RESEARCH ARTICLE

Sustainable Education and Digital Transformation
Volume 1, Issue 1, 2026, e43539
https://doi.org/10.33902/SEDT.202643539

Cooperative learning as a sustainable pedagogical strategy for enhancing mathematics achievement in secondary education

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Submitted: 3 January 2026 Revised: 16 February 2026 Accepted: 28 February 2026

Abstract

In the pursuit of sustainable and student-centered educational reform, cooperative learning has been widely advocated as a strategy to foster long-term engagement and academic growth. This study examined the effect of cooperative learning on the mathematical performance and attitudes of senior high school students at Nkawkaw Senior High School. Using a quasi-experimental non-equivalent control group pretest-posttest design, 140 Form Two students from Home Economics and Visual Arts were purposively selected and assigned to experimental and control groups. The experimental group was taught using cooperative learning, while the control group received traditional instruction. Data were collected through a researcher-made Mathematics Achievement Test and a questionnaire on students' attitudes toward mathematics. Descriptive and inferential statistics, including independent and paired sample t-tests, were employed for analysis. Findings revealed that students exposed to cooperative learning achieved significantly higher post-test scores compared to the control group, and demonstrated more positive attitudes toward mathematics. The study concludes that cooperative learning enhances both achievement and engagement, highlighting its value as an effective instructional strategy in mathematics education. These findings suggest that cooperative learning can support sustainable educational improvement by promoting inclusive participation, stronger peer-to-peer support, and more enduring positive dispositions toward mathematics—factors that contribute to long-term retention and continued engagement.

Keywords: Active learning; Attitudes toward mathematics; Cooperative learning; Mathematics achievement; Student-centered learning

1. Introduction

The importance of mathematics in life is so crucial that it cannot be overstated. Edekor and Agbornu (2020) assert that mathematics is the discipline concerned with the logic of shape, quantity, and order. Mathematics permeates our environment and influences all our activities. It serves as the fundamental component for all that nature provides and is present in nearly every aspect of our everyday existence. However, historically, mathematics has consistently posed the most difficult for students to comprehend during their academic journeys (Li & Schoenfeld, 2019). Consequently, educators employed diverse tactics and methodologies to convey the subject matter effectively. The collaborative learning strategy, in which students engage in group work to address problems, exchange ideas, and build knowledge, has been acknowledged as an effective instructional approach across multiple disciplines. Cooperative learning is a student-centered pedagogical approach in which students engage in activities collaboratively within groups. Group members will engage with one another to accomplish both their peers' and their individual lesson objectives (McCafferty et al., 2016).

Over the past decade, reports from the West African Examination Council indicate that Chief Examiners have consistently noted a decline in student performance in Mathematics in the West Africa Senior Schools Certificate Examination [WASSCE], decreasing from 49.9% in 2012 to 25.29% in 2019. Despite a notable enhancement in students' Mathematics performance in the WASSCE, reaching approximately 65% in 2020, a report by Graphic online on February 28, 2023, indicated that Ghanaian students continue to face difficulties in Mathematics, with a higher failure rate in this subject compared to other core subjects in the 2022 WASSCE for private candidates (Graphic online, 2023). The data indicates that merely 41.10% of the students who sat for the exam achieved grades A1–C6 in mathematics, signifying that approximately 60% of the students did not pass.

This plainly indicates that the issue of inadequate performance in mathematics in Ghana continues.

Mereku (2010) posits that the inadequate performance in mathematics may stem from the conventional methods utilized in the teaching and learning processes within Ghanaian classrooms. Mensah-Wonkyi and Adum (2016) ascribed the deficiency in comprehension of mathematical concepts to the conventional teaching methods employed, asserting that these methods do not foster creativity and critical thinking in mathematics education. Kizlik (2016) contended that the appropriate instructional method for teaching a specific lesson is contingent upon factors including the students' age and cognitive development, their prior knowledge, the subject matter itself, students' interests, and the lesson's objectives.

To cultivate mathematical comprehension in the classroom, students must engage more actively and creatively in acquiring knowledge, particularly in comprehending and resolving mathematical issues. Students must be let to develop, interact, and exchange ideas with peers, so enhancing their cognitive and emotional growth in mathematics. Cooperative learning is an educational methodology wherein groups of learners engage collectively to address an issue, accomplish a task, or produce a product (Laal, 2018). It can also be characterized as small cohorts of learners collaborating as a team to resolve a problem, fulfill a task, or achieve a shared objective (Isaac et al., 2019). Cooperative learning is an instructional approach in which small groups of students, possessing diverse levels of proficiency, engage in various educational activities to enhance their comprehension of a subject (Dyson & Casey, 2018). The cooperative learning method facilitates peer-to-peer learning and the acquisition of essential interpersonal skills (Topping et al., 2019).

Hiebert and Wearne (2016) assert that learners educated through cooperative learning exhibited superior problem-solving techniques compared to those instructed through conventional approaches. According to Slavin (2018), cooperative learning practices cultivate a more profound comprehension of mathematical topics among students. Webb (2017) indicated that students in collaborative groups exhibit increased motivation and interest in mathematics. Johnson et al. (2019) discovered that students educated in a cooperative learning environment exhibited enhanced communication skills, which were significantly correlated with their mathematical achievement. Gillies and Boyle (2020) also confirm that cooperative learning is generally more advantageous for students with lower levels of prior achievement. Certain mathematical concepts like probability have shown to be challenging for students.

