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Analyzing the impact of collaborative learning approach on grade six students' mathematics achievement and attitude towards mathematics

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Abstract

This study investigated the impact of collaborative learning on mathematics achievement and attitudes in sixth-grade students, comparing it to traditional didactic teaching. A quasi-experimental research design was utilized in which sixth-grade students were randomly assigned to either control or experimental groups. Pre- and post-tests assessed mathematics achievement using curriculum-aligned tests. In addition, attitudes toward mathematics were measured using the 'attitude towards mathematics' inventory developed by Tapai and Marsh in 2004. Both groups exhibited similar pre-test levels. The experimental group received collaborative learning, while the control group received traditional teaching. Post-tests after a 12-week intervention showed significant improvements in the experimental group's mathematics achievement, regardless of initial achievement levels. Positive changes in attitudes toward mathematics were also observed in the experimental group, with some progress in the control group. Collaborative learning appears promising for enhancing mathematics achievement and nurturing positive attitudes in elementary students.

Keywords: attitudes towards mathematics, collaborative learning, mathematics achievement, six graders

INTRODUCTION

In the landscape of mathematics education, the effectiveness of teaching methods remains a central concern of teachers (Fong-Yee & Normore, 2013; Koskinen & Pitkäniemi, 2022; Xhaferi, 2017). There are a variety of teaching methods that can be used to teach mathematics at elementary level, each with its own disadvantages and disadvantages (Kovacheva et al., 2022; NCTM, 2014; Unal, 2017;). Some of the potential innovative teaching methods include flipped classroom approach (Bishop & Verleger, 2013), collaborative learning (Hossain & Tarmizi, 2013; Vogel et al., 2016), project-based learning (Almazroui, 2023, p. 125-136), gamification (Deterding et al., 2011), adaptive learning systems (Brusilovsky et al., 2004), storytelling in math (Ginsburg, 2009), etc. Among all, collaborative learning, characterized by student interaction, cooperative problem-solving, and shared knowledge construction, has garnered substantial attention within the field of educational research as an innovative and promising pedagogical approach to improve students' math achievement and nurturing their positive attitudes towards mathematics (Agwu & Nmadu, 2023; Capar & Tarim, 2015; Hoang et al., 2023; Kibirige & Lehong, 2016; Lahann & Lambdin, 2014; O'Grady-Jones & Grant, 2023; Olanrewaju, 2019; Rao et al., 2020).

Collaborative learning is a teaching method that is carried out by more than two learners, the resources are shared in certain times, different abilities and skills of the learners are required during the activities completion in order to achieve certain goals or learning objectives through interactions, exchanges of experiences or changes of roles within the group in which all of these will impacted the achievement of the learners (Chu et al., 2017; Foldnes, 2016; Goodrich, 2018; Hwang & Chen, 2019; Li et al., 2023; Lim et al., 2023; Moreno-Guerrero et al., 2020). Shimazoe and Aldrich (2010) provides several benefits on the use of collaborative learning method for students. First, collaborative learning promotes deep learning of materials. Second, students achieve better grades in collaborative learning compared to

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Contribution to the literature

- This study provides robust empirical evidence supporting the positive impact of collaborative learning on mathematics achievement among elementary (grade six) students. While prior research had suggested the benefits of collaborative learning in mathematics education, this study adds to the existing literature by offering concrete data that demonstrates a significant improvement in students' mathematics performance after engaging in collaborative learning. This contribution reinforces the potential of collaborative learning as an effective pedagogical approach for enhancing academic outcomes in mathematics.
- The study not only confirms the positive effects of collaborative learning on mathematics achievement but also sheds light on its influence on students' attitudes towards the subject. By observing a substantial improvement in students' attitudes toward mathematics after participating in collaborative learning activities, this research contributes to a deeper understanding of the multifaceted benefits of collaborative learning. It underscores the role of collaborative learning in reducing mathematics anxiety, fostering a more positive perception of mathematics, and promoting greater confidence in the subject.
- The findings of this study also have significant implications for educational policy and practice. They emphasize the importance of incorporating collaborative learning strategies into mathematics curricula, especially at the elementary level. By demonstrating the positive outcomes of collaborative learning, this research provides a strong rationale for educators and policymakers to invest in professional development for teachers and to encourage the integration of collaborative learning activities in mathematics instruction. This study offers practical insights that can guide decisions about teaching methods, thereby improving mathematics education not only in Pakistan but also in educational contexts worldwide.

competitive or individual learning. Third, students learn social skills and civic values. Fourth, students learn higher-order, critical thinking skills. Fifth, cooperative learning promotes personal growth. Finally, students develop positive attitudes toward autonomous learning. It is based in the idea that students learn best by interacting with each other and sharing their knowledge and ideas (Hsu & Shiue, 2018; Shi et al., 2020). As, a result, group members who work in collaborative groups outperform students who work by themselves or in a competition with each other (as seen in competitive conventional classrooms) (Chen et al., 2018; Jeong et al., 2019; Johnson & Johnson, 2019; Law et al., 2017; Maharani et al., 2020; Sun et al., 2021).

This method, rooted in social constructivist principles, has the potential to cultivate deeper understanding and retention of subject matter (Johnson & Johnson, 2018). In addition, this approach aligns with contemporary educational paradigms, emphasizing active participation, the development of 21st century skills, and learner-centered pedagogy (Batool et al., 2018; Ku et al., 2013). Collaborative learning establishes a community in which students can get help and support from other group members immediately in a non-competitive learning environment, just raising their hands and waiting for the right answers to be given (Hossain & Tarmizi, 2013; Uz Bilgin & Gul, 2020). To explore the students' performance in mathematics and their attitudes towards mathematics in terms of collaborative learning effects, the researchers conducted this study in the elementary school with six grade students in Lahore, Pakistan. Its core objective is to contribute substantively to the discourse surrounding pedagogical approaches by empirically examining two distinct methods: collaborative learning and the traditional teaching paradigm. This study aims to shed light on how these two instructional strategies influence the math achievement and attitudes towards mathematics of grade six students, providing a contemporary perspective on the matter.

The rationale behind this study is grounded in the urgent need to discern and evaluate teaching strategies that can enhance mathematics education in Pakistan (Bhutta & Rizvi, 2022). Mathematics often poses challenges and evokes anxiety among students (Egodawatte, 2012; Hernández Suárez et al., 2022), which can hinder their academic performance and diminish their enthusiasm for the subject (Memon & Shaikh, 2020; Nasir et al., 2008). In a recent study conducted by Bhutta and Rizvi (2022) revealed that most students at elementary level (grade I to grade VIII) showed signifying poor performance and a weak understanding of mathematical concepts, respectively. The researchers identified one of the primary factors responsible for this poor performance and negative attitude towards learning mathematics as the teaching methods employed by the teachers (Samuel & Okonkwo, 2021). The findings of Bhutta and Rizvi (2022) also aligned with the results of study conducted by Ailaan (2017) and Tayyaba (2010).

