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Impact of Collaborative Teaching (CT) on Mathematics Students' Achievement in Pakistan

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The study explored the impact of CT on 8th grade students' achievement in mathematics. The experiment was conducted using Solomon Four-Group on 118 students in a public sector school in Punjab province. Two volunteer mathematics' teachers from the sampled school and the 2nd researcher participated in the experiment. Mathematics Achievement Test (MAT) was used to measure the academic achievement of the students in their abilities of conceptual understanding, procedural knowledge, and problem solving. MAT items were selected from the Mathematics item pool of National Educational Assessment System (NEAS) Pakistan. A Collaborative Mathematics Teaching Module (CMTM) was developed and implemented that included two content strands, Algebra and Geometry. The duration of the experiment was thirty seven days. Data were analyzed using descriptive and inferential statistics such as mean, independent sample t-test and 2×2 ANOVA. The results of the experiment revealed that CT had significant positive impact on students' conceptual learning achievement particularly on their conceptual understanding and procedural knowledge.

Keywords: *Collaborative teaching (CT), Mathematics achievement, collaborative Mathematics teaching module (CMTM)*
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Introduction

Mathematics is an important subject for development of reasoning faculties of the human mind. Famous educationists, Herbert, Froebel, and Maria recognized the importance of mathematics as they contend that the intellectual and cultural development of an individual cannot take place without studying mathematics (Yasoda, 2009). Moreover, mathematics plays an important role in developing abilities like thinking, reasoning, conceptual understanding, procedural knowledge, and problem solving required to become good citizens. Mathematics is also used by every individual in daily life. It provides foundation for the study of science subjects like Physics, Chemistry etc.

Mathematics has many characteristics such as its peculiar language and symbols that distinguish it from other subjects. It involves abstraction in concepts. Due to its abstract nature, unique language, and symbols, students face difficulty in learning mathematics. Some problems of students in learning mathematics are attributed to teaching (Russell, 2006), especially with a single teacher teaching in a

Mathematics' classroom. While working on mathematics problems, students may have feelings of mental fatigue and excessive exhaustion, difficulty in answering, correctly keeping pace with the writing speed of teacher, and lack of sufficient interest in the problem to inspire the required mental efforts. Single teachers cannot always cope with all such problems effectively because of a lack of interaction with every student, time, energies, knowledge, and teaching learning techniques.

In Pakistan, predominantly deductive method of teaching is used by one teacher in the class room that uses a process of transmission of knowledge, rather

than a process of concept construction. In general mathematics teachers teach from textbooks without relating the concepts with daily life. In general they start lessons with dictating formulae and asking students to memorize those formulae in order to solve the questions. Mathematics teachers generally do not collaborate with colleagues to discuss concepts or teaching methodology. Berry, Daughtrey, and Wieder (2009) argued that mathematics teacher can improve his teaching quality though collaboration with colleagues that helps in increasing students' achievement.

Cook and Friend (1995) as cited in Glaeser (n.d.) defined CT as "*a style of interaction between at least two co-equal parties voluntarily engaged in shared decision making as they work toward a common goal*". In teaching, it is a process in which two or more teachers plan, present, and assess classroom instruction. Their role varies based on the lesson activities and teachers' specific strengths in instruction. CT has been carried out in many ways such as through lead teacher modeling, station teaching, co-teaching, team teaching, and through consultation. Friend and Cook (2007 as cited in Chapple (2009)) described six ways to implement co-teaching, these are one teach-one observe, one teach-one assist, parallel teaching, station teaching, alternative teaching, and teaming.

Novicevic, Buckley, Harvey, & Keaton, stated several advantages of CT (Clarke & Kinuthia, 2009) such as use of different teaching styles enhance students' academic achievement; it improves the capability of students to critically evaluate the problems, give reasons, and apply the concepts effectively in different situations. It also helps teachers develop mutual trust and respect for each other, cover their specialty areas, and get fruitful information about content and teaching styles while collaborate with each other. Collaborative teaching enhances the quality of teaching by transforming it into a participative activity. It is a means to achieve enhanced learning outcomes because of its peer-reviewed and monitored nature. Its strength lies in the combined forces applied to address common goals or problems.

