed opinions of three experienced mathematics teachers at the SHS were sought for the purposes of proof reading the questions to reduce ambiguity and improve clarity of trigonometric expressions used. Finally, 3 experts in the field of mathematics education at the Teacher Education Department, University of Ghana revised and contributed to the test items' relevance and consistency in terms of the scope of the content and the curricular practices in the SHS mathematics syllabus. The TAT was employed to quiz the students conceptual understanding of the concepts taught during the CL-lesson.

Data collection and analysis

The first researcher submitted official letters of permission to heads of the SHS who in turn granted access to the assistant academic heads, heads of mathematics departments and the mathematics students in the selected schools. In consultation with the heads of the mathematics departments, the first researcher taught students at the two schools (Tier A and B) who participated in the study.

The administration of the questionnaires, TAT and essay type question occurred at the respective schools of the participants of the study (Tier A and B). This was purposed to report on the efficacy of CL in improving students understanding of trigonometry in an uninterrupted environment of the participants (Cohen et al., 2017). The TAT was scored out of hundred (100%) and analysed using paired sample *t*-test. The paired sample *t*-test was used in determining the mean difference between the two sets of observations (pre-test and post-test) at the end of instructions. The use of this tool of analysis was considered appropriate since observations were independent of one another with insignificant outliers in terms of the scores and consequently, were found to be approximately normally distributed. Hence, the use of paired sample *t*-test to determine the improvement (if any) in the students' pre-test and post-test scores in the study. Further, concerning the essay type question, a total mark of 5 was awarded (using WAEC standardized marking scheme A_0 =Wrong Answer, A_1 =Correct Answer, M_0 =Wrong Method, M_1 =Correct Method, B_0 =Wrong Basic Idea, B_1 =Correct Basic Idea) for which marks above 2.5 and below 2.5 were interpreted as favourable (positive) score and unfavourable (negative) score respectively. Further, the responses to open-ended items were coded, themed and analysed (Miles & Huberman, 1994).

Results

The effectiveness of the CL approach for teaching and learning of trigonometry was measured quantitatively by administering a 5-point Likert scale questionnaire and qualitatively with use of the open-ended items and excerpts from the essay type questions administered to 55 (Tier A=29 and B=26) students at the two SHS during real classroom implementation of the CL lessons designed by the authors. The results are presented in two sections: Students' disposition towards CL and an enhanced students' learning outcomes in trigonometry.

Students' disposition towards CL

The findings, in view of the subscales of CL (positive interdependence, promotive face to face interaction, social skills, individual accountability and group processing) in promoting teaching and learning of trigonometry are discussed.

Positive Interdependence

Student's positive disposition towards the subscale of positive interdependence showed the extent of their cooperation during group activities in the CL-lessons. Specifically, respondents unvaryingly agreed with all statements related to positive interdependence. For instance, participants affirmed that the specific roles allocated within the group facilitated their problem-solving abilities during classroom discussions ($M = 3.85$, $SD = 1.18$). Additionally, they expressed satisfaction with the level of participation within the lesson, indicating a high level of engagement ($M = 4.15$, $SD = 0.95$). The findings are presented in Table 2.

Table 2: Students reaction to the subscale of Positive interdependence

Items	M	SD
The specific responsibilities assigned to me in the group helped me to find solution to the question in class.	3.85	1.18
The lesson was participatory enough in class.	4.15	0.95
In this lesson, I got the chance to interact with my group members on the topic throughout the teaching period	3.93	1.10
Through the use of students' worksheet and cooperation received from my group members, I was able to solve realistic problems during the task stage of the lesson	3.73	1.19

The teacher’s role in the lesson was more of offering support and guidance to the me.	4.44	0.74
Overall	4.02	1.03

M=Mean, SD=Standard Deviation

Furthermore, participants acknowledged the opportunity for continuous interaction with their group members throughout the teaching session, highlighting the collaborative nature of the learning environment (M = 3.93, SD = 1.08). The utilization of student worksheets, coupled with the supportive efforts from group members, was perceived as instrumental in undertaking real-world challenges during the task-oriented phase of the lesson (M = 3.73, SD = 1.19).