In Pakistan, predominately deductive method of teaching is used by one teacher in the classroom that uses a process of transmission of knowledge, rather than a process of concept construction and active involvement of students in teaching and learning (Rehman et al., 2023). In general, mathematics teachers start lessons with dictating formulae to solve the questions (Mirza & Iqbal, 2014). Students viewed mathematics in abstract form and due to its abstract nature, unique language, and symbols, students face difficulty in learning mathematics (Hoyles, 2018; Utami & Hwang, 2022). Mathematics has unique nature that differentiates it from other subjects (Zhang et al., 2022). The abstract and symbolic nature of mathematics makes it unique among every other subject (Domingo et al., 2021; Pentang et al., 2021). This nature is affecting mathematics learning since learners viewed it as a difficult subject that is meant for only talented learners (Akinoso et al., 2021). Busari and Akinoso (2020) submitted that highly mathematics-anxious learners have characteristics of a strong tendency to avoid mathematics, undercuts their mathematics competence, and forecloses high-and-mighty career paths. Most students dread mathematics, and anxiety possessed leads to the kind of attitude possessed towards the subject (Areelu & Ladele, 2018; Ibañez & Pentang 2021;). The abstract is one of the nature and characteristics of mathematics served as the clue for discovering how to handle the teaching to reduce to minimal level this abstract nature (Bacsal et al., 2022).

Though, mathematics is dread by the majority of the students but, if the teacher adopts various methods that meet the needs and situations of every student, especially the activity-based strategy and students centered (Rehman et al., 2021). It will help students in learning mathematics without stress (Flipped Learning Network, 2014; Lo & Hew, 2017a; O´Flaherty & Philips, 2015; Wright & Park, 2022). It will also change the students' attitudes and feelings towards mathematics (Woodard, 2004). Teaching with relevant materials, use of different strategies that are student-centered such as concrete-representational-abstract strategy, incorporation of information and communication technology in teaching, collaborative strategy and others might serve as a remedy to learning difficulties in mathematics (Braun et al., 2017). In learning, the environment should be made conducive, allow free access to learning, and contributions from students (Freeman et al., 2014). A collaborative learning strategy is a form of strategy that gives every student equal access and opportunity to learning (Abed et al., 2020; Almazroui, 2023; Garcia et al., 2017; Ibañez & Pentang 2021; Timayi et al., 2015; Ummah & Hamna, 2021; Yemi et al., 2018). Therefore, understanding the potential of collaborative learning to improve both academic outcomes and attitudes towards mathematics holds substantial promise for addressing aforementioned challenges.

This research endeavors to provide empirical insights that can guide educators, curriculum designers, and policymakers in making informed decisions about the instructional strategies (collaborative learning or conventional teaching) that will best serve the educational needs of students in the subject of mathematics in the 21st century. The study findings may inform pedagogical decisions that can improve mathematics education not only in Pakistan but also in diverse educational contexts worldwide.

LITERATURE REVIEW

Extensive research on collaborative learning in math education focuses on its impact on academic achievement and narrowing achievement gaps in elementary students. Additionally, it positively influences students' math attitudes by reducing anxiety, increasing engagement, and fostering positive perceptions of the subject, as highlighted in recent studies. This literature review consolidates theoretical foundations for collaborative learning and key findings from recent studies, illuminating the effectiveness of collaborative learning in improving mathematics achievement and fostering positive attitudes towards mathematics.

Theoretical Underpinnings

The theoretical underpinning of collaborative learning is strongly influenced by social constructivist theory (Huang et al., 2022; Salonen et al., 2005; Yackel, 2011). Social constructivism posits that knowledge is not a fixed entity but is actively constructed by learners through interaction with others and their environment (Isohätälä et al., 2020; Vygotsky, 1978). Collaborative learning, with its emphasis on peer interaction and cooperative problem-solving, aligns closely with this perspective (De Backer et al., 2021b; Schreiber & Valle, 2013). According to Vygotsky's (1978) zone of proximal development, learners can accomplish more when they engage in collaborative activities with peers who have similar or slightly higher levels of knowledge. In a collaborative learning environment, students engage in collective problem-solving and knowledge construction, which can lead to a deeper understanding of mathematical concepts (Hadwin et al., 2018; Malmberg et al., 2017; Slavin, 2015). Moreover, collaborative learning environments that reduce anxiety by providing peer support and a positive learning atmosphere can potentially improve students' mathematics achievement and their attitudes towards mathematics (Bergmann & Sams, 2014; Dolmans, 2019; Hamdan et al., 2013).

Collaborative learning has gained prominence globally as a pedagogical approach that aligns with 21st century skills development and the demand for STEM proficiency (Johnson & Johnson, 2014; Simon, 2020). International studies have shown that collaborative learning can positively impact academic achievement and attitudes towards mathematics (OECD, 2016). This global perspective underscores the relevance of the study's findings beyond the context of Pakistan. This theoretical framework suggests that collaborative learning can facilitate the mathematics education among students in terms of their math achievement and attitude towards mathematics (Schreiber & Valle, 2013).

Collaborative Learning & Mathematics Achievement

Numerous studies have explored the positive effects of collaborative learning on mathematics achievement. For instance, Carlos Torrego-Seijo et al. (2021) investigated the impact of collaborative learning techniques tailored to grade-specific mathematics achievement among elementary students. Their findings showed that collaborative approaches significantly improved math scores and effectively addressed grade-specific learning objectives. The findings of this study also aligned with the research study results conducted by Ismail et al. (2022), Jones et al. (2022), and Simpson (2023). Similarly, a meta-analysis by Gillies (2016, 2019) revealed a consistent pattern of improved mathematics achievement among students who engaged in collaborative activities. Collaborative learning was consistently associated with higher math performance.

Similarly, Alam and Agarwal (2020) delved into the role of teacher professional development in implementing collaborative learning in elementary mathematics education. Their case study highlighted that well-trained teachers were more successful in implementing collaborative learning strategies, which led to improved mathematics achievement among their students. The study results also aligned with research findings of Alam et al. (2021). Moreover, Johnson and Johnson (2019) conducted a large-scale study across multiple elementary schools and emphasized that effectively implemented collaborative learning techniques resulted in significantly higher mathematics achievement scores among students. This underscores the importance of cooperative interdependence and teacher facilitation in collaborative learning environments. These findings also aligned with study conducted by Kwame and Samuel (2020). In addition, a study by Lou et al. (2017) found that elementary students who engaged in collaborative problem-solving activities scored significantly higher on math assessments compared to those in traditional, teacher-centered classrooms.

Collaborative learning has consistently demonstrated its potential to improve academic performance in mathematics. A study conducted by Uya (2023) found that students engaged in collaborative learning consistently outperformed those in traditional, expository classrooms in terms of mathematical achievement. Recent studies, such as the one conducted by Samanta et al. (2021), have continued to highlight the positive impact of collaborative learning on mathematics achievement. Their research demonstrated that students engaged in collaborative problem-solving tasks consistently outperformed their peers in traditional classrooms. Bao et al. (2021) also contributed to this body of evidence, showing that elementary students who participated in collaborative problem-solving tasks achieved significantly higher mathematics scores compared to those in traditional classrooms. These findings collectively aligned with recent research study conducted by Li et al. (2023) and Rusti (2023).

Likewise, collaborative learning interventions have shown promising results in narrowing achievement gaps among both elementary and grade six students. Lee and Boo (2022) demonstrated that collaborative learning interventions were particularly effective in reducing the achievement gap between high- and low-achieving students in mathematics. This finding suggests that collaborative learning can play a vital role in promoting equitable academic outcomes. These results aligned with the recent research study conducted by Uya (2023). Similarly, Kim and Son (2023) expanded on this notion by exploring the effectiveness of collaborative learning interventions in elementary level mathematics education. Their study confirmed that these interventions were successful in narrowing achievement gaps, benefiting both high-achieving students and those who required additional support. Additionally, Campbell (2023) examined the effect of collaborative learning on reducing achievement gaps in elementary mathematics, further emphasizing its role in promoting more equitable math outcomes.