Probability and decision-making manifest in childhood, typically linked to games of chance, although their formal study commences in middle school or high school. Mathematics students find probability learning challenging due to difficulties in comprehending probability concepts and problem contexts (Memnun et al., 2019). Instruction in probability is typically highly theoretical and axiomatic, leading students to perceive it as impractical and complex (Ruiz, 2018). Several studies describe probability as a discipline that quantifies uncertainty and serves as a cornerstone for mathematical literacy (Garfield & Ahlgren, 2020). Probability enhances communication, problem-solving, and decision-making abilities in uncertain situations (Greer, 2016; Sari & Hadi, 2020).

Mezhennaya and Pugachev (2019) advocate for innovative approaches to address students' difficulties in learning probability. Komarudin (2019) developed an experimental methodology employing dice and coins to improve understanding of probability. Activity-based and student-centered strategies can make mathematics learning more effective and stress-free (Rehman et al., 2021; Wright & Park, 2022). Employing relevant materials, integrating information and communication technology, and utilising collaborative strategies may alleviate learning difficulties in mathematics (Braun et al., 2017). A cooperative learning strategy provides equitable access to educational opportunities (Almazroui, 2023). Consequently, recognising the potential of cooperative learning to enhance academic performance in mathematics presents significant promise for addressing these challenges.

2. The Aim

The importance of this study lies in its potential to provide evidence for sustainable, student-centered improvement in mathematics education through cooperative learning. In many secondary school settings, low achievement and negative attitudes toward mathematics continue to limit students’ engagement and long-term progress. By examining cooperative learning as an alternative to traditional teacher-centered instruction, the study addresses the need to identify pedagogical approaches that can improve both academic performance and learners’ dispositions toward mathematics. This study is also significant for classroom practice. Its findings are expected to offer teachers empirically grounded insights into how cooperative learning can support inclusive participation, peer-assisted learning, and higher-order thinking. Such evidence may help teachers move from rigid content delivery toward facilitation strategies that better respond to diverse learning needs. At the system level, the results may inform school leaders and educational authorities about whether cooperative learning is a viable strategy for improving mathematics outcomes, thereby supporting decisions related to curriculum implementation, teacher professional development, and instructional support. Finally, the study contributes context-specific evidence to the cooperative learning literature and may encourage further replication in other districts. The findings may guide pedagogical choices that enhance mathematics teaching in Ghana and other educational settings.

The purpose of the study is to analyze the effect of cooperative learning on the mathematical performance of senior high school students. The primary objective of the research is to determine the comparative impact of the cooperative learning method on mathematics achievement among students in contrast to a traditional approach. Hence, the study was guided by the following research question:

RQ 1) What impact does cooperative learning have on students' performance in mathematics?

RQ 2) How does the use of cooperative leaning in teaching influence the attitudes of students towards the study of Mathematics?

3. Theoretical Framework

Cooperative learning is predicated on constructivist theory, which asserts that knowledge is constructed and conveyed by students. The learning process should be understood as the activation of existing cognitive structures or the construction of new cognitive structures that accommodate incoming information. Learning occurs interactively among all students and professors, rather than through passive knowledge acquisition. Moreover, cooperative learning is characterized from various perspectives: social presence, motivational dynamics, cognitive presence, and community of inquiry (Lowyck & Pöysä, 2001). Consequently, students at in Ghana require instruments that empower them to assume control of the learning process, rather than adhering to conventional methodologies employed in educational institutions. Furthermore, students require projects and workshops designed to enhance and cultivate their talents through interdisciplinary courses that promote cooperative learning (Anderson, 2014).

Cooperative learning is a pedagogical strategy in which students collaborate to mitigate adverse outcomes and enhance satisfaction derived from the group's high-level performance. The students experience heightened intrinsic motivation towards learning, improved capacity to empathize with others' viewpoints, and reduced anxiety and stress levels (Felder & Brent, 2007). The primary benefit of collaborative learning is its capacity to navigate diverse situations systematically, facilitating learners' progression from one phase to another. Cooperative learning promotes learning and engagement through individual inquiry while repositioning teachers as facilitators who guide and support students’ interaction (MacPherson, 2008).

The efficacy of peer review may be constrained if learners experience rivalry among themselves, which can negatively impact the reliability of feedback (Tsay & Brady, 2012). Furthermore, students may continue to be concerned about their rankings and those of their peers. To mitigate these problems, relocating learners from their teams after the completion of team assessments is likely to yield more dependable responses. An additional component that could enhance competition and foster cooperation is the implementation of a principle-based ranking system to evaluate teamwork, rather than utilising a grading curve. Cooperative learning, an instructional technique, involves students collaborating to attain a shared objective under specific conditions, which encompass the following elements (Felder & Brent, 2007). The effective use of collaborative skills, as learners are encouraged and supported to enhance and utilise decision-making, trust-building, communication, conflict resolution, and leadership abilities.