Moreover, participants recognized the teacher's supportive role, emphasizing guidance and assistance rather than authoritative instruction, which contributed to a positive learning experience (M = 4.44, SD = 0.74). These results give emphasis to the efficacy of positive interdependence in fostering collaborative learning environments conducive to student engagement and problem-solving.

Similar observations were made from the responses to the open-ended items. Thus, student’s responses to the question: “Describe how the placement of students into groups facilitated the lesson” were stated as:

Stud_12: Grouping us brought about the shared responsibilities to enable us to coordinate and achieve our objectives as a group

Stud_10: Our group was assigned some activities on the topic by our teacher. The brilliant ones helped the weak ones in the group.

Remarkably, all the items measuring positive interdependence, a subscale of CL recorded mean values greater than 3.73, which indicates high level of students’ disposition towards positive interdependence in trigonometric lesson delivery.

Promotive Face to Face Interaction

A positive outlook from the perspective of the students concerning their active participation in the CL-lesson were observed. The findings indicate unanimous agreement among participants regarding various aspects of face-to-face promotive interaction. In particular, participants endorsed the statement "The lesson allowed me to share ideas with my colleagues in the group on the concept taught in class" (M = 4.13, SD = 0.90). Similarly, participants affirmed their engagement in lesson activities by way of sharing ideas on the topic during the instruction (M = 4.00, SD = 1.04). Table 3 presents views of the participants on the subscale of Promotive Face to face interaction

Table 1: Students reaction to the subscale of Promotive face to face interaction

Items	M	SD
The lesson allowed me to share ideas with my colleagues in the group on the concept taught in class.	4.13	0.90
I was involved in activities that enabled me to share ideas on the topic during the lesson.	4.00	1.04
My views and contributions were respected by my mates during group discussions in the lesson.	4.33	0.96
The teacher clearly defined the lesson’s objectives to guide me during the lesson	4.45	0.79
Overall	4.02	0.92

M=Mean, SD=Standard Deviation

Additionally, participants felt that their viewpoints and contributions were respected by their peers during group discussions within group discussions (M = 4.33, SD = 0.96). Also, participants acknowledged the effectiveness of the teacher’s input in defining clearly, the lesson's objectives to guide them throughout the session (M = 4.45, SD = 0.79). Thus, these findings point out the importance of face-to-face promotive interaction in fostering active participation, mutual respect, and clarity of objectives within educational settings.

Likewise, evidence from the responses to the open-ended items revealed by way of response to “In what way did the lesson activities encourage you to share ideas on the concept taught?” Some specific responses gathered were:

Stud_13: In my group, we shared ideas on the task that was assigned to us, corrected some mistakes of our colleagues and in fact it helped each and every one of us to improve.

Stud_11: I had misconceptions about certain aspects of the topic but got support from colleagues in the group

Stud_15: It was made easier for us to acknowledge our strengths and weaknesses since such fault was easily identified and corrected by our fellow counterpart during group discussions.

Overall, the 4.00 high mean recorded posits the relevance of this subscale in promoting fruitful discussions within the inter an intra group activities during lessons with CL as the means of instruction.

Individual Accountability

The participants responded to closed-items on statements concerning their individual participation in the lessons with CL. The findings indicate unanimous agreement among participants regarding the statements related to Individual Accountability. For example, participants strongly affirmed the notion of viewing their group members

as supportive allies in the learning environment rather than competitors within the classroom setting (M=4.16, SD=.98). The results are presented in Table 4.

