The Effect of Cooperative Learning with Metacognitive Scaffolding on Mathematics Conceptual Understanding and Procedural Fluency

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Abstract: This study investigated the effect of metacognitive scaffolding embedded within cooperative learning on fifth-graders' mathematics conceptual understanding and procedural fluency in learning and solving problems and tasks involving the addition and subtraction of fractions. The participants were 240 male students enrolled in Irbid educational district in Jordan. Six fifth-grade classrooms were randomly selected from three different male primary schools i.e., two classes from each school. Three instructional methods were compared using a quasi-experimental design. The methods were (a) cooperative learning with metacognitive scaffolding (CLMS), (b) cooperative learning with no metacognitive scaffolding (CL), and (c) traditional instructional method (T). A pre-test that measures pre-conceptual understanding and pre-procedural fluency was conducted before the beginning of the study. The results showed that students in group CLMS significantly outperformed students in groups CL and T in mathematics conceptual understanding and procedural fluency. The results also showed that students in group CL significantly outperformed their counterparts in group T in mathematics conceptual understanding and procedural fluency.

Keywords: Metacognitive Scaffolding, Cooperative Learning, Conceptual Understanding, Procedural Fluency.

Introduction

Instructional design has moved through a series of development phases. The move from behaviorism through cognitivism to constructivism represents shifts in emphasis away from an external view to an internal view of learning. To the behaviorist, the internal processing is of no interest; to the cognitivist, the internal processing is only of importance to the extent to which it explains how external reality is understood. In contrast, the constructivist views the student as a builder of her / his knowledge (Terhart, 2003). This turning point of learning processes asks for designing of instruction that deals with students as builders not receivers of knowledge, students who construct knowledge through interaction and connecting their experiences and their prior knowledge with the current situations, and students who have learning strategies to help in building their knowledge and understanding. Thus, successful and effective instruction emphasizes the teaching of strategies that enable students to learn with understanding.

There is general agreement that learning mathematics with understanding involves more than competency in basic skills. Much more than mastering arithmetic and geometry, learning mathematics with understanding deals with conceptual understanding and procedural fluency. Conceptual understanding refers to the student's ability to connect new mathematics ideas with ideas she / he has been known, to represent the mathematical situation in different ways, and to determine similarities/differences between these representations (Donovan, Bransford, & Pellegrion, 1999). Procedural fluency refers to knowledge of procedures or algorithms, knowledge of when and how to use them appropriately, and skill in performing them flexibly, accurately, and efficiently (Kilpatrick, Swafford, & Findell, 2001).

New applications and new theories have expanded significantly the role an instructional method plays in developing the learning of mathematics with understanding. Documents such as those produced by the National Council of Teachers of Mathematics (NCTM, 2008) suggest that traditional mathematics instruction has been challenged by the changing expectations of the skills and knowledge of workers, and therefore, mathematics instruction must shift from concentrating on the products to the learning processes that comprise learning strategies, planning, monitoring, and evaluation. In other words effective mathematics instruction gives special attention to teach learners how to learn and how to evaluate their learning processes.

Among the strategies of improving students' learning mathematics with understanding is a recommendation for using cooperative learning (NCTM, 2008; Kramarski, Mevarech, & Lieberman, 2001). Johnson and Johnson (2007) defined cooperative learning broadly: as ''students working together to achieve learning goals.'' (p. 404). Researchers agree that mathematical communication within the learning community is crucial for the development of students' mathematical understanding (Alrø & Skovsmose, 2003; Forman, 2003). According to Vygotsky (1978), learning with understanding occurs within a social context. When students interact with each other, they typically will learn, receive feedback, and be informed of something that contradicts with their beliefs or current understanding. This conflict often causes students to recognize and reconstruct their existing knowledge. Cooperative learning has been strongly recommended to be used in improving students' cognitive performance, social relationships, and mathematical understanding (Tarım, 2009; Tarım, 2003; Tarım & Artut, 2004).

However, Emmer and Gerwels (2002) affirmed that cooperative learning was useful and effective only when group members offered suggestions, when they were open to negotiation of ideas, and when they shared prior experiences. There may be times when group members do not know how to ask questions or how to elaborate thoughts, or there may be times when group members are not willing to ask questions or respond to others' questions, or there may be times when group members do not see the need for cooperation. Webb and Mastergeorge's (2003b) model of cooperative learning revealed that different conditions and patterns of cooperation might lead to different learning outcomes. Therefore, cooperative learning needs to be structured and guided to be useful and effective.