Lastly, the collaborative leaning has consistently demonstrated its potential to enhance mathematics achievement at elementary level. A study conducted by Ahmad and Dogar (2023) found that students engaged in collaborative learning activities in experimental group outperformed those taught with traditional teaching in terms of mathematics achievement. The research findings also collectively aligned with recent research study conducted by Chiuphae (2023), Mathias et al. (2023), and Obafemi et al. (2023). The literature strongly supports the positive impact of well-implemented collaborative learning on math achievement and reducing achievement gaps among elementary students. It fosters inclusive and successful math classrooms, promoting equitable outcomes.

Collaborative Learning & Students Attitudes Towards Mathematics

In the realm of collaborative learning and its impact on students' attitudes towards mathematics, a body of research spanning multiple studies and diverse contexts sheds light on the multifaceted benefits of this pedagogical approach.

Huang et al. (2012) conducted a longitudinal study encompassing various elementary classrooms, uncovering compelling evidence that collaborative learning interventions possess a lasting influence. Their findings revealed that students who engaged in collaborative activities maintained their improved attitudes towards mathematics even after the interventions concluded. This enduring effect underscores the long-term value of collaborative learning. Similarly, Kim et al. (2022) delved into the connection between collaborative learning and mathematics attitudes within a diverse environment. Their research illuminated how collaborative learning experiences heightened students' sense of belonging and relatedness, thereby contributing to more positive attitudes towards mathematics, especially among culturally diverse student populations. These findings collectively aligned with the study conducted by Alsmadi et al. (2023) and Zahroh et al. (2023).

Chen et al. (2018) explored the effects of collaborative learning on students' attitudes towards mathematics. Their findings showcased those students participating in collaborative learning activities exhibited more positive attitudes, heightened motivation, and reduced anxiety concerning mathematics compared to their peers in traditional, non-collaborative settings. Furthermore, Johnson and Johnson (2018) conducted a large-scale study involving elementary students across multiple schools. Their research underscored the potential of collaborative learning techniques, when effectively implemented, to cultivate more positive attitudes towards mathematics among students. This study emphasized the critical role of cooperative interdependence and teacher facilitation in achieving these positive outcomes.

Nazari (2023) contributed valuable insights by examining the impact of collaborative learning on narrowing attitude gaps in mathematics. Their study revealed that collaborative learning interventions were particularly effective in bridging the attitude gaps between high-achieving and lower-achieving students, fostering a more equitable attitude distribution. In line with these empirical studies, Gillies (2016) conducted a comprehensive meta-analysis encompassing various studies centered on collaborative learning in elementary mathematics classrooms. Their extensive analysis not only demonstrated the positive influence of collaborative learning on academic achievement but also illuminated its equally substantial impact on students' attitudes and perceptions of mathematics. Students reported increased enjoyment of math and reduced math anxiety, underscoring the multifaceted benefits of collaborative learning. The study results also aligned with the study results mentioned by Gillies et al. (2023).

Mathematics anxiety, a formidable barrier characterized by tension and apprehension (Ashcraft et al. 2007), can significantly hinder the development of positive attitudes towards mathematics. Collaborative learning, with its supportive and non-threatening environment, is widely recognized as an effective tool for alleviating mathematics anxiety (Muis et al., 2018). Furthermore, the study conducted by Garcia and Martinez (2021) involving elementary students provided empirical evidence of collaborative learning's power in enhancing students' attitudes towards mathematics. Collaborative learning activities, such as peer tutoring and group problem-solving, were instrumental in cultivating increased interest in math and bolstering students' confidence in their mathematical abilities. This positive transformation highlighted the role of collaborative learning in mitigating mathematics anxiety (Kalogeropoulos et al., 223).

Additionally, collaborative learning has demonstrated its capacity to foster engagement and enjoyment in mathematics. When students collaboratively tackle challenging problems, they often experience an elevated sense of accomplishment (Johnson et al., 2014). The research by Ganley et al. (2020) further supported this notion, showcasing that elementary students engaged in collaborative activities tended to exhibit more positive sentiments about mathematics. Collaborative learning experiences cultivated a sense of accomplishment and heightened engagement, ultimately contributing to more favorable attitudes. Moreover, pivotal role of teacher facilitation in collaborative learning cannot be understated. Wang and Fang (2020) delved into this aspect and established that skilled teacher facilitation played a crucial role in creating a positive and productive collaborative learning environment. Effective facilitation positively influenced students' attitudes towards mathematics, emphasizing the pivotal role of teacher support in shaping attitudes (Jekayinfa et al., 2023).

The literature review underscores the diverse advantages of collaborative learning, emphasizing its efficacy in improving math performance and fostering favorable attitudes among elementary students, regardless of their cultural contexts.

Research Questions

Collaborative learning in mathematics education has emerged as a significant area of research, drawing attention for its potential to impact both academic achievement and students' attitudes towards mathematics. Extensive studies have explored the multifaceted benefits of collaborative learning, shedding light on its effectiveness in enhancing mathematics achievement (Alam et al., 2021; Alsmadi et al., 2023; Gillies, 2016; Hoang et al., 2023; Johnson & Johnson, 2019; Jones et al., 2022; Kim & Son, 2023; Li et al., 2023; Lou et al., 2017; Simpson, 2023; Uya, 2023; Zahroh et al., 2023) while concurrently fostering positive attitudes among elementary students (Ahmad & Dogar, 2023; Chen et al., 2018; Chiuphae, 2023; Gillies, 2019; Huang et al., 2012; Johnson & Johnson, 2018; Johnson et al., 2014; Kim et al., 2022; Mathias et al., 2023; Nazari, 2023; Obafemi et al., 2023). This literature review synthesizes key findings from recent research, highlighting the potential of collaborative learning methods to improve mathematics outcomes (Ganley et al., 2020; Ismail et al., 2022; Kim & Son, 2023; Rusti, 2023) and shape students' attitudes towards the subject (Ashcraft et al., 2007; Garcia & Martinez, 2021; Jekayinfa et al., 2023;

Table 1. Research design

Groups	Pre-test	Practice	Post-test
Experimental group (n=26)	Experimental & control group pre-test application	Treatment (collaborative learning)	Experimental & control group post-test application
Control group (n=26)	Experimental & control group pre-test application	No treatment (conventional teaching)	Experimental & control group post-test application

Table 2. Sample distribution in quasi experimental research design (pre-/post-test design)

(n=52)	n: Random assignment to experimental group (26)	O_1: Pre-test: MAT & ATMI	X_T: Treatment: Collaborative learning	O_2: Post-test: MAT & ATMI
	n: Random assignment to control group (26)	O_1: Pre-test: MAT & ATMI	X: No treatment: Conventional teaching	O_2: Post-test: MAT & ATMI

Kalogeropoulos et al., 223; Muis et al., 2018; Wang & Fang, 2020).

As collaborative learning continues to gain recognition as a pedagogical approach, it is essential to consider its implications for mathematics education comprehensively. This literature serves as a foundation for the development of research questions (**RQ**) that was delve into the following aspects:

RQ1. To what extent does collaborative learning impact mathematics achievement among grade six students?

RQ2. How does collaborative learning influence grade six students' attitudes towards mathematics?

By investigating these research questions, we can further elucidate the potential of collaborative learning to enhance both mathematics achievement and students' attitudes, ultimately informing best practices in elementary mathematics education.