Table 4: Students reaction to the subscale of Individual Accountability

Items	M	SD
I see my group members as helpful mates in the learning process rather than competitors in class	4.16	0.98
Through the group’s activities I have learnt to solve questions on my own without relying on my colleagues in the group always	4.09	1.02
Teacher continually assesses my individual contributions during the group’s activities throughout the lesson	4.02	1.08
Overall	4.09	1.03

M=Mean, SD=Standard Deviation

Furthermore, they expressed concurrence with the statement highlighting their ability to independently tackle questions within the group's activities, diminishing reliance on their peers (M=4.09, SD=1.02). In addition, participants acknowledged the teacher's consistent evaluation of their individual contributions throughout the group activities within the lesson (M=4.02, SD=1.08). These results depict a robust endorsement of the principles and practices associated with fostering individual accountability within the learning environment.

Further, the open-ended items elicited responses as to whether students were individually engaged in the lesson, some of the responses in relation to the question: “Describe how you were engaged individually during the lesson” were:

Stud_14: I was tasked to solve questions independently before being asked to put our individual solutions together for the purposes of reaching consensus on a single solution as the answer for the group.

Stud_13: The individual activities assigned to us during the lesson, questions targeted at the individual group members helped in mastering the concept during the lesson

Generally, participants expressed their participation in the CL-lessons with a high mean score (M=4.09 SD=1.03) via the individual roles they actively played in mastering the content of the subject matter during the teaching and learning sessions of the study.

Social Skills

The data portrays a positive attitude of students towards the congenial atmosphere created during instructions in class. The analysis of the results indicates a strong consensus among participants regarding their social skills. Specifically, participants demonstrated agreement with all the provided statements. For instance, participants affirmed the effectiveness of disciplinary measures implemented during group activities to resolve issues with their peers in the classroom (M=4.02, SD=.87). Table 5 depicts the views of the students in relation to the closed-ended items.

Table 5: Students reaction to the subscale of social skills

Items	M	SD
The disciplinary measures that were put in place during group activities helped me to solve problems with my group members in the classroom.	4.02	0.87
I understood better in the questions we solved together as a group	4.02	1.05
My teacher’s fairness in applying the rules in the lesson motivated me to work together with my group members in solving questions.	4.09	0.97
There was respect for each other’s opinion during group work activities.	4.22	1.03
The rules for a successful group activity were formulated by myself and colleagues during the lessons	3.93	0.86
Overall	4.10	0.96

M=Mean, SD=Standard Deviation

Furthermore, participants acknowledged enhanced comprehension during collaborative problem-solving sessions (M=4.02, SD=1.05), attributing this to the joint effort within the group. Moreover, participants expressed appreciation for their teacher's equitable enforcement of rules, which served as a motivating factor for co-operative work (M=4.10, SD=.97).

Additionally, participants highlighted the presence of mutual respect for each other's viewpoints during group work activities (M=4.22, SD=1.03). Besides creating an atmosphere devoid of disdainful remarks from each other during group activities, participants attributed the successful group activities during lessons to their active involvement in the formulation of guidelines (M=3.9, SD=.86) that aided their understanding of the concepts taught, emphasizing a sense of ownership and collaborative decision-making within the group dynamic.

In addition to the above observations, the students’ responses in relation to the question: “Describe how the guidelines facilitated the group activities during the lesson” were reported in the study. Some specific responses gathered were:

Stud_10: It ensured that each student in the group stayed focus and participated fully because the class was under control.

Stud_12: I was put on my toes and as such was disciplined throughout the entire lesson, it helped us in the class.

Stud_14: It actually guided our actions during the group discussions since there is little room for interruptions. so, we attained the set goals in the lesson.

Stud_15: It created an environment where students defended their individual solutions in the group without any fear or being mocked by their colleagues during discussions in the groups.

Thus, generally, social skill was perceived as positive from the perspective of students. This indicates high levels of tolerance, respect for one another and cooperation from group members during the enactment stage of the lessons.

Group Processing

In view of the presentations conducted by the groups, during the teaching and learning of trigonometry, the participants depicted positive disposition towards the statements asked about the relevance of this subscale in their learning of trigonometry. The findings indicate a high level of agreement among participants regarding group processing. Specifically, participants expressed consensus on various aspects. In particular, they acknowledged understanding certain mathematical concepts through feedback received from their colleagues during the lesson (M=4.20, SD=0.89). The views of the students are presented in Table 6.