4. Conceptual Framework for the Study

The study's conceptual framework (figure 1) is grounded in the principles of cooperative learning, which are derived from the theoretical framework encompassing social learning theory, cognitive elaboration theory, social interdependence theory, and cognitive development theory. These theories facilitated the discovery and implementation of cooperative learning methodologies. Social Interdependence is a basic component of these theoretical frameworks, referring to the condition in which an individual's outcomes are influenced by the acts of others or by situations when one student's activities can substitute for another's. This dynamic student interaction not only immediately impacts academic performance but also yields other advantageous learning effects. These results augment enthusiasm, elevate motivation, and raise academic achievement (Gupta & Pasriga, 2013). This illustrates the numerous advantages of cooperative learning and corresponds with the interrelated principles of the previously described theories. Theoretical foundations shaped the conceptualization and representation of the interaction among the research variables in Figure 1.

Figure 1
Conceptual Framework for the Study

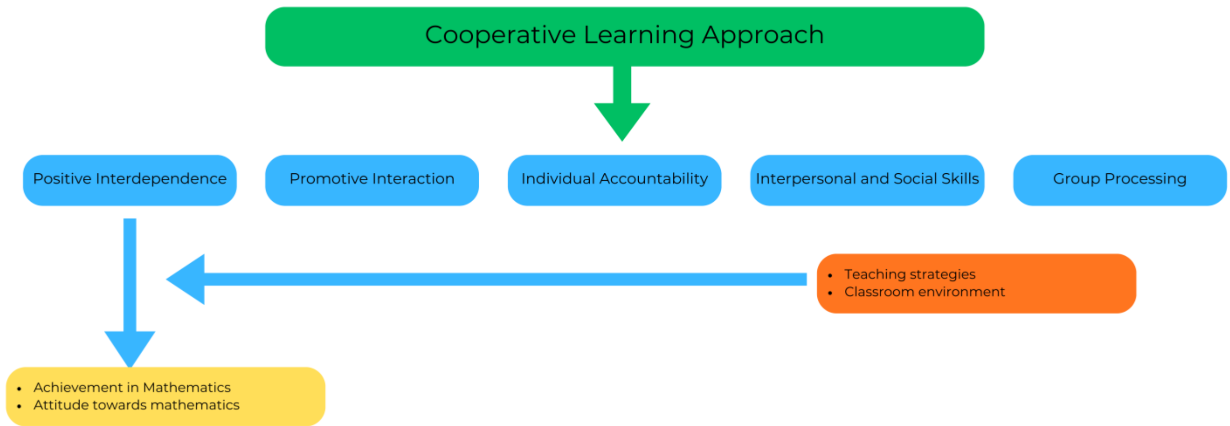

Figure 1 clarifies the complex interactions between the research components by demonstrating how the theoretical ideas affect the way the various variables interact. Through the integration of these ideas in the conceptual framework, the research aims to offer a more comprehensive comprehension of the cooperative learning process, emphasizing the importance of its theoretical foundation in determining educational success.

Prior research consistently reports that cooperative/collaborative learning is associated with improved mathematics achievement compared with traditional instruction. Quasi-experimental evidence indicates that students taught through collaborative strategies often outperform those in control groups, suggesting the approach can be an effective classroom intervention for strengthening mathematical performance (Mathias et al., 2023; Olanrewaju, 2019). Beyond mean score gains, the literature also notes the potential of well-implemented cooperative learning to support more inclusive mathematics classrooms and reduce performance disparities among learners.

Studies further suggest that cooperative learning positively influences students' attitudes toward mathematics. Empirical findings link cooperative approaches with higher motivation and engagement, more favorable attitudes, and stronger self-efficacy—factors that may contribute to the development of a positive mathematical identity (Mazana et al., 2018; Mathias et al., 2023). Reviews and meta-analytic evidence similarly indicate benefits not only for achievement but also for learners' perceptions and affective responses to mathematics, including increased enjoyment and reduced mathematics-related anxiety (Gillies, 2016; Gillies & Boyle, 2023). At the same time, the literature highlights implementation challenges—such as teacher readiness, managing group dynamics, and the effective integration of technology—suggesting that outcomes depend on instructional design and classroom conditions (Borba et al., 2017; Nazari, 2023).

5. Method

5.1. Research Design

The study adopted the quasi-experimental group design, specifically, the non-equivalent control group pretest-posttest design. The advantage of this design is its ability to compare scores before and after treatment in both the experimental and the non-equivalent control groups. This design was considered because intact classes were used as both experimental and control groups, and any attempt at randomizing participants into groups would have disrupted the existing classes in the school.

5.2. Participants

The sample for the study was one hundred and forty (140) second-year students of Nkawkaw Senior High School. Four (4) intact from two classes were selected from both Home Economics two (2) and Visual Arts (2) classes for the study. These were Home Economics 2A and 2B and Visual Arts 2A and 2B. These classes were selected based on their perceived disinterest in the subject mathematics probably due to their previous abysmal performances in mathematics compared to students offering other courses in the school. There were thirty-five (35) Home Economics 2A students consisting of twenty-three (23) girls and twelve (12) boys and thirty-four (34) Home Economics 2B students consisting of twenty-four (24) girls and ten (10) boys. Also, there were thirty-six (36) Visual Arts 2A students consisting of sixteen (16) girls and twenty (20) boys and thirty-five (35) Visual Arts students consisting of thirteen (13) girls and twenty-two (22) boys. Home Economics 2A and Visual Arts 2B were assigned to the experimental group and Home Economics 2B and Visual Arts 2A were assigned to the control group. The students in the two classes (Home Economics 2A and Visual Arts 2B) assigned to the experimental group were further put into nine (9) groups of four (4) for Home Economics 2A and also nine (9) groups of four (4) for Visual Arts 2B. The selection of these classes for the study was done purposively and in consultation with the assistant head of academics and the head of the mathematics department. The two classes selected for the control group had similar mean scores. Table 1 gives a summary of the respondents.