METHODS

Study Design

A quasi-experimental (pre-/post-test design) quantitative research was conducted to determine the effect of collaborative learning technique on sixth graders' mathematics achievement and their attitudes towards mathematics. The design is robust in addressing key internal validity concerns in educational research. To mitigate extraneous variables and uphold internal validity, we randomly assigned participants to both the experimental and control groups (Cohen et al., 2017). The control group was identified as the group that was taught through conventional teaching method (didactic method), while the experimental group was identified as the group receiving an intervention (taught by collaborative learning). The research design of this study is presented in **Table 1**.

Sample

Six grade students at public school situated in the urban area were selected through accessible sampling from district Lahore, Pakistan as a participant. The study groups were randomly selected using readily accessible sampling, a targeted sampling technique. The selection criteria for the sample through accessible sampling were ease of access, willingness to participate in the study, and availability during the designated period (Thomas, 1997). There were 52 participants in total in the study groups, with 26 students in the experimental group and 26 students in the control group. The sample distribution as per the study design is presented in **Table 2**. All participants completed the pre- and post-tests.

Test Instruments

Two mathematics achievement tests (MATs), pre-test and post-test, were used to answer **RQ1**. The pre and post-test question items differed in nature; however, the concepts were the same for both. We developed a total of 60 multiple choice items for each pre and post-test of MAT from the content strand of grade six national mathematics curriculum, to measure students' mathematics achievement at the initial stage. The development of test items was made keeping in view the proportionate ratio of learning outcomes of Algebra and Geometry in accordance with the state level exam test blueprint (i.e., 66.6% and 33.3%, respectively) and the value of point-biserial correlation coefficients of the items (from 0.20 to 0.50) recommended for selection of good items (Mcalpine, 2002; Wells & Wollack, 2003). Before administering the tests to the participants, a pilot study was conducted with 200 students in the winter of 2022/2023 for the pre-test and the summer of 2023 for the post-test. Four instrument development experts ensured the technical aspects of construct validity, and four mathematics content experts ensured the face and content validity of the pre and post-tests. To ensure the validity of content strands and mathematical abilities of MAT's a table of specification was developed for reference see **Table 3**.

Following the pilot study, item analysis was performed, and only items with discrimination index values greater than 0.20 and difficulty index values ranging from 0.30 to 0.70 were included in the final pre-test and post-test, as recommended by Munir et al. (2013).

Table 3. Table of specification of MATs

No	Content strand	Conceptual understanding		Procedural knowledge		Problem-solving		Total	
		n	%	n	%	n	%	n	%
1	Algebra	10	25.0	7	17.5	10	25.0	27	67.5
2	Geometry	5	12.5	3	7.5	5	12.5	13	32.5
Total		15	37.5	10	25.0	15	37.5	40	100

Note. n: Number of items & %: Percentage of weightage in test

Table 4. Example items from ATMI

Factors	Number of items	RCA	Example items
Self-confidence	15	0.73	1. I am always under terrible strain in mathematics class. 2. Studying mathematics makes me feel nervous. 3. I feel a sense of insecurity when attempting mathematics. 4. Mathematics make me feel uncomfortable.
Value	10	0.79	1. Mathematics is a very worthwhile and necessary subject. 2. Mathematics is important in everyday life. 3. A strong math background could help me in my professional life. 4. I can think of many ways that use math out of school.
Enjoyment	11	0.77	1. I usually enjoy studying mathematics in school. 2. I like to solve new problems in mathematics. 3. I would prefer to do an assignment in math than write an essay. 4. I am happier in a math class than any other class.
Motivation	5	0.71	1. I am confident that I can learn advance mathematics. 2. I plan to take as much mathematics as I can during my education. 3. I am willing to take more than the required amount of mathematics. 4. The challenges of mathematics appeal to me.

Note. RCA: Reliability Cronbach's alpha

The final version of pre- and post-MATs were comprised 40 items, measuring three mathematical abilities i.e., conceptual understanding (37.5%), procedural knowledge (25.0%), and problem-solving (37.5%). Pre-test was carried out on control and experimental group students prior to the intervention and post-test after the intervention. When examining the results of the pre- and post-MATs, it was defined that '1' point if the transaction and result were correct, and a '0' point for incorrect or blank answers. The total score of each student was then calculated. Cronbach's alpha reliability coefficients for the pre-test was 0.84 and 0.80 for post-test.

Furthermore, in our study, we utilized the "attitude towards mathematics inventory (ATMI)," developed by Tapia and Marsh in 2004, as the second instrument to assess the attitudes of sixth-grade students toward mathematics. This instrument employed a five-point Likert-type scale, consisting of 41 items grouped into four constructs: self-confidence, value, enjoyment, and motivation. The response options for the items were categorized, as follows: strongly disagree (1), disagree (2), neutral (3), agree (4), and strongly agree (5). Before administering ATMI to both the control and experimental groups, a confirmatory analysis was conducted by the researchers to assess each factor individually as well as the entire scale's validity.

As part of the pilot phase, the inventory was administered to 200 sixth-grade students who shared similar demographic and environmental characteristics. During this pilot phase, the researchers initially evaluated the reliability of the entire scale (reliability coefficient=0.79) and each of its four constructs, with values of 0.73 for self-confidence, 0.79 for value, 0.77 for enjoyment, and 0.71 for motivation, followed by a confirmatory analysis. The analysis aimed to ensure that the factor loading of each item and construct exceeded the minimum threshold of 0.3, as recommended by Merriam and Tisdell (2016). It is important to note that all statements within the inventory were subjected to scrutiny to meet established standards for inclusion in the instrument. Notably, the inventory comprised a total of 10 negative statements and 31 positive items. To prevent potential data analysis errors, the negative items were appropriately coded in reverse. A selection of sample items from the inventory is presented in **Table 4** for reference.

Procedure of Study

The participants in this study were selected following approval from the Scientific Research Ethics Committee of the relevant institution. Subsequently, one group of sixth-grade students was designated as the experimental group, receiving instruction through collaborative learning, while the other group served as the control group and received instruction through conventional teaching methods, specifically the didactic approach. The experimental group underwent a 12-week intervention, with sessions held four times a week, totaling 180 minutes of instruction.

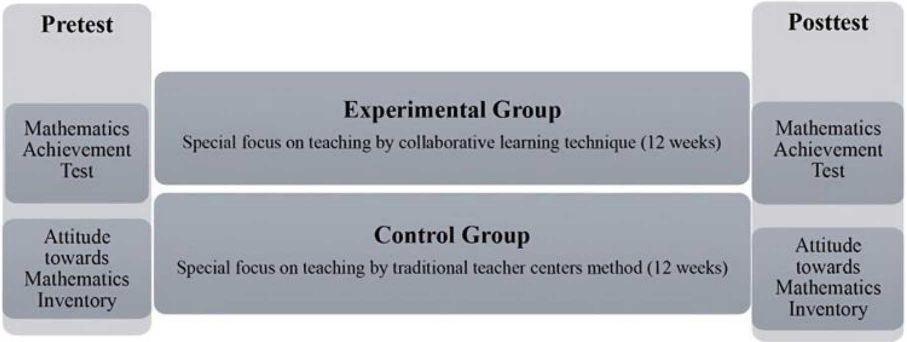

Figure 1. Treatment design (Source: Authors' own elaboration)

Prior to the intervention, both groups underwent a pre-test (pre-MAT) to ensure that they commenced at the same level of mathematical achievement and shared similar attitudes toward mathematics. It is noteworthy that both groups were instructed by the author, who fulfilled roles in both the experimental and control groups.