Veenman, Wilhelm, & Beishuizen (2004) suggest metacognitive strategies to be taught to enable learners to learn with understanding. Metacognition researchers have sought instructional methods that use metacognitive strategies to enhance learning mathematics with understanding. For example, Desoete, Roeyers, & Huylebroeck (2006); King (1991a, 1994); Kramarski and Mizrachi (2006); Mevarech and Kramarski (1997); Kramarski, Mevarech, & Arami (2002); and Xun (2001) suggest structuring group interaction to provide metacognitive strategies that focuses on students' understanding of the task, on awareness and self-regulation of strategy application, and on constructing connections between prior and new knowledge. Metacognitive strategies are techniques that learners use to plan, monitor and control, and evaluate their own cognitive processes (Woolfolk 2007).

Metacognitive instruction provides each student with the opportunity to learn mathematics with understanding via the use of metacognitive questions. Kramarski et al. (2001) and Kramarski and Mizrachi (2006) affirm that successful learners ask themselves metacognitive questions before (through planning), during (through monitoring), and after (through evaluation) the learning task. For example, at the planning stage the learner asks him or herself metacognitive questions such as: "What in my prior knowledge will help me with this particular task? What should I do first? Do I know where I can go to get some information on this topic? How much time will I need to learn this? What are some strategies that I can use to learn this?" At the monitoring stage the successful learner asks him or herself metacognitive questions such as: "Did I understand what I just heard, read or saw? Am I on the right track? How can I spot an error if I make one? How should I revise my plan if it is not working? Am I keeping good notes or records?" And at the evaluation stage the successful learner asks him or herself metacognitive questions such as: "Did my particular strategy produce what I had expected? What could I have done differently? How might I apply this line of thinking to other problems?"

Metacognitive strategies according to Piaget's (1970) cognitive development stages require abstract thinking that students become proficient in when they reach the formal operation stage (12 years and above). Young students, for example, 10 year olds need to be supported, guided, or pushed to be metacognitive thinkers. Vygotsky (1978) explains the differences between students' current abilities and their potential development as the distance between the actual students' independent level and their potential level under guidance, support, or in collaboration with more capable peers. Scaffolding provides an opportunity for students to develop knowledge and skills beyond their independent current level, and this closes the distance between what is and what is possible. That is, with scaffolding, students are supported to go beyond their current thinking, so that they continually increase their capacities (Choi, Land, & Turjeon, 2005; Mevarech & Fridkin 2006; Panitz, 2009; Schoenfeld, 1992).

Choi et al. (2005) found that scaffolding is an essential instructional element to facilitate metacognition and learning. Mevarech and Fridkin (2006) examined the effects of scaffolding students to ask self-questions on their mathematical knowledge, mathematical reasoning, and metacognition. Findings showed that students who used self-questions significantly outperformed students who were not using them on mathematical understanding. Kramarski and Mizrachi (2006) found that students who were exposed to metacognitive guidance outperformed students that were not exposed to metacognitive guidance on real life mathematical tasks and self-regulated learning. Webb, Franke, Chan, Freund, & Shein (2009) found that when learners were trained to explain their thinking, it helped them to clarify their explanations, justify their reasoning and problem-solving strategies, and correct any misconceptions. Kauffman (2004) tested the effect of self-monitoring scaffolding in his investigation of students' use of self-regulated learning strategies. Students who received self-monitoring scaffolding, which prompted students to post a confidence judgment about the completeness of their learning, had higher achievement in conceptual understanding than the control group.

While research studies (Acar & Tarhan, 2008; Doymus, 2008; Kirschner, Strijbos, Kreijns, & Beers 2004b; Kramarski & Mizrachi, 2006; Mevarech & Fridkin, 2006; NCTM, 2008;Tarım, 2009; Tarım, 2003; Tarım & Artut, 2004; Webb et al.,2009) have shown that cooperative learning is a successful learning method, other research findings (Fantuzzo, Ginsburg, Miller, & Rohrbeck, 2003; Lopata, Miller, & Miller, 2003; Slavin, Hurley, & Chamberlain, 2003) revealed that the benefits of cooperative learning are highly dependent on the specific design of the cooperative learning groups. Lopata et al. (2003) found that only 23% of students applied the cooperative learning correctly.