Various mathematics teaching approaches are in use all over the world such as direct instruction (teacher centered), CT, content focused, and classroom focused (Therese & Deborah, 1986). Teaching by a single teacher mostly remains teacher centered focusing on content coverage using deductive methods whilst collaborative teaching helps in focusing upon the learner using a variety of methods. Smylie et al. (1996) found that single teacher teaching was negatively associated with student achievement; conversely co-teaching's control over resources and accountability for outcomes was positively associated with student success. (as cited in Marble & Green, 2011). Researchers like Doebler & Smith (1996) and Hammer, & Giordano(2011) recommend that team teaching, a model of collaborative teaching, is effective for teaching mathematics (Wadkins, Wozniak, and Miller, 2004). It is better than other teaching approach and it yielded positive effects on students' achievement in USA, UK, China, Australia, Canada and other developed countries (Mcduffe, Scruggs, & Mastropieri, 2007).

In Pakistan some research studies have been conducted focusing on collaborative learning. For example Qaisar (2011) examined the effect of collaborative student group work for concept development in the content strand of numbers in the subject of mathematics at grade five. Less research has been done in the context of CT where two or more teachers teach together. Consequently, there is need to investigate the feasibility of using CT and its effectiveness in the context of Pakistan. The study was designed to answer the following questions:

1. Is CT better than the traditional teaching in enhancing students' learning achievement in mathematics?
2. What is the impact of CT on students' conceptual understanding, procedural knowledge, and problem solving?

Hypotheses

To find out the answers of the questions stated above, following null hypotheses were framed:

Ho_1: There is no significant difference between the mean achievement scores of students' in mathematics taught through CT and traditional teaching.

Ho_2: There is no significant difference between the mean achievement scores of students' conceptual understanding taught through CT and traditional

teaching.

Ho_3: There is no significant difference between the mean achievement scores of students' procedural knowledge taught through CT and traditional teaching.

Ho_4: There is no significant difference between the mean achievement scores of students' problem solving taught through CT and traditional teaching.

Methodology

The study was quantitative in nature; Solomon Four-Group experimental research design was used to investigate the effectiveness of CT, which best controls the threats, subjects' characteristics, mortality, instrument decay, testing, maturation, and regression, to internal validity of an experiment (Gay, 2000) as compared to other experimental designs. A public school situated in a rural area was selected conveniently from district Sargodha. Random selection of a public school was not possible as the heads of the schools did not allow for random assignment of students into four groups. Three mathematics' teachers, two volunteers from the sampled school and the 2nd researcher, participated in the experiment. The researcher and one of the mathematics teachers from the school taught the experimental groups by CT and the other school teacher taught the control groups using traditional teaching method. The co-teachers planned and implemented the lessons together to the experimental group. They developed a Collaborative Mathematics Teaching Module (CMTM), focusing on two content strands (Algebra and Geometry) and it was validated by two experts of teaching mathematics teaching. The module described lesson by lesson the role of two collaborating teachers in the classroom. On the other hand the control group students were taught through deductive method of teaching mathematics. In the start of the experiment the researcher made a schedule of lectures and provided it to the teachers involved in the study. The co-teachers used different co-teaching strategies i.e. one teach-one assist, parallel teaching, and teaming. The sample was 118 mathematics' students of 8^{th} grade. The researcher assigned the students into four groups randomly. The class sizes of the two experimental groups and two control groups were same i.e. 29 and 30. The duration of the experiment was 37 days.

Research Instrument

A Mathematics Achievement Test (MAT) was used as a research instrument to measure the academic achievement of the students. Multiple Choice items were adopted from the item bank of National Education Assessment System (NEAS) with due permission from the authorities. The selection of test items was made keeping in view the proportionate ratio of learning outcomes of Algebra and Geometry in accordance with the test blue print (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; Craig & Wollack, 2003). It consisted of 32 items measuring three mathematical abilities i.e. conceptual understanding (30%), procedural knowledge (40%), and problem solving (30%). To ensure the validity of content strands and mathematical abilities of MAT a specification table was developed.