During the intervention period, students in the experimental group collaborated in small groups, each consisting of four students. The classroom environment was conducive to group work, active participation, and discussions while working on mathematical problems. The teacher's function was that of a facilitator, creating an ideal collaborative learning environment within the classroom. In this facilitative role, the teacher elucidated the overarching concepts and formulas on the whiteboard, after which students tackled similar problems from the selected content of the sixth-grade mathematics textbook within their groups, autonomously seeking solutions.

Following problem-solving, students compared and discussed their outcomes within their respective groups and with other groups. The author refrained from intervening in the groups' problem-solving processes unless all other alternatives had been exhausted. No feedback was provided to individual students or small groups during this phase.

Conversely, students in the control group received traditional instruction, with the teacher employing conventional didactic method. The content covered by the control group paralleled that of the experimental group. The researchers adhered to a consistent curriculum map for daily lesson planning, ensuring that when the experimental group focused on algebra concepts, the control group was likewise engaged in algebraic concepts. Effective classroom management was imperative for both groups, necessitating the development of comprehensive lesson plans by the authors to guide instruction. At the culmination of the intervention, all students in both groups completed a post-test (post-MAT) and ATMI. For a visual representation of the study's treatment design, refer to **Figure 1**.

Data Analysis

Before proceeding with the statistical analysis, a thorough check for missing data was conducted on all variables. The data for this research were collected through MATs (pre- and post-MAT), each consisting of 40 items and attitudes towards mathematics inventory, comprised of 41 items. Data analysis was performed using SPSS version 28.0. To ascertain the distribution characteristics of the data, a Kolmogorov-Smirnov test was selected as the appropriate statistical tool. This choice was informed by the sample size in both the control and experimental groups, which fell below the recommended threshold of 50 participants per group, as advocated by Pallant (2007).

The results of the Kolmogorov-Smirnov test indicated a non-normal distribution pattern for both the post-test data collected at time T2 in the experimental and control groups. Specifically, for MATs, the test statistic was $W(52)=0.155$, with a p-value of 0.00. Similarly, the data on attitudes toward mathematics exhibited non-normality, with test statistics $W(52)=0.263$ and $p=0.000$. In light of these findings and in order to address both research questions (**RQ1** and **RQ2**), we chose to employ the Mann-Whitney U test (Coman et al., 2013).

Additionally, to evaluate students' progress in terms of their mathematics achievement between the post-test (data collected at time T2) and their pre-test scores (data collected at time T1) in both the control and experimental groups, we utilized a parametric paired sample t-test. This choice was made because the data exhibited a normal distribution for the control group, as indicated by test statistics ($W[52]=0.162$, $p=0.076$; pre-test & $W[52]=0.118$, $p=0.200$; post-test), and for the experimental group, with test statistics ($W[52]=0.156$, $p=0.105$; pre-test & $W[52]=0.119$, $p=0.200$; post-test). Likewise, to assess students' progress in terms of their attitudes toward mathematics in the post-test (data collected at time T2) compared to their pre-test scores (data collected at time T1) within both the control and experimental groups, we opted for a parametric paired sample t-test.

Table 5. Comparing pre-test scores of control & experimental groups in mathematics achievement

Groups	n	Mean	Median	Standard deviation	U	z	p	r
Control	26	18.69	17.00	6.43	304.50	-.61	.54	0.08
Experimental	26	17.58	16.00	5.69				

Table 6. Comparing pre-test scores of control & experimental groups in attitudes towards mathematics

Groups	n	Mean	Standard deviation	df	t-value	Significance	Cohen's d
Control	26	3.46	.458	50	1.44	.156	0.03
Experimental	26	3.27	.499				

This decision was based on the observation that the data exhibited a normal distribution for the control group, supported by test statistics (W[52]=0.106, p=0.200; pre-test & W[52]=0.090, p=0.200; post-test), and for the experimental group, with test statistics (W[52]=0.138, p=0.200; pre-test & W[52]=0.124, p=0.200; post-test) (Fisher & Marshall, 2009). These analytical decisions were guided by the need to rigorously analyze the research findings within the context of our study.

RESULTS

The results presented here are a culmination of rigorous data analysis and interpretation, offering valuable insights into the potential benefits of collaborative learning in mathematics education for grade six students. Our research journey involved the implementation of collaborative learning intervention within grade six classrooms, with a focus on assessing the subsequent changes in students' mathematics achievement scores. Furthermore, we scrutinized how this intervention influenced the students' attitudes toward mathematics.

Before embarking on the intervention phase, a thorough analysis of the pre-test data collected from both the control and experimental groups was conducted. This step aimed to ensure that both groups commenced the study at an equivalent baseline concerning mathematics achievement and attitudes toward mathematics. To compare the mathematics achievement levels, we applied the non-parametric Mann-Whitney U test. This selection was based on the results of the Kolmogorov-Smirnov test, which revealed a non-normal distribution pattern for the pre-test scores data collected at the same time (T1) from both groups (W[52]=0.157, p=0.000). A detailed presentation of the results is provided in **Table 5**.

In addition to mathematics achievement, we also examined the participants' attitudes toward mathematics. For this purpose, an independent sample t-test was employed, as the Kolmogorov-Smirnov test indicated a normal distribution of pre-test scores data (collected at the same time T1) from both the control and experimental groups (W[52]=0.081, p=0.200). The corresponding findings are presented in **Table 6**. These meticulous analytical procedures served as the foundation for our subsequent investigation into the impact of collaborative learning interventions on mathematics achievement and attitudes toward mathematics among grade six students.

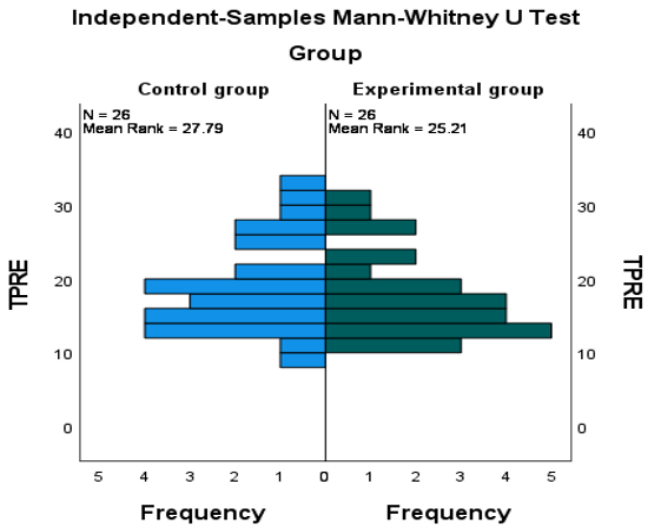

Figure 2. Comparing mathematics achievement pre-test scores of both groups (Source: Authors' own elaboration, using SPSS feature plotting)

According to **Table 5**'s Mann-Whitney U test findings, there was no significant difference between the mathematical achievement of experimental group students (Md=16.00, n=26) and control group students (Md=17.00, n=26), with a very small effect size of r=0.08. Correspondingly, the pre-test results for both groups were equal prior to the intervention.

In **Figure 2**, a graph comparing the mean pre-test scores of students in the control and experimental groups depicts the same result as **Table 5**.

As per **Table 6**'s independent sample t test results, there existed no significant mean difference in pre-test scores of control group (mean [M]=3.46, standard deviation [SD]=.458) and experimental group students (M=3.27, SD=.499; t[50]=1.44, p=.156, two-tailed). The magnitude of the differences in the means (mean difference=.191, 95% CI: -.076 to .458) was almost same with very low effect size=0.03. which means, students in both groups were at same level in terms of their attitudes towards mathematics prior to intervention.