Table 6: Students reaction to the subscale of Group processing

Items	M	SD
I understood some mathematical concepts through feedback from my colleagues in the lesson.	4.20	0.89
The group presentation experiences in the lesson helped me to develop problem-solving skills.	3.91	0.97
The teacher provides clarity to my questions which helped me to understand the lesson.	4.40	0.81
Overall	4.17	0.89

M=Mean, SD=Standard Deviation

Further, participants of the study affirmed that their problem-solving skills improved as a result of engaging in group presentations during the lesson (M=3.91, SD=0.97). Moreover, participants acknowledged the effectiveness of the teacher's explanations in clarifying their queries, thereby enhancing their comprehension of the lesson (M=4.40, SD=0.81). These findings collectively suggest a positive perception of group dynamics and instructional support in the learning process.

The quantitative findings further corroborate the comments obtained in response to the question: "In what way did the group presentations enhance your understanding of the concept taught during the lesson? The responses elicited from the students were observed as follows:

Stud_11: Our group presentation in class today helped in bringing clarity to the alternative solutions proposed by other groups in the lesson.

Stud_13: The group presentations helped raise the confidence level of some of us since we got the solution right.

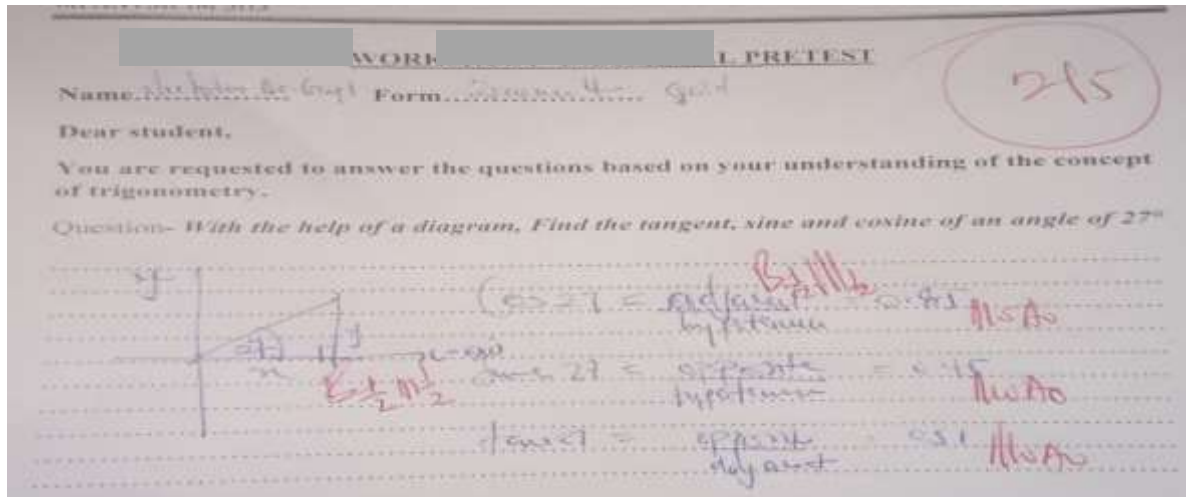
Stud_14: This activity helped us to get swift feedback from our teacher, know what and where to improve and stay clear of any misconception during the lesson.

Stud_15: It positioned us to be part and parcel of the teaching and learning process.

It could be observed from the overall mean recorded (M=4.17, SD=0.89), that students exhibited a positive disposition toward the subscale of group processing during instructions.