However, there still exists uncertainty as to the mechanism by which improving students' mathematics conceptual understanding and procedural fluency occurs within various cooperative learning environments. Does cooperative learning alone improve students' mathematics conceptual understanding and procedural fluency? Or their cooperation needs to be structured and guided? Research studies (Mevarech and Fridkin, 2006; Panitz, 2009; Tarja, Tuire, & Sanna, 2006) have shown a positive relationship between metacognitive strategies and the features of cooperative learning. Moreover, Desoete et al. (2006) and Boekaerts and Cascallar (2006) found that learners in the metacognitive program achieved significant gains in mathematics performance and mathematical procedures.

If metacognitive strategies are provided to guide students' cooperation, are young students able to apply metacognitive strategies by their own, or do they need external support to do so? There is a broad theoretical and empirical consensus that the influence of metacognition on the outcome of learning is strongly linked to scaffolding (Chin, 2007; Choi et al., 2005; Kramarski and Mizrachi, 2006; Mevarech and Fridkin, 2006; Webb et al., 2009). Metacognitive scaffolding is an instructional technique that concentrates on monitoring student's current level of understanding and decides when it is not adequate. It supports students to manage their thinking, recognize when they do not understand something, and adjusts their thinking accordingly, not just guides them to master mathematical procedures (Choi et al., 2005). Findings of studies into the effects of metacognitive scaffolding have shown a positive effect on the learning outcomes (Azevedo & Hadwin 2005; Azevedo, Moos, Greene, Winters, &

Cromley, 2008; Bannert 2006; Bannert, Hildebrand, &Mengelkamp, 2009; Lin & Lehman 1999; Veenman, Kok, & Blote, 2005).

To date, however, research has provided relatively little insight into the role of metacognitive scaffolding on young learners mathematics conceptual understanding and procedural fluency. Various research studies have been conducted on the separate effects of metacognitive strategies or cooperative learning on mathematics achievement, attitudes, and self-efficacy. Thus, the purpose of this study was to investigate the effect of cooperative learning with metacognitive scaffolding on mathematics conceptual understanding and procedural fluency. Particularly, the study was conducted to investigate if there were any statistically significant differences in mathematics conceptual understanding and procedural fluency levels between students taught via the cooperative learning with metacognitive scaffolding instructional method (CLMS), students taught via the cooperative learning instructional method (CL), and students taught via the traditional instructional method (T).

Method

It is important to note that everyday classroom instructions and all reading materials used in the participating schools are in the Arabic Language (except for classes focused on the teaching of English). Therefore, all the materials and instruments used in this study were translated into Arabic.

Population and Sample

The population of this study was comprised of male fifth grade students enrolled in the first public educational directorate in Irbid District in Jordan in the first semester for the academic year 2010 / 2011. The first public educational directorate in Irbid District includes 44 male primary schools.

In order to implement this study in a naturalistic school setting, existing intact classes were used. The sample consisted of 240 male students who studied in six & fifth-grade classrooms and were randomly selected from three different male primary schools i.e., two classes from each school. The size of the classes was approximately similar (40 + 40 in CLMS, 40 + 39 in CL, and 40 + 41 in T) and the mean age of the students was 10.6 years. The three schools were also randomly selected from the primary schools where mathematics was taught in heterogeneous classrooms with no grouping or ability tracking. Students in the selected schools were from approximately equivalent socioeconomic status as defined by the Jordan Ministry of Education.

Experimental Conditions

The three schools were assigned randomly to three groups. The three groups were different from one another in terms of the instructional method, materials used, and teacher's role duration and learner's role duration. The CLMS group was asked metacognitive questions by the teacher, students used metacognitive questions cards in cooperative learning setting, and the teacher's role was gradually reduced. The CL group studied cooperatively with neither teacher's metacognitive questions nor using metacognitive questions cards, whereas the T group studied in the usual manner with neither cooperative learning, teacher's metacognitive questions, nor metacognitive questions cards. The followings are the details of each group:

CLMS Group (n = 80)**:** In this group, the teacher and learners applied CLMS method two months before the formal experiment with practice units. In the present study, in the first session, the teacher introduced and explained the new topic for about 30 minutes to the whole class by asking himself and training students to ask metacognitive questions regarding planning. For example, before solving the problem / task, instead of saying, First we..., next we..., then we..., the teacher said, "I need to know what the whole problem / task is about, is it about the whole numbers, fractions, additions, or subtraction, etc?" During his explanation process, the teacher asked and trained students to ask metacognitive questions regarding monitoring. For example, did I understand what I have just decided to do? Am I on the right track? At the end of his explanation, the teacher asked and trained students to ask metacognitive questions regarding evaluation such as: Did the solution make a sense, and how can I decide that? Did my particular strategy produce what I had expected? After the teacher's explanation, students worked cooperatively using the metacognitive questions cards that guide and support students to ask metacognitive questions regarding planning, monitoring, and evaluation. In other words, students under this condition were instructed and reminded frequently to think about the questions, and use the questions to facilitate their problem solutions.