Table 1
Distribution of Respondents by Classes

Classes	*Allocation*	*Group*	*Number*	*Percentages*
Home	2A	Experimental	35	25.0
Economics	2B	Control	34	25.7
Visual	2A	Control	36	24.3
Arts	2B	Experimental	35	25.0
Total			140	100.0

Table 1 show that 70 of the students who constituted the sampled students were from Home Economics 2A and Visual Arts 2B with a percentage of 50% whereas the control group had 34 students from Home Economics 2B and 36 students from Visual Arts 2A with a total percentage of 50.0%. This is an indication that the two groups had equal representation of the number of students for the study.

5.3. Instruments

The researcher used test and questionnaires as data collection instruments for the study. The test is in the form of a pre-test and post-test. The test was researcher-made Mathematics Achievement Test [MAT]. The Mathematics Achievement Test consists of ten multiple-choice and three written questions. All the questions were adopted from past examinations of the West African Examination Council [WAEC]. Students were to answer all ten (10) multiple-choice questions and any two of the three written questions. The questions in the test were based on the concept of Probability. Each of the multiple-choice questions of the MAT had four options (A-D). The Mathematics Achievement Test was administered to both the experimental, and control groups as a pre-test and post-test after it had been reshuffled. Also, a questionnaire consisting of twenty items was constructed to collect data on students' attitudes toward mathematics before and after the application of the cooperative learning approach. The questionnaire was constructed using a four-point Likert scales ranging from strongly agree to strongly agree which was answered by students from the experimental group.

5.4. Data Analysis Procedure

The study used data from the tests and the analysis was done using Statistical Package for the Social Science version 27. The responses from the instruments yielded quantitative data that were analyzed quantitatively. In this study the researcher employed both descriptive and inferential data analysis to analyze the data. Data obtained from participants in both groups on the pre-test and post-test were analyzed statistically using independent *t*-test. The inferential statistics was used to determine if there is a significant difference between the performance of the two groups before and after the intervention. The independent *t*-test was applied to verify the intervention's effects on the male and female students of the groups. Prior to conducting the independent samples t-tests, skewness and kurtosis were employed to assess the normality of the pre-test and post-test score distributions for both the control and experimental groups. Kline (2015) asserts that suitable normality is represented by skewness values between −2 and +2, and kurtosis values between −7 and +7. The pre-test scores exhibited kurtosis levels of 0.63 and -0.10, along with skewness values of 1.07 for the control group and 0.83 for the experimental group. Post-test scores demonstrated improved symmetry, with skewness values of 0.29 for the control group and -1.07 for the experimental group, alongside kurtosis values of −0.93 and -0.22. These findings indicate that all distributions fell within acceptable limits, hence confirming the normalcy hypothesis. Consequently, it was appropriate to utilise independent samples t-tests to assess group performance prior to and during the intervention (George & Mallery, 2019).

6. Results and Discussions

6.1. Impact of Cooperative Learning on Students' Mathematics Performance

A pre-test was administered to the two groups (control group and experimental group) one week before the intervention to check whether the two groups were comparable in terms of their performance before the intervention. Table 2 displays the groups' entry characteristics test results that are the group statistics for the pre-test scores.

Table 2
Group Statistics for the Pre-Test Scores

Group	*N*	*Mean*	*SD*	*SE Mean*
Experimental	70	9.77	1.89	0.23
Control	70	10.13	1.57	0.19

Source: Fieldwork, 2025.

Table 2 presents the descriptive statistics for the pre-test scores of the experimental and control groups. Both groups consisted of 70 students. The mean pre-test score for the experimental group was 9.77 (SD = 1.89), while the control group recorded a slightly higher mean score of 10.13 (SD = 1.57). The small difference in mean scores suggests that the two groups were comparable prior to the intervention. Levene's Test of Equality of Error Variances was performed to assess the assumption of homogeneity of variances (F (1, 138) = 0.51, p = 0.49), indicating that the assumption of equal variances was satisfied. After confirming that the variances were equal, an independent samples t-test was done to see if the difference in mean of the pre-test scores between the experimental and control groups was statistically significant. Table 3 shows a summary of the test outcomes.

Table 3

Independent Sample t-test of Pre-Test Scores

F	*Sig.*	*t*	*df*	*Sig. (2-tailed)*	*Mean Difference*	*Std. Error Difference*	*95% CI Lower*	*95% CI Upper*
0.51	0.48	1.21	138	.23	0.36	0.33	−1.02	0.31

Source: Fieldwork, 2025,

An independent samples t-test was conducted to determine whether there was a statistically significant difference between the mean pre-test scores of the experimental and control groups. The results showed no statistically significant difference, $t(138) = 1.21$, p = .23. This confirms that the two groups were equivalent in mathematics performance prior to the intervention.