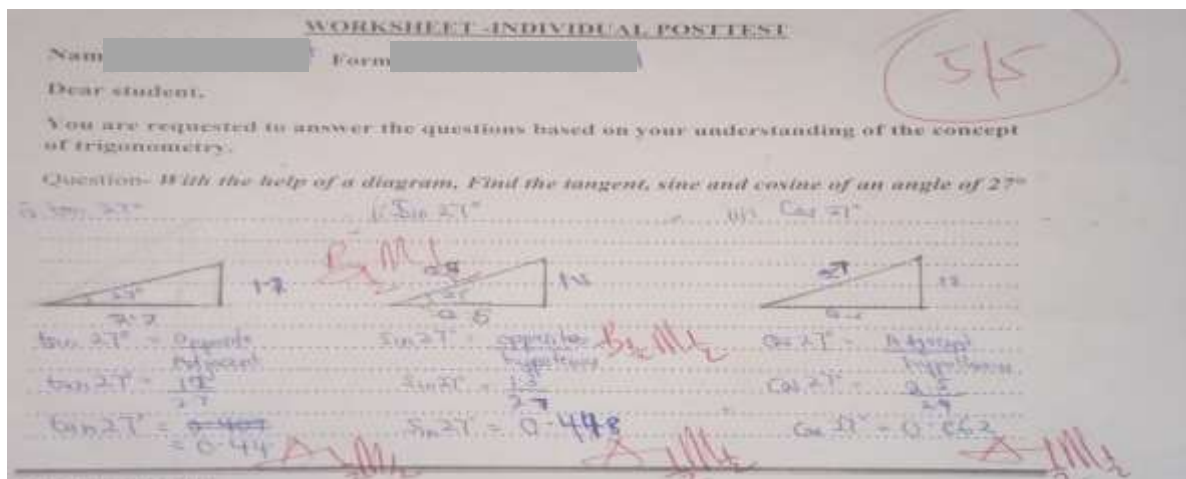
Enhanced students' learning outcomes in trigonometry

The improvements in students' learning of trigonometry using CL were further understood and explained in the students improved learning outcomes. Data collected particularly during the enactment stage of the lesson were used in addressing this question. Application of trigonometric ratios as a topic in the mathematics teaching syllabus in two different classes at the Tiered Schools were taught. Evidence of a particular student's [De-Graft-pseudonym for the purposes of this study] improvement in performance in connection to the essay type question administered before and after the lesson is shown in Figures 1A and 1B. Thus, Figures 1A and 1B show excerpts of the performances of De-Graft's pre-test and post-test administered in the study. It could be observed that, De-Graft showed improvement in the test scores after the lesson. This evidence follows through all the questions as the student's provided clarity to the various steps (working-proof of the solution) in solving the essay type question and demonstrating conceptual understanding through the construction of appropriate diagram in the solution on the answer booklet provided to the participants.



A₀=Wrong Answer, A₁=Correct Answer, Mo=Wrong Method, M₁=Correct Method, B₀=Wrong Basic Idea, B₁=Correct Basic Idea

Figure 1A: Excerpt of De-Graft's Pre-Test Score.



A₀=Wrong Answer, A₁=Correct Answer, Mo=Wrong Method, M₁=Correct Method, B₀=Wrong Basic Idea, B₁=Correct Basic Idea

Figure 1B: Excerpt of De-Graft's Post-Test Score.

For example, from Figure 1A and 1B, De-Graft's post-test score increased from 2 out of 5 to 5 out of 5 on the pre-test and post-test respectively. As observed from the excerpts, De-Graft's could not account for the processes leading to the answer that was asked in relation to the trigonometric ratios of sine, cosine and the tangent of an angle given during the pre-test. In particular, the question (*with the help of the diagram find the sine, cosine and the tangent of an angle of 27⁰ degree*) could not be solved. Thus, De-Graft was unable to draw the proper right-angled triangle diagram to illustrate the concept of the question. Again, his inability to apply the appropriate trigonometric ratio to the tangent of an angle of 27⁰ degree in the pre-test, implied rote method of learning the three ratios of trigonometry with little or no relational understanding. Hence, the abysmal performance in relating to the question before the CL lesson.