In this way, one of the group's members read the problem and asked his colleagues aloud. The colleagues listened to the question and tried to answer. Whenever there was no consensus, the group members discussed the issue until the disagreement was resolved. When the disagreement was resolved, the summarizer orally summarized the solution, the explanation, and the justification and discussed with his colleagues. With the solution, explanation, and justification were in hand, the recorder wrote them down and the presenter presented them to the whole class. During these processes, the teacher monitored each learning group and intervened by asking more metacognitive questions if necessary. At the end of the session, the teacher collected the metacognitive questions cards and assessed and evaluated students' performance, discussed with the whole class to ensure that students carefully process the effectiveness of their learning group, and had students celebrate the work of group members. For the next sessions, the teacher and students followed the same method and procedures and the group members' roles were rotated after each session. However, the metacognitive scaffolding input by the teacher was gradually reduced, for example, the teacher's time in the first session was 30 minutes, in the second session it was about 25 minutes, in the third session it was about 20 minute and so on until the time became when the teacher taught for about 10 minutes regarding the new topic and the students continued learning by their own using the metacognitive questions cards.

CL Group (n = 79)**:** In this group, the teacher and learners applied CL method two months before the formal experiment with practice units. In the present study, in the first session, the teacher introduced and explained the new topic for 25 minutes to the whole class and then proceeded to teach in a usual manner. For example, he used the board and explained the main ideas of today's lesson. After the teacher's explanation of the new topic to the whole class, students were asked to do their exercises and solve the assigned mathematical problems in groups for 15 minutes. The reader read the problem aloud; the colleagues discussed the learning task and asked themselves different questions (but they were not trained to ask metacognitive questions). The summarizer, the recorder, and the presenter played the same roles of their counterparts in the CLMS group. At the end of the session, the students ensured that all of them mastered the task. During the session, the teacher intervened when needed to improve task work and teamwork, but he did not use metacognitive scaffolding, namely, he asked questions regarding the task such as: what are the procedures of adding two fractions with different denominators, and he responded to students' questions. Finally, the teacher assessed and evaluated students' performance, ensured that students carefully process the effectiveness of their learning group, and had students celebrate the work of group members. For the next sessions, the teacher and students followed the same method and procedures. However, group members' roles were rotated each session.

T Group (n = 81)**:** The control group served as a comparison group with no intervention. Therefore, the teacher of this group continued teaching as he usually did. In the whole 14 sessions of implementing T method, the teacher introduced, explained, and manipulated the new concepts and procedures of today's lesson using the board and the textbook for 35 minutes to the whole class. After the teacher's explanation, the students practiced the mathematical items individually using their textbooks and teacher's notes and sometimes employed any method the teacher saw fit for 10 minutes. When the students faced difficulties during solving the mathematical problems / tasks, and finally could not find the solution, they asked for the teacher's help. So the teacher intervened when needed to help some students to solve their mathematical problems. Sometimes the teacher explained and informed the students about the procedures of solving the problem / task. At the end of each session, the teacher reviewed the day's lesson with the whole class.

Within each group, the teachers continued conducting classes according to their assigned teaching methods until the end of the first semester. In the present study, the focus was on the "Adding and Subtracting Fractions" unit that was taught in all classrooms for 15 sessions (14 sessions for implementing each method and 1 session for administrating the test) with 45 minutes for each . At the end of implementing the study (15^{th} session), all students were asked to complete the mathematics test.

Teachers' Training

Each of the three male teachers who participated in this study taught two classrooms. All the teachers were men who had similar levels of education (B.Ed. major in mathematics), had more than 7 years of experience in teaching mathematics, and had taught in heterogeneous classrooms. Prior to the beginning of this study, the teachers assigned to the experimental groups participated in one week training sessions that focused on teaching students to learn mathematics with understanding. The materials included the mathematics textbooks, explicit lesson plans, and examples of metacognitive questions.