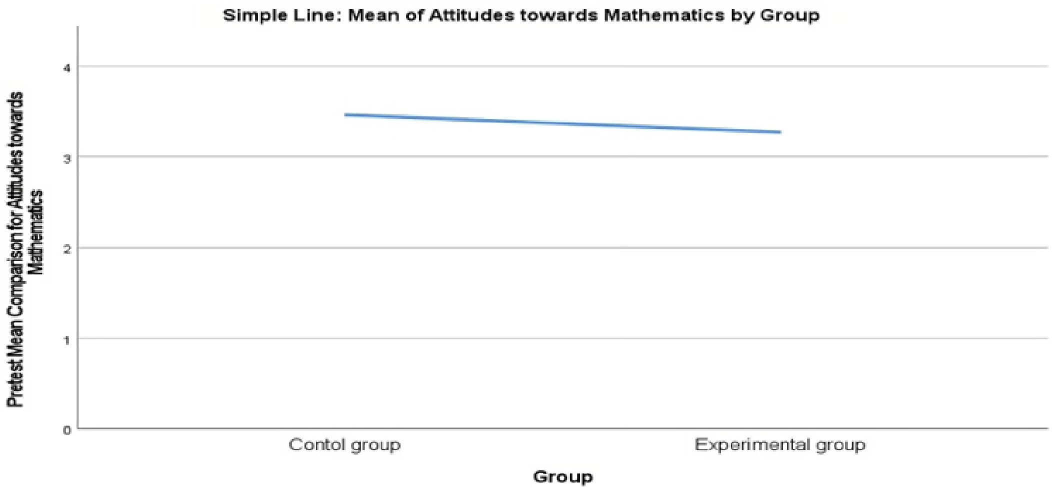

Figure 3. Comparing pre-test scores of control & experimental groups for attitudes towards mathematics (Source: Authors' own elaboration, using SPSS feature plotting)

Table 7. Comparing post-test scores of control & experimental groups in mathematics achievement

Groups	n	Mean	Median	Standard deviation	U	z	p	r
Control	26	19.38	19.50	5.61	661.00	5.92	.00	0.23
Experimental	26	32.92	33.00	3.24				

In Figure 3, a line graph comparing the mean pre-test scores of students in the control and experimental groups depicts the same results as Table 7.

Research Question 1

To assess the impact of collaborative learning interventions on the mathematics achievement of grade six students, we employed a non-parametric Mann Whitney U test. This statistical analysis involved a comparison between the post-test scores of students in the control group and those in the experimental group, allowing us to evaluate the effectiveness of collaborative learning in contrast to the conventional didactic teaching method.

The Mann-Whitney U test brought to light that post-test scores of experimental group students were significantly high (Md=33.00, n=26) opposed to control group students (Md=19.50, n=26), U=661.00, z=5.92, p=.000, with a small effect size r=.23. Consequently, it is established that after the intervention, students in the experimental group significantly improved their post-test scores compared to those in the control group. Which means treatment (collaborative learning) evidently enhance students' mathematics achievement at elementary level opposed to those who received instruction by conventional didactic method. The comparison of mean scores in post-test for control and experimental group students in terms of mathematics achievement is presented in the form of simple graph in Figure 4.

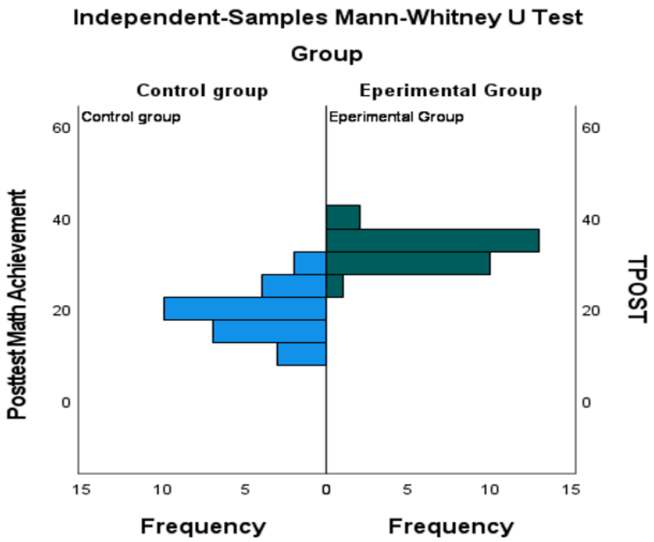

Figure 4. Comparing mathematics achievement post-test scores of both groups (Source: Authors' own elaboration, using SPSS feature plotting)

Research Question 2

In order to evaluate the influence of collaborative learning intervention on the attitudes towards mathematics among sixth-grade students, we conducted a rigorous non-parametric Mann-Whitney U test. This statistical examination encompassed a thorough comparison between the post-test scores of students belonging to both the control group and the experimental group. This approach enabled us to critically assess the efficacy of collaborative learning in juxtaposition to the traditional didactic teaching method.

Table 8. Comparing post-test scores of control & experimental groups in attitudes towards mathematics

Groups	n	Mean	Standard deviation	df	t-value	Significance	Cohen's d
Control	26	3.74	3.70	.384	673.50	6.15	.00
Experimental	26	4.78	4.78	.068			

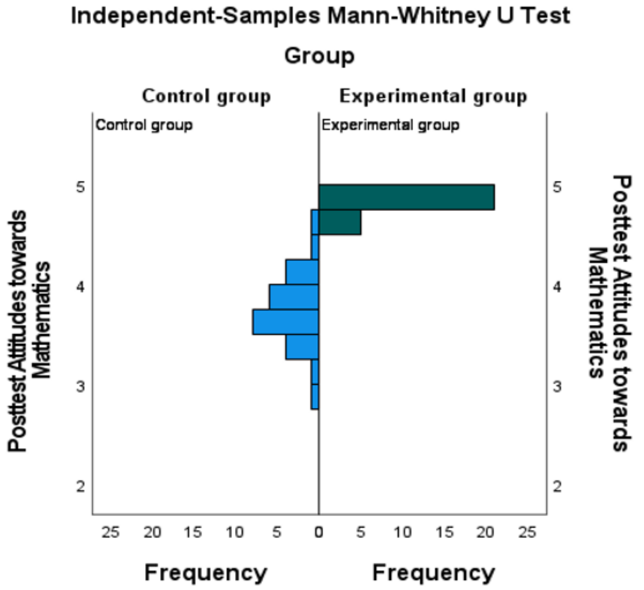

Figure 5. Comparing attitudes towards mathematics posttests of both groups (Source: Authors' own elaboration, using SPSS feature plotting)

The Mann-Whitney U test revealed a noteworthy difference in post-test scores between the experimental group (Md=4.78, n=26) and the control group (Md=3.70, n=26), with U=673.50, z=6.15, and p=.000. Furthermore, the effect size was found to be small (r=.24) (**Table 8**).

This statistical analysis establishes that following the intervention, students in the experimental group exhibited a significant improvement in their post-test scores when compared to their counterparts in the control group. In essence, it is clear that the treatment, which involved collaborative learning, demonstrably enhanced students' attitudes towards mathematics at the elementary level in contrast to those who received instruction through the conventional didactic method. To visualize this comparison of mean post-test scores for both control and experimental group students regarding their attitudes towards mathematics, we have provided a simple graph in **Figure 5**.