However, at the post-test, (thus, after the students were grouped with some assigned roles, provided with opportunities to discuss at length their ideas on *sine, cosine and the tangent of an angle* through the provision of related activities on the students work sheet individually and collectively as a group as well as the provision of platform for the groups to project their solution on the chalkboard for the purposes soliciting alternate ideas and views from non-group members during the teaching and processes) De-Graft's was able to account for the processes that led to the solution of pre-test item. As such, De-Graft's related to the question by displaying his conceptual understanding of the diagrammatic representation of an appropriate trigonometric ratio to the tangent of an angle of 27⁰ degree in the post-test. Specifically, De-Graft's ability to construct an angle of 27⁰ in a right-angled triangle with the aid of a rule and a protractor accounted for his understanding of the question. Consequently, he related to the definitions of the three ratios of trigonometry and solved for the angles as shown in the post-test (see Figure 1B). To this end, De-Graft answered the question with the correct methodology with a suitable diagram to represent

the main ideas sought by the question he could not answer in the pre-test (see Figure 1A). Hence, it could be asserted that, the effective utility of the CL as a pedagogy might have accounted for the improvement in De-Graft’s individual pre-test score. Thus, students’ performance improved post introduction of the CL by the authors. In addition, the results of the TAT were scored and analyzed using paired sample t-test. Table 7 shows the results of the paired sample t-test of the TAT scores obtained before and after CL lessons with students in the two-tiered schools.

Table 7: Paired Sample T-test for the Two-Tiered Schools.

	<i>M</i>	<i>SD</i>	Paired differences			
			<i>Md</i>	<i>T</i>	<i>df</i>	<i>p</i>
Post-test scores	7.92	1.093	5.54	37.131	54	.000
Pre-test scores	2.38	1.169				

The results from the Table show the paired sample t-test with a significant (mean difference = 5.54, 95% CI: 5.23 to 5.85) mean difference. A very large eta squared (eta squared = 0.98) was obtained from the analysis which depicts that, there was significant difference in the student’s pre-test and post-test scores obtained before and after CL lessons. Thus, students’ performance in the Tiered A and B schools improved after they were introduced to the CL lesson on the concepts taught.

In a nutshell, the qualitative findings corroborate the quantitative findings, highlighting that, the deployment of CL as a pedagogical tool in the classroom context was effective in enhancing students meaningful learning of trigonometry.

Discussions

The study sought to explain the effectiveness of CL in improving students’ learning of trigonometry. The discussions in connection with this study was presented from two perspectives as reported in the results section as; enhanced students’ learning outcomes and perceived students’ experiences with the CL-based lessons. Enhanced students’ learning of concepts in trigonometry with CL-lesson was explained based on the qualitative and quantitative analysis of the improvements that occurred in students’ learning outcomes as depicted in Tables 2-7 and Figure 1A and Figure 1B. In particular, analysis of the results (Figures 1A and 1B) at the individual pre-test and post-test scores of the students showed that, the CL-lesson enhanced students’ mastery of the concepts of trigonometry. The results of this study are consistent with the studies (Asomah et al., 2023a; Ahmadi, 2000; Oloyede et al., 2012; Shafiuiddin, 2010) who assessed the impact of CL strategy in teaching mathematics students. These studies affirmed the effect of CL on students’ performance, interest, motivation, conceptual understanding, and their attitudes toward mathematics. The results of these studies established that, students performed better when they were taught with CL than those in traditional sections and their attitude towards mathematics improved as was the case in the current study where there were improvements in the performance and dispositions of students in the two schools taught (see Tables 2-7). The authors indicated a better superiority of the CL as an instructional approach in mathematics courses to a more traditional method of instruction. This observation was also implied in this study although the current study did not compare the CL lessons directly with the traditional method of teaching. Specifically, the results align with this study because the views of the students on the new teaching method (CL) agree with sentiments as expressed in the study of Ahmadi (2000) (see qualitative analysis of students’ responses to the researcher interview). Again, in the said studies of (Assan-Donkoh et al., 2019; Ahmadi, 2000; Edekor & Agbornu, 2020; Oloyede et al., 2012), they averred that, CL is very dynamic, thus students are more actively involved in the exploration of mathematical concepts and ideas as well as the resolution of specific task. This was also observed in the current study as the introduction of the CL lessons made the students active participants in constructing their own understanding of the subject matter. In relation to other disciplines, effectiveness of CL has proven to be effective. In particular, the studies of Oloyede et al. (2012), Bukunola and Idowu (2012) who explored the effectiveness of CL strategies on Nigerian Junior Secondary School students’ academic achievement; however, Bukunola and Idowu (2012) concentrated on the Basic Science. Their study employed a number of intact classes in the selected co-educational Junior Secondary Schools as the sample. The results revealed that CL had significant effects on students’ post-test academic achievement scores in Basic Science. Again, the results revealed that the CL had a significant effect on students’ retention of Basic Science concepts taught. Thus, as student performance improved, their retention also improved as was evidenced in this study. Moreover, this study resonates with the findings of Vaughan (2002) who observed the effects of CL on the students’ performance and attitudes in relation to mathematics. The analysis of pre- and post-test scores showed favourable changes in the students’ attitudes and performance. This further affirms the current study’s position on SHS students’ improvement in their learning outcome. In addition, Whicker et al. (1997) findings in their study aligns with similar observations in the current study. In their study, the effects of CL on students’ achievement and attitudes in secondary school mathematics classroom were found to be favourable. They found that students who experienced CL lessons performed better on the test scores than students