The CLMS teacher was trained explicitly about using cooperative learning with metacognitive scaffolding in the teaching of mathematics in general and particularly in the teaching of Adding and Subtracting Fractions. He was exposed to some examples about the nature of the metacognitive questions and how to use and train students to use the metacognitive questions cards in a cooperative learning setting. He was informed to use metacognitive questions in his explanations and coach his students to use metacognitive questions when they solve the mathematical problems. The procedures of selecting groups and assigning group members were explained to the teacher. The CL teacher was trained about teaching mathematics within cooperative learning setting, and about selecting groups and assigning groups' members. Finally, the T teacher was not exposed to the metacognitive scaffolding or to the cooperative learning training, he was asked to teach as he used to teach in a usual manner. The researcher checked his lesson plans and his methods of teaching to ensure that he followed the traditional method. The researcher met all teachers for feedback and assessment regarding the application of the assigned teaching method.

Instructional Materials

In order to study the students' mathematics conceptual understanding and procedural fluency in a naturalistic setting of the classroom, the instructional materials used in this study were based on the fourth unit from the mathematics textbook (Adding and Subtracting Fractions) designed by the Ministry of Education for all fifth-grade students in Jordan, teacher's lesson plans, and metacognitive questions card.

A set of metacognitive questions cards was developed by the researcher based on the metacognition components (planning, monitoring, and evaluation) designed by Jacobs and Paris (1987); and North Central Regional Educational Laboratory, (NCREL, 1995). These questions were designed to facilitate students' understanding of domain knowledge and develop metacognitive thinking, such as questions regarding making decisions about approaching the problem / task, selecting the appropriate strategies to deal with the problem / task, and regarding generalizing the solution processes to other situations. These questions were categorized into the following groups of metacognitive questions:

Planning: “What is the problem / task all about?” “What are the strategies we can use to solve the problem / task and why?” (There were 8 questions in this category).

Monitoring: “Are we on the right track?” (There were 9 questions in this category).

Evaluation: “What explanations can we make and what evidence do we have to justify that our solution is the most viable?” (There were 5 questions in this category).

Measurement Instruments

To assess students’ mathematics conceptual understanding and procedural fluency, a pre- test and a post-test were used in this study. The pre-test and post-test questions were similar in content but their order and numbering were randomized. Two months before the beginning of this study, the pre-test was conducted, the results were collected and used as a covariate.

Test Validity and Reliability

Two experienced mathematics teachers, two education mathematics supervisors, and two mathematics education university lecturers reviewed the test. Each looked at each question and assessed which of the mathematical proficiency strand (CU or PF,) the question represents , and rated their confidence in their response, using scale from 1 (very weak) to 5 (very strong). Only questions, which had received 4 or more scores from all evaluators, were selected as test questions. The evaluators’ suggestions, feedback, and comments were taken into account until there were no discrepancies among them. Prior to the beginning of the study, a pilot test was carried out and the scores from the pilot study test were collected to determine the Cronbach’s Alpha reliability coefficient. Cronbach’s alpha reliability coefficient of the test was 0.88.

Based on the learning objectives, specifications table was constructed. The specifications table contained (6) dimensions: represent addition and subtraction of fractions using visual and numerical models (Q 1,2,3), specify which fraction is greater or less than the other fraction (Q4), simplify fractions and convert mixed numbers to fraction (Q6,7,8), add and subtract fractions, including mixed numbers (Q 5), estimate sums of fractions to approximate solutions (Q 10), and solve word problems involving addition and subtraction of fractions (Q11).

The mathematics test questions consisted of 16 mathematical items and a real-life problem. The mathematics test covered the following topics: equivalent fractions, simplifying fractions, comparing and ordering fractions and mixed numbers, adding and subtracting fractions, and adding and subtracting mixed numbers. The test questions were composed of three kinds of items. One kind (10 items) was based on multiple-choice items. For example:

1- If $\frac{6}{11} + \frac{8}{11} = \frac{14}{11}$ is true, which of the following is true? (Conceptual Understanding).

a) $\frac{6}{11} = \frac{8}{11} + \frac{14}{11}$

b) $\frac{6}{11} + \frac{14}{11} = \frac{8}{11}$

c) $\frac{14}{11} - \frac{6}{11} = \frac{8}{11}$

d) $\frac{8}{11} - \frac{14}{11} = \frac{6}{11}$

2- The mixed number $5\frac{2}{3}$ is equivalent to the improper fraction: (Procedural Fluency).

a) $\frac{15}{3}$ b) $\frac{17}{3}$ c) $\frac{17}{5}$ d) $\frac{10}{3}$

The second kind (6 items) was based on open-ended tasks. For example:

1- Draw a circle and shade it to show $\frac{4}{6}$. (Conceptual Understanding).