A post-test was administered to the two groups (control group and experimental group) after the intervention to check the efficacy and the effect of the intervention on students' achievements in mathematics and this provides answers to the research question one. Table 4 shows the descriptive statistics for the post-test results for the two groups.

Table 4

Group Statistics for Post-Test Scores

Group	*N*	*Mean*	*Std. Deviation*	*Std. Error Mean*
Experimental	70	18.26	2.01	0.24
Control	70	15.41	2.18	0.26

The descriptive statistics for the post-test scores indicate that the experimental group achieved a higher mean score (M = 18.26, SD = 2.01) than the control group (M = 15.41, SD = 2.18). This is an indication that students from the experimental group performed better than those from the control group after the intervention. Levene's Test of Equality of Error Variances was conducted to assess the assumption of homogeneity of variances (F (1, 138) = 1.35, p = .25), suggesting that the assumption of homogeneity of variances was satisfied.

After confirming that the variances were equal, an independent samples t-test was done to see if the difference in mean post-test scores between the experimental and control groups was statistically significant. The results are shown in Table 5.

Table 5

Independent t-Test results of the Post-Test from the two groups

F	*Sig.*	*t*	*df*	*Sig. (2-tailed)*	*Mean Difference*	*Std. Error Difference*	*95% CI Lower*	*95% CI Upper*
1.35	.25	−8.01	138	<.001	−2.84	0.35	−3.55	−2.14

Source: fieldwork (2025)

An independent samples t-test revealed a statistically significant difference between the post-test scores of the experimental and control groups, t (138) = −8.01, p < .001. The experimental group outperformed the control group, indicating that cooperative learning had a significant effect on students' mathematics achievement. It can therefore be argued that students from the experimental group performed significantly better than those from the control group which is the result of the use of cooperative learning. The researcher then again compared the scores from the pre-test and post-test to get a better idea of how much each group learnt and this is shown in Table 6.

Table 6
Within Groups Comparison

Group	*Test Type*	*N*	*Mean*	*Std. Deviation*
Experimental	Pre-Test	70	9.77	1.57
Experimental	Post-Test	70	18.26	2.01
Control	Pre-Test	70	10.13	1.89
Control	Post-Test	70	15.41	2.18

Results from the paired samples t-tests showed statistically significant improvements from pre-test to post-test for both groups. However, the experimental group demonstrated a greater mean gain than the control group, indicating that cooperative learning led to stronger learning gains.

Table 7
Paired Samples t-Test (Within-Group)

Group	*t*	*df*	*Sig. (2-tailed)*	*Mean Difference*	*SD*	*SE Mean*	*95% CI Lower*	*95% CI Upper*
Experimental	28.86	69	<.001	8.48	2.46	0.29	7.89	9.07
Control	21.86	69	<.001	5.29	2.02	0.24	4.80	5.77

Table 7 indicates that both the experimental and control groups made statistically significant progress from the pre-test to the post-test. The experimental group recorded a t-value of 28.86 (df = 69, p < .001), while the control group recorded a t-value of 21.86 (df = 69, p < .001). Although both groups demonstrated significant improvement, the magnitude of change was greater for the experimental group than for the control group. This is further supported by the confidence intervals, with the experimental group showing a 95% confidence interval ranging from 7.89 to 9.07, compared to 4.80 to 5.77 for the control group. These results indicate that students exposed to cooperative learning achieved greater learning gains in mathematics than those taught using the traditional method. The experimental group not only attained higher post-test scores but also demonstrated greater improvement from pre-test to post-test. The findings therefore provide empirical support for the effectiveness of cooperative learning in enhancing students' mathematics performance.

6.2. Influence of Cooperative Learning on Students' Attitudes toward Mathematics

Students' attitude towards mathematics both before and after the intervention measured their perceptions on attitudes of learners in interventional programmes. The descriptive statistics employed in the beginning were more concerned with the ability to describe the baseline attitudes of students as they engaged in cooperative learning before and after the intervention. Hence, a paired samples t-test was conducted for purpose of ascertaining whether indeed there were differences that existed among the students' attitudes prior to implementation of cooperative learning and after its implementation.

As per Table 8, a review of the attitudes towards mathematics prior to the intervention in the experimental group shows that most students had negative attitudes towards mathematics. Majority were not interested in Mathematics (57.1%, M = 1.5), and did not feel comfortable with problem-solving (70.0%, M = 1.4) and disliked assignments on Mathematics (71.4%, M = 1.5). Surprisingly, most of the students recognized that mathematics was important to their future career (78.5%, M = 2.7) however reported being weak at this subject (90%) neither liked contributing nor discussing about mathematics (97.2%, M = 2.8). High levels of anxiety were observed with a 98.5% who said they usually experienced anxiety during exams (M = 2.9). There was low participation in extra-curricular Mathematics clubs which stood at 90%. Similar scenario is reflected when it comes to seeking for help using available resources wherein only as few as 92% indicated that they could do so if faced with any challenge regarding Mathematics hence no better than those engaging in extra-curricular activities involving Mathematics. In the case of effort to improve mathematics skills, only 42% believed so whilst for the fun of people engaging in mathematics activities or new concepts exploration was just 30%. Hence, overall, the mean attitude score of 1.69 reflects predominantly negative perceptions, suggesting limited interest, confidence, and enjoyment in mathematics among the students prior to the intervention.