in the comparison group and as such, affirms the current study's pretest and post-test scores where students improved on their pre-test scores as result of the introduction of the CL-lessons. Again, Bosson-Amedenu, et al., (2021); Shafiuddin (2010) also examined the effect of CL on mathematics. The main objectives of the study were to find out the effectiveness of the CL approach over conventional method in learning mathematics at high school level and compare the achievement of the high, average, and low achievers when taught using the CL method as an instructional approach. The results showed a significant difference between the post-test scores of students in cooperative learning method and conventional method group. Thus, students performed well when taught through CL approach. The current study's student's performance on the pre-test and post-test corroborates the findings of Shafiuddin (2010). This is because after exposing students to the CL-lessons, this study registered much improved trigonometric performance in the students' post-test in comparison with their pre-test scores.

At the crux of this study, was the relevance of CL as a means of instruction for the teaching and learning of Trigonometry at the SHS. To this end, the authors contend that, in the wake of the student's positive disposition towards CL lesson, it is critical that CL-based materials in the form of exemplary lessons are designed to guide in-service and pre-service teachers to maximise the gains and minimise the weaknesses associated with this pedagogy. Further, it is important that teachers adopt activity-based lessons as a means of maximising the features (Positive interdependence, Individual accountability, Face-to-face promotive interaction, social skills and Group processing) of CL in teaching mathematics.

Conclusions and implications

The results showed that, the enhanced learning outcomes in the performances of the students as reported in the study was one possible reason that explained the improvements in students' learning of trigonometry using the CL approach. The study further revealed improved and significant performance in students' pre-post-tests scores after participating in the CL lessons in all the two senior high schools involved in the study. Finally, the students' overall positive dispositions towards the CL-lessons which were reflected in high means scores on the subscales -Positive interdependence, Individual accountability, Face-to-face promotive interaction, social skills and Group processing, depicted favourable experiences with the CL-lesson is another reason that explained the improvements in students' learning of trigonometry. To this end, the authors argue that, to develop higher order thinking skills in students the use of CL in the teaching and learning of trigonometry ought to be prioritised. It is recommended that; management of educational institution should consider conducting professional development training for educators who desire CL as a means of instruction.

Limitations and further research

The study was limited to only students from public SHSs in the Cape Coast Metropolis. Hence, the deficit in the generalization of the findings of this research over all SHS. Thus, it would be worthy to note of a replication of this study in other subject disciplines such as biology, physics and chemistry as well as art related subjects at the SHS level; since the deployment of CL as a pedagogical strategy is not limited to mathematics.

Conflicts of Interest

The authors declare no conflicts of interest.

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Data availability statement

As a result of the anonymity and confidentiality of the participants in this study, the supporting data are exclusively available@ rkasomah@ug.edu.gh

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