Table 1: Table of Specification of Mathematics Achievement Test (MAT)

Sr. no. ---	Content Strand	Conceptual Understanding (CU)		Procedural Knowledge (PK)		Problem Solving (PS)		Total	
		No of Items	% weightage in Test	No of Items	% weightage In Test	No of Items	% weightage In Test	No of Items	% weightage in Test
1	Geometry	4	9.37	4	15.6	3	9.37	11	34.3
2	Algebra	6	18.7	9	28.12	6	18.7	21	65.6
Total		10	30	13	40	9	30	32	100

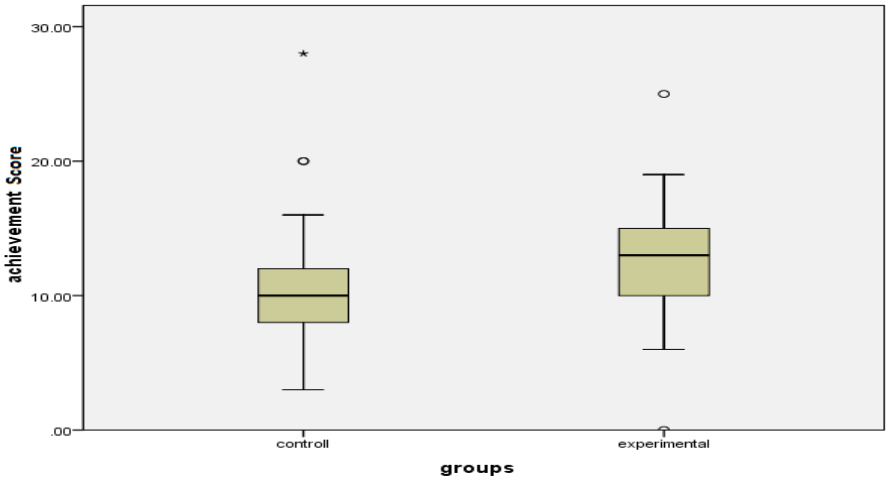


Figure 1: Box plot of control and experimental groups

Data Screening

Fifteen students' post-test scores were dropped from the analysis on the basis of their short attendance i.e. less than 75%. The criterion of short attendance was set before starting the experiment. The data of remaining 103 subjects were analyzed through SPSS-16. Scores of another five students identified, through Box plot, as outliers were also excluded from the analysis. For this study the outliers are shown on the Box plot in figure 1.

There were five outliers, three in the control group and two in the experimental group leaving 98 subjects' scores for analysis. The descriptive statistics of 98 subjects are shown in table 4 and figure 2.

Normality of the data

In order to check the normality of the data Shapiro-Wilk test of normality was applied. According to Ghasemi and Zahediasl (2012), "*researchers recommend the Shapiro-Wilk test as the best choice for testing the normality of data.*" The detail is shown in the table 2.

Table 2 shows that p values i.e. 0.224 for control group and 0.119 for experimental group are greater than 0.05. The null hypotheses for the Shapiro-Wilk test were accepted. It means that the data of both the groups is significantly normal data.

Table 2: Normality of the data of control and experimental groups

Group	Shapiro-Wilk Statistic	df	Sig.
Control	.971	53	.224
Experimental	.960	45	.119

Table 3: Normality of the data of pre-tested and not pre-tested subjects

Group	Shapiro-Wilk Statistic	Df	Sig.
Without pre-test	.956	50	.060
pre-tested	.979	48	.542

Table 4: Mean achievement scores of with and without pre-test subjects in the control and experimental groups

Group	Pre-tested	Not pre-tested	Total
Experimental group	E_1 (n=24) $\bar{X}_{11} = 12.29$	E_2 (n=21) $\bar{X}_{12} = 13.38$	(n=45) $\bar{X}_1 = 12.80$
Control group	C_1 (n=24) $\bar{X}_{21} = 10.38$	C_2 (n=29) $\bar{X}_{22} = 9.83$	(n=53) $\bar{X}_2 = 10.07$
Total	(n=48) $\bar{X}_3 = 11.33$	(n=50) $\bar{X}_4 = 11.32$	N= 98

Table 3 shows that p values i.e. 0.060 for not pre-tested subjects and 0.542 for pre-tested subjects are greater than 0.05. The null hypotheses for the Shapiro-Wilk test were accepted. It means that the data of both the groups is normally distributed data.