2- Simplify the fraction $\frac{18}{24}$ to the simplest form. (Procedural Fluency).

The third kind was a real-life problem. The problem asked students to decide the better buy from two different prices and quality of mixed fruit juice. The student had to calculate the mixed fruit juice volume in each shop, compare the prices and quality, and decide the better buy.

The total score of the test was 22 (12 for conceptual understanding items and 10 for procedural fluency items). The 16 mathematics test items and the real-life problem scoring were as follows:

Multiple-choice items: For each item, students received a score of either 1 (correct answer) or 0 (wrong answer), and a total score ranging from 0 to 10.

Open-ended task items: For each item, students received a score of either 1 (correct answer) or 0 (wrong answer), and a total score ranging from 0 to 6.

The real-life problem: A scoring rubrics was adapted from the Kramarski et al. (2001) procedure with a repeated 0.86 interjudge reliability. Two criteria, which tightly correspond to the conceptual understanding and procedural fluency, were identified as important for measuring students' ability to solve the real-life problem. Students' answers were scored on these criteria, each criterion ranges from 0 (no solution) to 3 (highest level solution), and a total score ranging from 0 to 6. The criteria were:

1. Organizing information (summarizing the data in a table, diagram, or any other representation for comparisons and identifying similarities/differences between the representations- *Conceptual Understanding*).

2. Processing information (figuring the calculations correctly, writing the solution processes, and provide an appropriate solution to the required task- *Procedural Fluency*).

Results

Table 1 presents overall means, standard deviations, adjusted means, and standard errors of each dependent variable by the instructional method, CLMS, CL, and T.

Table 1
Means, standard deviations, adjusted means and standard errors for each dependent variable by the instructional method.

Dependent Variables		The Instructional Method		
		Method1 N= 80	Method2 N= 79	Method3 N= 81
Conceptual Understanding (CU)	Mean	9.71	9.00	8.7201
	SD	1.7	1.8	2.1
	Adj. mean	9.85[a]	8. 91[a]	7.96[a]
	Std. Error	.165	.166	.163
Procedural Fluency (PF)	Mean	8.9	8.6	8.1
	SD	0.8	1.1	0. 7
	Adj. mean	8.98[a]	8.53[a]	8.11[a]
	Std. Error	.092	.092	.091

Note. a. Evaluated at covariates appeared in the model: pre-CU = 4.6375, pre-PF= 5.5000.
Total score on CU = 12 and total score on PF = 10.

By looking at table 1, it can be noted that there were little differences between the means of the three groups in terms of conceptual understanding (9.71, 9, 8.72) and procedural fluency (8.9, 8.6, 8.1). However, the adjusted mean scores of the CLMS group (9.85) was higher than the adjusted mean scores of the CL group (8.91), which, in turn, was higher than the adjusted mean scores of T group (7.96) in terms of conceptual understanding. Also, the adjusted mean scores of the CLMS group (8.98) was higher than the adjusted mean scores of the CL group (8.53), which, in turn, was higher than the adjusted mean scores of T group (8.11) in terms of procedural fluency. In this regard, Miller and Chapman (2001) confirmed that the use of covariate (pre-test) is to adjust for preexisting differences in nonequivalent (intact) groups.

To examine if there were statistically significant differences in CU and PF adjusted mean scores between the CLMS, the CL, and the T groups, while controlling the pre-CU and the pre-PF, one-way multivariate analysis of covariance (MANCOVA) was conducted (run on SPSS). Table 2 presents the results of MANCOVA.

Table 2
Summary of multivariate analysis of covariance (MANCOVA) results by the instructional method and follow-up analysis of covariance (ANCOVA) results.