Table 8
Students Views before the Intervention

	Disagree		*Neutral*		*Agree*		*Mean*	*Remarks*
	N	*%*	*N*	*%*	*N*	*%*		
Mathematics is interesting to me.	40	57.1	25	35.7	5	7.2	1.5	Disagreed
I feel confident in my ability to solve math problems.	49	70.0	09	12.9	12	17.1	1.4	Disagreed
I enjoy working on mathematics assignments and homework.	50	71.4	05	7.2	15	21.4	1.5	Disagreed
I believe that mathematics is important for my future.	05	7.2	10	14.3	55	78.5	2.7	Agreed
I am comfortable participating in math-related discussions in class	68	97.2	00	0.0	02	2.8	1.1	Disagreed
I feel anxious and anxiety when solving mathematics problems or exams.	0	0.0	01	2.8	69	98.5	2.9	Agreed
I actively engage in extracurricular math-related activities or clubs	63	90.0	07	10.0	0	0.0	1.1	Disagreed
I use various resources to study mathematics	65	92.8	05	7.2	0	0.0	1.1	Disagreed
I believe that anyone can improve their mathematics skills with effort	30	42.8	26	37.2	14	20.0	1.8	Neutral
I think mathematics is fun	60	85.7	08	11.5	02	2.8	1.2	Disagreed
I enjoy exploring new mathematical concepts	64	91.4	06	8.6	0	0.0	1.2	Disagreed

After the completion of the treatment, students in the experimental group were once again asked to complete a post-project survey which was similar to the pre-project survey. Table 9 presents the responses of the respondents regarding their attitude towards mathematics after receiving instruction in mathematics through the cooperative learning approach. Students were asked to express their opinions about whether they liked their experience in mathematics or not by selecting the option that best describe their opinion.

As shown in Table 9, the approach to cooperative learning was found to have a positive effect on students' attitudes towards mathematics. The majority of the respondents accepted that the method made students more participative in class activities (95.7%, M = 2.9), made it fun to learn (97.0%, M = 2.9) and inspired them to learn more (93.0%, M = 2.9). Most students also confirmed that cooperative learning influenced their focus during lessons (68.6% agree, M = 2.9) and contributed positively towards content mastery (98.5% agree, M = 2.5). Moreover, 77.2% showed that group study assists them effectively work with colleagues (M= 2.7), and 85.7% agreed on better content retention (M= 2.5). A larger proportion of the learners suggested that they should be taught as a team in cooperative learning (95.7%, M= 2.9). Generally, the findings indicate a positive shift in students' attitudes, with an average mean score of 2.8, demonstrating that cooperative learning enhanced engagement, motivation, and enjoyment in mathematics.

Table 9
Students Views after the Intervention

Statements	*Agree*		*Disagree*		*Not Sure*		*Mean*	*Remark*
	N	*%*	*N*	*%*	*N*	*%*		
The teaching method (cooperative learning) encourages me to participate more in class activities.	67	95.7	0	0.0	03	04.3	2.9	Agreed
Learning mathematics in groups was very enjoyable and interesting.	68	97.0	02	03.0	0	0.0	2.9	Agreed
I was motivated to learn the concept well when working in groups.	65	93.0	0	0.0	05	07.0	2.8	Agreed
Learning through groups enables me to concentrate more during lesson delivery	48	68.6	12	17.1	10	14.3	2.5	Agreed
Learning through groups enables me to master the content very well	69	98.5	0	0.0	01	01.5	2.9	Agreed
I can study well with my mates using cooperative learning.	54	77.2	09	12.8	07	10.0	2.7	Agreed
I found that I can retain better learning with cooperative learning	60	85.7	02	03.0	08	11.3	2.7	Agreed
I found it difficult to understand the concept when studying in groups.	67	95.7	02	2.8	01	01.5	2.9	Agreed

To verify whether cooperative learning had a potential to influence students' attitudes towards mathematics, a paired samples *t*-test was carried out comparing pre-intervention and post-intervention attitude mean scores of students in the experimental group (see Table 10).

Table 10
Paired Samples t-Test for Students' Attitudes toward Mathematics

Variable	*Pre M (SD)*	*Post M (SD)*	*Mean Difference*	*t (df)*	*p*	*Cohen's d*
Attitudes	1.62 (0.43)	2.82 (0.40)	−1.20	−12.57 (69)	<.001	1.50

The findings showed there was a statistical significance in the improvement of student's attitude towards mathematics after the intervention ($t(69) = -12.57$, $p < .001$). The average attitude score escalated from 1.62 before the intervention to 2.82 after the intervention with an effect size in the high range (Cohen's $d = 1.50$), indicating that students' perceptions and feelings towards mathematics improved considerably. This result implies that CL significantly influenced the participants into developing positive attitudes towards the subject.