Furthermore, to assess the progress observed in the control & experimental group students between time points T1 and T2 (pre- and post-test) concerning their math achievement and attitudes towards mathematics, we conducted a paired sample t-test after verifying the normality of the data. In this analysis, we compared the pre-test and post-test scores of the control & experimental group students for both the math achievement and attitudes towards mathematics variables. The detailed results can be found in **Table 9** & **Table 10**.

The study unveiled a significant disparity in mathematics achievement between the experimental group students over two assessment points, denoted as T1 and T2. Initially, at the pre-test stage (T1), their mean score stood at 17.58 (SD=5.690). However, following the collaborative learning intervention, their average score saw a remarkable increase to 32.92 (SD=3.230) during the post-test (T2) assessment. This stark improvement was supported by a highly significant paired sample t-test, t(25)=-14.52, p<.001 (two-tailed). The mean rise in mathematics achievement scores was substantial, measuring 15.34, with a 95% confidence interval ranging from -17.52 to -13.17. Further underscoring the magnitude of this effect, the eta squared statistic yielded a value of 0.84, indicating a large effect size. In summation, it is evident that students exposed to collaborative learning exhibited a significant and substantial enhancement in their mathematics achievement by the conclusion of the experiment.

Conversely, in the control group, no statistically significant difference in mathematics achievement was observed between time points T1 and T2. At the outset, their mean score at the pre-test stage (T1) was 18.69 (SD=6.430), which showed minimal change, reaching 19.38 (SD=5.610) at the post-test stage (T2). The analysis, performed using a paired sample t-test, yielded a non-significant result, t(25)=-.441, p>.000 (two-tailed). The mean difference in mathematics achievement scores was meager, registering at .692, with a 95% confidence

Table 9. Comparing mathematics achievement (pre- & post-test) scores of control & experimental group students

Groups	Pre-test		Post-test		df	t	p	Cohen's d
	Mean	Standard deviation	Mean	Standard deviation				
Control	18.69	6.430	19.38	5.610	25	-.441	.663	.08
Experimental	17.58	5.690	32.92	3.230	25	-14.520	.000	.84

Table 10. Comparing attitudes towards mathematics (pre- & post-test) scores of control & experimental group students

Groups	Pre-test		Post-test		df	t	p	Cohen's d
	Mean	Standard deviation	Mean	Standard deviation				
Control	3.46	.458	3.74	.384	25	-5.568	.000	0.25
Experimental	3.27	.499	4.78	.068	25	-15.510	.000	0.90

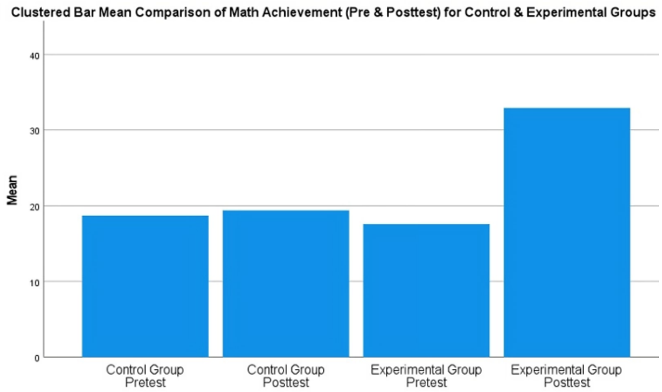

Figure 6. Comparison mathematics achievement (pre- & post-test) scores for both groups (Source: Authors' own elaboration, using SPSS feature plotting)

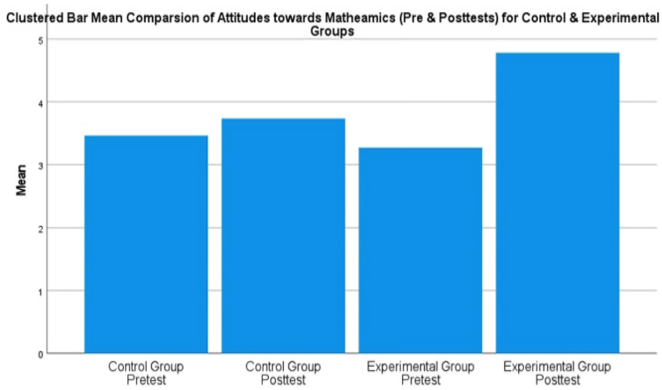

Figure 7. Comparison attitudes towards mathematics (pre- & post-test) scores for both groups (Source: Authors' own elaboration, using SPSS feature plotting)

interval spanning from -3.927 to 2.543. Moreover, the eta squared statistic indicated a very small effect, with a value of 0.08. In conclusion, students who underwent conventional didactic instruction did not exhibit any significant improvement in their mathematics achievement over the course of the experiment.

In light of these findings, it is evident that the collaborative learning intervention had a profound and positive impact on students' mathematics achievement. **Figure 6** provides a visual representation in the form of a bar chart, illustrating the comparison of mean scores in pre- and post-tests for both control and experimental group students concerning their mathematics achievement.

A distinguished and statistically significant transformation in students' attitudes towards mathematics was evident among the experimental group participants across time points T1 and T2. Initially, at pre-test stage (T1), mean attitude score was 3.27 (SD=0.499). Subsequently, a substantial enhancement was observed, with the mean attitude score rising significantly to 4.78 (SD=0.068) at post-test stage (T2). This noteworthy change was confirmed through a highly significant paired sample t-test, $t(25)=-15.51$, $p<.001$ (two-tailed). The mean difference in attitude towards mathematics scores amounted to 1.51, accompanied by a 95% confidence interval ranging from -1.71 to -1.30.

Moreover, the effect size, as measured by eta squared, was substantial, registering a value of 0.90. In conclusion, it is confidently established that the intervention exerted a profound influence on students' attitudes towards mathematics. Their attitudes underwent a discernible shift towards a more positive outlook on mathematics learning compared to their initial attitudes, as assessed by the pre-test.

Similarly, a statistically significant improvement in "attitudes towards mathematics" was observed among the control group students across time points T1 and T2. Initially, at the pre-test stage (T1), the mean attitude score stood at 3.46 (SD=0.458). Following the intervention, this score experienced a substantial enhancement, reaching 3.74 (SD=0.384) at the post-test stage (T2). This change was reaffirmed through a significant paired sample t-test, $t(25)=-5.568$, $p<.001$ (two-tailed). The mean difference in attitude towards mathematics scores amounted to 0.27, accompanied by a 95% confidence interval ranging from -0.374 to -0.172. Additionally, the effect size, as measured by eta squared, was small, yielding a value of 0.25.

In light of these findings, it is evident that students in the control group, instructed through the conventional didactic method, exhibited an improvement in the development of their positive attitude towards mathematics in the post-test compared to their pre-test scores. However, this improvement, while statistically significant, was not as substantial as the transformation observed in their counterparts in the experimental group, who were taught through collaborative learning, as evidenced in **Table 8**. A visual representation illustrating the comparison of mean scores in pre and post-tests for both control and experimental group students concerning their attitude towards mathematics can be found in **Figure 7**, depicted as a simple bar chart.

DISCUSSION

The primary objective of this study was to examine the impact of collaborative learning on the attitudes of sixth-grade students towards mathematics and their academic performance in the subject. To achieve this aim, two specific research questions were formulated. These questions were investigated through a quasi-experimental pre-/post-test design, and the collected data were subsequently analyzed using both independent and dependent sample t-tests. The findings resulting from this analysis have been presented graphically in the preceding section.

In the following section, we will explore the extent to which the results of our research questions align with or diverge from previous studies in the field. This comparative analysis will shed light on the unique contributions of our study and its implications within the broader context of existing research. Subsequently, in the concluding section, we will provide a comprehensive summary of our findings, discuss any limitations encountered during the study, and suggest avenues for further research in this area.