Descriptive Analysis

Significance of difference between the mean scores of the experimental and control groups was calculated using 2×2 ANOVA. There were four groups: two on the basis of treatment (experimental and control); each further divided in to two groups on the basis of pre-test (pre-tested and not pre-tested). The dependent variable is the academic achievement scores of the students.

Table 4 shows that the mean scores of control and experimental groups with pre-test were 10.38 and 12.29, respectively. Similarly, the mean scores of control and experimental groups without pre-test were 9.83 and 13.38, respectively. Also, the overall mean scores of control and experimental groups were 10.07 and 12.80, respectively. It means that the experimental groups out performed the control groups on the achievement test.

Table 5: Difference between mean achievement scores of control and experimental groups

Source	SS	df	S^2	F	p
Experimental and control groups	180.864	1	180.864	19.504	.000
Pre-tested and not pre-tested groups	1.775	1	1.775	.191	.663
Groups *Conditions	16.192	1	16.192	1.746	.190

p=.05, (n=96)

Table 6: Difference between the mean achievement scores of students' conceptual understanding taught through collaborative and traditional teaching

Group	n	$\bar{x}$	SD	df	t	Sig.
Control	53	3.69	1.659	96	-3.494	.001
Experimental	45	4.80	1.423			

p=.05, (n=96)

Table 7: Difference between the mean achievement scores of students' procedural knowledge taught through collaborative and traditional teaching

Group	n	$\bar{x}$	SD	df	t	Sig.
Control	53	4.11	1.37	96	-3.712	.000
Experimental	45	5.4	1.93			

p=.05, (n=96)

Table 5 shows that there is significant difference between the mean scores of control and experimental group as the p value i.e. .000. Thus, the null hypothesis, $H0_1$, stating that "there is no significant difference between the mean achievement scores of students taught through collaborative teaching and traditional teaching" was rejected. The mean achievement score of experimental group i.e. 12.80 was greater than the mean achievement score of the control group i.e. 10.07. It was concluded that CMTM had better impact on students' achievement in mathematics. Table 5 also shows that there is no significant difference between the achievement score of students who were pre-tested and those who were not pre-tested as the p value i.e. 0.63 was greater than 0.05. No significant interaction was found between the test and the treatment, as the p value i.e. 0.190 was greater than the 0.05.

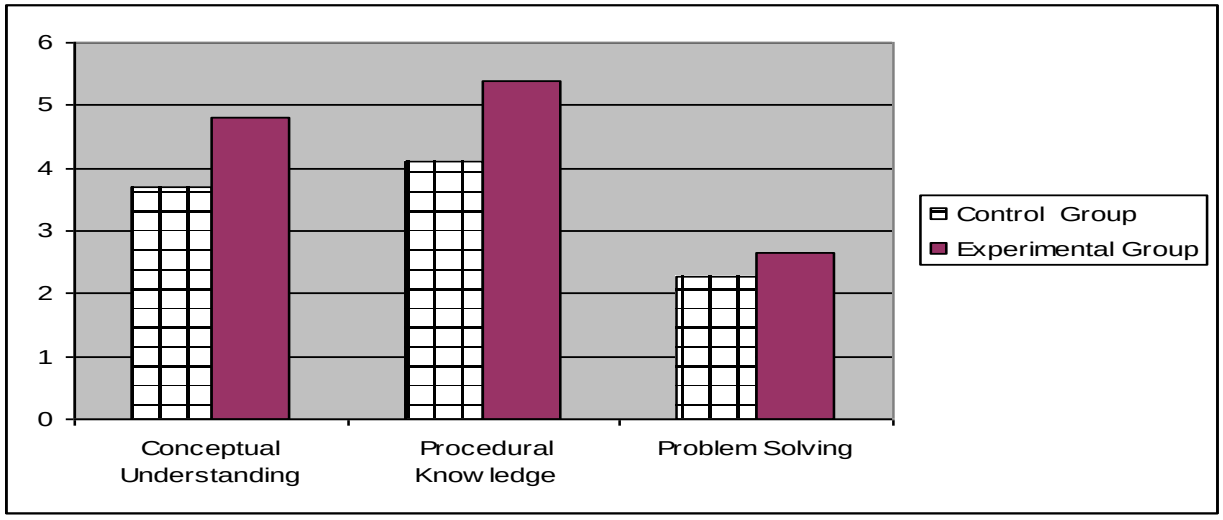
Table 6 indicates a significant difference between the mean scores of students' of control and experimental groups' achievement in conceptual understanding of mathematics. The value of $t_{96} = -3.494$, $p = .001$ was significant at 5% alpha. The null hypothesis, H_{02}, stating no significant difference between the mean scores of students' achievement in conceptual understanding of mathematics, was rejected. The mean achievement scores of students of the two groups i.e. 4.80 and 3.69, in their conceptual understanding ability showed that the students taught through collaborative teaching performed better on the achievement test than the students taught by one teacher. The graphical representation of mean achievement scores is given in Figure 2.