7. Discussion

7.1. Effect of Cooperative Learning on Students Achievement

The results of this study show that cooperative learning has a substantial positive effect on students' mathematics achievement. To align with sustainable education goals, this improvement should be discussed not only as a short-term score gain but also as a mechanism for building durable learning engagement and capacity over time. A growing body of research indicates that collaborative learning environments can yield stronger outcomes than traditional teacher-centered classrooms. The constructivist paradigm, which emphasizes that learners actively build understanding through social interaction (Vygotsky, 1978), provides a foundation for cooperative learning. In this context, peer interaction can promote deeper processing, conceptual understanding, and retention. Gillies (2016) notes that cooperative learning structures support deeper learning by engaging students in shared problem-solving, peer explanation, and mutual accountability—processes that are particularly relevant in mathematics, where reasoning and procedural fluency must be integrated. Gambari et al. (2016) found that cooperative learning can improve mathematical competence by strengthening understanding and promoting positive interdependence. Students may benefit from receiving explanations from both teachers and peers, which can support comprehension of mathematical concepts and procedures.

Cooperative learning may also contribute to more consistent achievement outcomes. This aligns with Bayat and Tarmizi (2020), who reported reduced score variation in collaborative testing conditions, suggesting improved collective understanding. From a sustainability perspective, reduced performance dispersion can be framed as a contribution to equity and inclusion, as it may help narrow learning gaps that otherwise accumulate into long-term disadvantages. In mathematics education, where uneven understanding may lead to persistent learning deficits, such consistency is particularly meaningful. Cooperative learning can further strengthen motivation and engagement, which are critical for sustained learning. Khan and Ahmad (2019) reported that students are more likely to persist and remain interested in mathematics tasks when working collaboratively. This finding should be linked to sustainable learning environments by emphasizing that motivation and engagement are prerequisites for long-term participation and continued achievement, not merely immediate classroom compliance. The cooperative learning perspective is also compatible with social cognitive theory (Bandura, 1997), which highlights learning through observation, modeling, and social reinforcement. Through small-group work, students can observe problem-solving strategies, develop self-efficacy, and receive immediate feedback—conditions that support understanding of challenging mathematical ideas.

Slavin's (2015) cooperative learning theory suggests that structured group interaction can improve academic performance and strengthen social skills and classroom cohesion. Slavin (2015) highlights the importance of positive interdependence and individual accountability, both of which are typically embedded in well-designed cooperative learning tasks. In addition, the current results complement Ramirez et al.'s (2018) view that collaborative learning can reduce mathematics anxiety and foster a supportive environment. Students who feel overwhelmed in traditional settings may perform better in groups where peers provide academic and emotional support, lowering performance pressure and encouraging risk-taking during problem-solving.

Thus, the improved post-intervention performance in this study supports the view that cooperative learning is a promising instructional approach for mathematics classrooms. Its effectiveness may stem from engaging students cognitively, emotionally, and socially—dimensions that jointly contribute to mathematical understanding, procedural competence, and learner confidence. The study's results are consistent with prior research supporting cooperative learning in mathematics education, particularly at the basic level. Implications for sustainable education include the need to institutionalize student-centered pedagogies through teacher professional development, classroom implementation support, and assessment practices that value reasoning and collaboration alongside individual mastery. This suggests that teachers and curriculum developers should move beyond rote memorization and passive learning by adopting interactive approaches that support equitable and sustainable learning outcomes.

7.2. Students' attitude Towards Mathematics

To address persistent concerns about low performance and limited interest in mathematics, it is essential to examine students' attitudes toward the subject, as attitudes influence learners' willingness to participate, persist, and achieve. Attitudes are commonly understood to involve emotional, cognitive, and behavioral components, each shaping how students engage with mathematics learning. In this study, students' perceptions, feelings, and engagement-related behaviors were assessed prior to the cooperative learning intervention. Evidence indicates that negative attitudes toward mathematics are associated with reduced motivation, increased anxiety, and lower achievement (Mensah et al., 2017). Mathematics anxiety, in particular, can undermine working memory, problem-solving, and classroom participation (Ramirez et al., 2018), creating a cycle in which avoidance of mathematics tasks reinforces negative perceptions and limits meaningful learning opportunities.

From a sustainable, student-centered education perspective, these affective barriers are not merely individual issues but also indicators of learning environments that may not adequately support long-term engagement and equitable participation. While students may develop interest through broader learning opportunities such as extracurricular engagement and diverse learning resources (Ayotola & Adedeji, 2019), limited involvement in such activities can signal weak intrinsic motivation and low attachment to the subject. Therefore, instructional approaches should intentionally address students' emotional experiences and participation patterns, particularly given that attitudes are shaped by prior experiences and the nature of classroom instruction. Teacher-centered approaches may not consistently build confidence or sustained interest (Gillies, 2016), whereas cooperative learning has been shown to support peer assistance, motivation, and more positive orientations toward mathematics. By encouraging supportive interaction, cooperative learning can also strengthen communication and social relations, which may reduce stress and enhance confidence (Opolot-Okurut et al., 2018). Overall, the findings underscore that students' attitudes toward mathematics are multidimensional and influenced by both internal and instructional factors; without addressing negative attitudes and anxiety, progress in learning and achievement may be constrained.

Post-intervention results in this study indicate that cooperative learning was associated with more positive student attitudes toward mathematics. Cooperative learning is designed to promote teamwork and active participation, shifting students from passive reception toward engaged involvement in the learning process. This pattern is consistent with prior research suggesting that cooperative learning can strengthen students' motivation, interest, and affective connection to mathematics. Structured group interaction can foster a sense of belonging and support, which may increase engagement and confidence (Gillies, 2016), particularly in mathematics where anxiety is common. Cooperative learning can also contribute to a supportive classroom climate that reduces stress and encourages participation. In addition, the emphasis on positive interdependence, individual accountability, and face-to-face interaction (Johnson & Johnson, 2017) may create conditions where students feel safer to ask questions, clarify ideas, and receive timely feedback from peers.