Collaborative Learning & Mathematics Achievement (RQ1)

The findings of this study unequivocally demonstrate the positive impact of collaborative learning on mathematics achievement among grade six students. Through the Mann-Whitney U test, it was revealed that the post-test scores of students in the experimental group, who received instruction through collaborative learning, were significantly higher than those of students in the control group who were taught using the conventional didactic method. This significant difference in post-test scores underscores the effectiveness of collaborative learning in enhancing mathematics achievement.

The observed improvement in mathematics achievement among students in the experimental group aligns with a substantial body of research (Ahmad & Dogar, 2023; Alam & Agarwal, 2020; Alam et al., 2021; Carlos Torrego-Seijo et al., 2021; Chiuphae, 2023; Gillies, 2016; Hoang et al., 2023; Johnson & Johnson, 2019; Jones et al., 2022; Kim & Son, 2023; Kwame & Samuel, 2020; Lee & Boo, 2022; Li et al., 2023; Lou et al., 2017; Mathias et al., 2023; Obafemi et al., 2023; Simpon, 2023; Uya, 2023). These studies consistently highlight the positive impact of collaborative learning on academic performance in mathematics. The collaborative learning environment, characterized by peer interaction and cooperative problem-solving, fosters a deeper understanding of mathematical concepts and promotes higher-order thinking skills (Bao et al., 2021; Campbell, 2023; Chen & Chen, 2012; Ismail et al., 2022; Johnson & Johnson, 2018; Rusti, 2023; Samanta et al., 2021). This deeper engagement with the subject matter likely contributes to the observed improvement in mathematics achievement.

In summary, the findings provide robust evidence that collaborative learning significantly enhances mathematics achievement among grade six students. This underscores the potential of collaborative learning as a pedagogical approach to address the challenges associated with mathematics education.

Collaborative Learning & Students Attitudes Towards Mathematics (RQ2)

The study's second research question sought to investigate how collaborative learning influences grade six students' attitudes towards mathematics. The results reveal a significant improvement in students' attitudes towards mathematics following their engagement in collaborative learning activities.

Both the experimental group, exposed to collaborative learning, and the control group, taught through the conventional method, showed improvement in their attitudes towards mathematics over time. However, the experimental group exhibited a notably larger improvement. This underscores the potency of collaborative learning in positively shaping students' attitudes towards mathematics.

The findings resonate with the broader literature on collaborative learning's impact on attitudes towards mathematics (Alsmadi et al., 2023; Ganley et al., 2020; Garcia & Martinez, 2021; Huang et al., 2012; Muis et al., 2018; Nazari, 2023; Kim et al., 2022; Wang & Fang, 2020; Zahroh et al., 2023). Collaborative learning environments, characterized by peer support, reduced anxiety, and positive learning atmospheres, have consistently been associated with more favorable perceptions of mathematics. The reduction in mathematics anxiety is particularly noteworthy, as anxiety is a significant barrier to developing positive attitudes towards the subject (Ashcraft et al., 2007; Jekayinfa et al., 2023; Kalogeropoulos et al., 2023). The study's findings align with previous research, highlighting that collaborative learning effectively mitigates mathematics anxiety and fosters increased attitude and confidence in mathematics (Chen et al., 2018; Garcia & Martinez, 2021; Gillies et al., 2023).

The observed improvement in attitudes towards mathematics among students in the experimental group is indicative of the transformational power of collaborative learning experiences. Collaborative learning not only enhances academic achievement but also contributes to a more positive and engaging learning environment (Johnson et al., 2014). The collaborative problem-solving, sense of accomplishment, and heightened engagement experienced by students likely contribute to their improved attitudes.

In conclusion, the study provides compelling evidence that collaborative learning positively influences grade six students' attitudes towards mathematics. This finding underscores the multifaceted benefits of collaborative learning, as it not only enhances academic performance but also fosters a more positive outlook on mathematics learning.

Implications & Recommendations

The implications of this study are far-reaching, with relevance not only to elementary mathematics education in Pakistan but also to diverse educational contexts worldwide. The findings underscore the potential of collaborative learning as a pedagogical approach to address the challenges associated with mathematics education, particularly in terms of achievement and attitudes.

For educators and policymakers, these findings suggest the need to consider the integration of collaborative learning strategies into mathematics curricula. Professional development opportunities should be provided to equip teachers with the skills and knowledge necessary to effectively implement collaborative learning in the classroom. Furthermore, collaborative learning should be viewed as a means to promote equitable outcomes, as it has demonstrated its capacity to narrow achievement gaps among students.

Incorporating collaborative learning activities into mathematics instruction can create a more engaging and supportive learning environment, ultimately contributing to enhanced mathematics achievement and more positive attitudes towards the subject. Teachers should be encouraged to facilitate collaborative learning experiences that promote peer interaction, cooperative problem-solving, and reduced mathematics anxiety.

Future research in this area could explore the long-term effects of collaborative learning on mathematics achievement and attitudes, extending beyond the scope of this study's timeframe. Additionally, investigating the impact of collaborative learning across different grade levels and cultural contexts could provide valuable insights into its universality and adaptability.

Limitations

As with all studies, there were limitations that affect the generalizability of the results. The two main limitations were sample characteristic and teacher bias.

This study designed to examine the impact of manipulative on sixth grade students' mathematics achievement and their attitudes towards mathematics. The sample size was small and only included students in the 6th grade at one school in central region of Lahore, Pakistan. Due to the small number of participants, differences in participant characteristics can have a significant impact on comparison findings. The students who took part all attended the same school, which serviced a largely middle-class community with little diversity. It's possible that results would be different for students of various ages, ethnicities, or socioeconomic status.

The effectiveness of collaborative learning may depend on the teacher's ability to use them effectively. Some teachers may be more skilled in incorporating collaborative learning than others, which cold confound the results of the study.

CONCLUSIONS

This study has demonstrated that collaborative learning is an effective pedagogical approach with a substantial impact on grade six students' mathematics achievement and attitudes. The findings affirm its potential to significantly improve academic performance and foster positive attitude of mathematics. Collaborative learning emerges as a transformative strategy for educators and policymakers to enhance mathematics education and promote equitable outcomes. However, recognizing its context-specific nature and limitations, further research is warranted to explore its broader applicability and long-term effects. In sum, collaborative learning holds the promise of shaping a more confident and enthusiastic generation of mathematics learners, transcending boundaries and benefiting diverse educational contexts worldwide.

Author contributions: H-SS &SA: study conception & design, analysis & interpretation of results, & draft manuscript preparation & **SA:** data collection. All authors have agreed with the results and conclusions.

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Ethical statement: The authors stated that the study has ethical approval provided by the Institute of Education and Research Negligible Risk Ethics Sub-Committee at University of the Punjab, Lahore. With human participants involved in the research, informed consent was obtained from the responsible administration committee of University Laboratory High School, University of the Punjab, Lahore as well as from the possible participants by first describing the nature of study in the orientation session. The authors further stated that details about the research were included in a Participant Information and Consent Sheet. Upon participants agreeing to take part in the study, each participant was required to read, sign, and date the Participant Information and Consent Sheet. This was done prior to participants taking any part in the research. It was also made clear to each participant, on the Participant Information and Consent Sheet, that they could withdraw from the research at any time and their data would be destroyed and not used in any way. Informed consent was obtained from all individual participants involved in this study.

Declaration of interest: No conflict of interest is declared by authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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