Table 7 indicates significant difference between the mean scores of students' of the control and experimental groups' procedural knowledge in mathematics. The null hypothesis, H_{03}, stating no significant difference between the mean scores of students' achievement in procedural knowledge, was rejected. The students taught through collaborative teaching performed better than the students taught by single teacher.

Table 8: Difference between the mean achievement scores of students' problem solving taught through collaborative and traditional teaching

Group	n	$\bar{x}$	SD	d f	t	Sig.
Control	53	2.26	1.195	96	-1.469	.145
Experimental	45	2.64	1.367			

p=.05, (n=96)



There was no significant difference between the mean scores of experimental and control groups students' achievement in problem solving. The null hypothesis, $H_0 4$, stating no significant difference between the mean scores of the two groups' students' achievement in problem solving, was accepted. However the mean achievement scores of the two groups i.e. 2.64 and 2.26, in problem solving ability in mathematics show that the students of experimental group performed slightly better than the students of the control group. See Figure 2.

Figure 2: Mean scores of students of control and experimental groups on conceptual understanding, procedural knowledge, and problem solving mathematical abilities

Discussion

This study exhibited a positive impact of CT on students' learning achievement. This method of teaching has already established its positive effects on students' learning achievement in USA, UK, China, Australia, Canada and other developed countries (Mcduffe, Scruggs, & Mastropieri, 2007). The findings of the study are in-line with the findings of studies by Murawski and Swanson (2001), Jang (2006), Parker (2010), and Goddard, Goddard, & Moran (2007).

CT was effective in enhancing students' conceptual understanding and procedural knowledge but did not significantly raise their scores in problem solving. This might be due to using English as a medium of instruction. The research was conducted in a government school, situated in rural area of the Punjab province. The mother tongue of all the students at this school is Punjabi. The medium of instruction is generally Urdu, the national language. The MAT was in English language and the test items of problem solving were word problems requiring reasonable English language proficiency. Another plausible reason is the short duration of the experiment. It might have been due to students' learning practices in mathematics as most of the

students in Pakistan learn mathematics' concepts and procedures by memorizing and drill. It was also a post-facto speculation that the co-teachers focused on developing understanding of the concepts because it was observed that students of 8th grade were quite weak in mathematical concepts. Nevertheless CT proved to be a better alternative to single teacher teaching in Pakistan.

Suggestions and Recommendations

In the light of findings of the study following suggestions and recommendations are put forward:

1. In Pakistan single teacher teaching is practiced in schools. Findings show that CT is a better alternative to single teacher teaching mathematics. It is recommended that pre-service teacher training institutions should include "CT in Mathematics" as a unit in the Methods of Teaching course. The main objective of this unit should be to educate and prepare prospective teachers about using various strategies of teaching mathematics including collaborative teaching. The unit should aim at developing sense of openness and sharing and collaborating for developing lesson plans, related classroom settings/ management and teaching-learning.

Suggestions for Further Research

1. The present study used one teach-one assist, parallel teaching, and team teaching models of CT. It is suggested that further research in the context of CT should use other collaborative settings such as alternative teaching, station teaching etc.
2. This study was carried out on male students of public schools at 8th grade. The findings of this study tell us that CT has positive impact on the students' academic achievement in mathematics. Further research may be conducted on female students of public schools, private schools' students, on different grade levels and of different ability students.
3. The factors like social learning of students and teachers, classroom learning environment, students' attitude towards mathematics teaching, and classroom discipline may also be explored using collaborative teaching.
4. The study included two content strands i.e. Algebra and Geometry. Further research may extend to other content strands i.e. Arithmetic, Data analysis and probability.

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