The motivational benefits of cooperative learning have also been documented in the literature. Students in cooperative groups may demonstrate higher intrinsic motivation and greater persistence when faced with challenging tasks (Khan & Ahmad, 2019). Group structures can support attention and sustained focus because students recognize that their contributions affect group progress (Bayat & Tarmizi, 2020), which is particularly relevant for mathematical reasoning that requires careful sequencing and sustained concentration. Cooperative learning may further enhance conceptual understanding and retention through participatory discussion, as students identify misconceptions and consolidate knowledge through explanation and dialogue (Gambari et al., 2016). Importantly, cooperative learning may also reduce mathematics anxiety by distributing performance pressure and providing emotional and academic support within the group (Ramirez et al., 2018). As students collaborate respectfully, manage differences, and experience shared success, classroom culture can become more positive and achievement-oriented (Ogunmakin & Akomolafe, 2017). In summary, the results align with existing evidence that cooperative learning can improve students' attitudes toward mathematics by creating a more participatory, supportive, and student-centered learning environment. Such attitudinal improvements are relevant to sustainable education aims because they can strengthen long-term engagement and inclusive participation in mathematics learning, which are critical for sustained academic progress.

8. Conclusion

This study contributes to the limited empirical evidence on cooperative learning in Ghana by examining its effects on senior high school students' mathematics achievement and attitudes within a probability unit. Using a quasi-experimental design, students in the experimental group received cooperative learning instruction, while the control group was taught through a traditional approach. The findings indicate clear differences between the groups: students exposed to cooperative learning demonstrated significantly higher post-intervention mathematics performance and more positive attitudes toward mathematics than those in the control group. These results suggest that cooperative learning can be a viable student-centered strategy for improving both cognitive (achievement) and affective (attitudes) outcomes in mathematics. From a sustainable education perspective, strengthening learners' engagement and attitudes is particularly important because these factors support continued participation and long-term learning development, rather than short-term performance alone. The findings also imply that cooperative learning may foster supportive classroom interactions that help students learn through structured information sharing and collaborative problem-solving. In practice, the study supports the integration of cooperative learning into secondary mathematics instruction in Ghana, alongside guidance for teachers on how to structure groups, ensure individual accountability, and sustain productive collaboration. At the policy level, the evidence may inform curriculum implementation and teacher professional development initiatives that promote student-centered pedagogy as part of broader efforts to improve educational quality. Future research should extend this work using larger and more diverse samples, explore longer-term effects, and examine implementation conditions that enable cooperative learning to be scaled sustainably across schools.

9. Recommendations

Based on the findings of this study, several recommendations are proposed for classroom practice, school improvement, and future research in ways that align with sustainable, student-centered educational development.

First, cooperative learning should be introduced progressively from the early stages of schooling so that learners develop productive group-work norms, communication skills, and habits of knowledge sharing. Early exposure can strengthen foundational mathematics learning and support more positive attitudes toward the subject over time, which is important for sustained engagement and long-term achievement.

Second, mathematics teachers are encouraged to adopt structured cooperative learning strategies as part of regular instruction to promote active participation and meaningful learning. This recommendation is supported by students' post-intervention views indicating that cooperative learning helped them remain engaged, contribute during lessons, and learn more effectively. To ensure sustainable implementation, teachers should be supported with practical guidance on group formation, clear roles, individual accountability, and classroom routines that maintain inclusive participation.

Third, where girls experience persistent challenges in particular mathematics areas, cooperative learning may be used intentionally to strengthen confidence, participation, and performance. Teachers should combine cooperative structures with appropriate pedagogical supports and—where feasible—context-appropriate technology that enhances collaboration and access to learning resources. In line with sustainable education priorities, such efforts should aim to reduce participation gaps and promote equitable learning opportunities for all students.

For further research, future studies should extend the investigation beyond probability to additional topics in the senior high school mathematics curriculum in order to determine whether cooperative learning yields similar effects across content areas. In addition, because this study used a quantitative approach, future work is encouraged to employ mixed methods designs. Combining quantitative outcomes with qualitative evidence (e.g., classroom observations and student/teacher interviews) would provide deeper insight into how cooperative learning influences learning processes, attitudes, and implementation conditions, thereby supporting stronger conclusions and more scalable guidance for sustainable practice.

Author Contributions: Every author contributed to the article's conception, design, data gathering, interpretation, writing, and critical revision. The article's final draft has been approved by all writers.

Data availability: Upon reasonable request, the corresponding author will provide the datasets created and/or analysed during the current work.

Declaration of Conflicts of Interest: Regarding the authoring of this study and the publication of this paper, the authors affirm that they have no potential conflicts of interest.

Ethics statement: This study was approved for publication by the ethics committee since it was overseen by faculty supervisors. The names of the participants were not stated. Every participant in the study gave their informed consent. The goal, methods, and freedom to discontinue participation at any moment without consequence were explained to the participants. The subjects' anonymity and confidentiality were maintained for the entire study.

Funding: The research and/or writing of this article were not supported financially by the authors.

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