MANCOVA Effect, Dependent Variables, and Covariates	Multivariate F Pillai's Trace	Univariate F df = 2, 237
Group Effect	16.55 (*p* = 0.00)	
Conceptual Understanding (CU)		33.05 (*p* = 0.00)
Procedural Fluency (PF)		22.60 (*p* = 0.00)
Pre-CU	66.99 (*p* = 0.00)	
Pre-PF	3.33 (*p* = 0.038)	

The results indicated statistical significant differences, F (2,237) = 16.55, p = 0.00. The covariates pre-CU, F (2,237) = 66.99, p = .000, and pre-PF F (2,237) = 3.33, p = 0.038 had statistical significant effects. Further, the results of the univariate ANCOVA tests, which are represented in table 4, indicated that there were statistically significant differences in CU and PF. The F ratio of CU (*2, 237*) was 33.05, p = 0.00. The F ratio of PF (*2, 237*) was 22.60, p = 0.00.

To identify significantly where the differences in the adjusted means resided, a post hoc pairwise comparison using the /lmatrix command was conducted (run on SPSS). Table 3 is a summary of post hoc pairwise comparisons.

Table 3
Summary of post hoc pairwise comparisons

	Dependent Variables			
	Conceptual Understanding (CU)		Procedural Fluency (PF)	
Comparison Group	Adj.Mean Difference	Sig	Adj.Mean Difference	Sig
Method1 vs. Method2	0.94	0.00	.45	.001
Method1 vs. Method3	1.89	0.00	.87	0.00
Method2 vs. Method3	.95	0.00	.42	.001

Note.
The adjusted mean differences shown in this table are the subtraction of the second condition (on the lower line) from the first condition (on the upper line); for example, .94 (Adjusted Mean Difference for Conceptual Understanding) = CLMS – CL.

The post hoc pairwise comparison results showed that the students in group CLMS significantly outperformed the students in groups CL and T in conceptual understanding and procedural fluency. The results also showed that students in group CL significantly outperformed their counterparts in group T in mathematics conceptual understanding and procedural fluency. The adjusted mean differences are presented below.

Conceptual Understanding (CU). The students in CLMS group (M = 9.71, SD = 1.7, Adj.m = 9.85) significantly outperformed the students in the other two groups (CL and T), with an adjusted mean difference of (.94, p = 0.00 and 1.89, p = 0.00) respectively. On other hand, the cooperative learning (CL) group (M = 9, SD = 1.8, Adj.m = 8.91) significantly outperformed the control group (T) (M = 8.01, SD = 2.1, Adj.m = 7.96) with an adjusted mean difference of (.95, p =0.00) (Effect sizes on CU were .34 and .47 for comparing the CLMS and CL, and CL and the T group, respectively).

Procedural Fluency (PF). The students in CLMS group (M = 8.9, SD = .8, Adj.m = 8.98) significantly outperformed the students in the other two groups (CL and T), with an adjusted mean difference of (.45, p = .001 and .87, p = 0.00) respectively. On other hand, the cooperative learning (CL) group (M = 8.6, SD = 1.1, Adj.m = 8.53) significantly outperformed the control group (T) (M = 8.1, SD = .7, Adj.m = 8.11) with an adjusted mean difference of (.42, p = 0.001) (Effect sizes on PF were .43 and .71 for comparing the CLMS and CL, and CL and the T group, respectively).

Discussion and Conclusion

Since the samples are limited to the male fifth-grade students in the primary schools of Irbid directorate and to a duration of 14 sessions, and since the study is limited to the 'Adding and Subtracting fractions', any generalization drawn from this study should be considered with caution.

The findings of the present study indicated that students taught via the CLMS method significantly outperformed their counterparts taught via the CL method who, in turn, significantly outperformed the students taught via the T method in mathematics conceptual understanding and procedural fluency. These findings confirm that cooperative learning with metacognitive scaffolding not only improves the traditional mathematics performance, but mainly improves conceptual understanding (CU) and procedural fluency (PF).

Effects of the Instructional Methods on CU and PF.

According to constructivist theories, information is retained and understood through elaboration and construction of connections between prior knowledge and new knowledge (Terhart, 2003). Asking metacognitive questions within cooperation setting enabled learners in the CLMS group to construct their knowledge and skills. These questions (e.g., What in my prior knowledge will help me with this particular task?) assisted learners to retrieve their previous knowledge, compare with the new knowledge, build connections between them, and then conclude the solution. These findings are similar to Mevarech and Fridkin (2006) findings that indicated that the more often students are exposed to metacognitive support, the greater their ability to construct their knowledge and therefore gains more in mathematics.

The effectiveness of cooperative learning with metacognitive scaffolding on CU support Kauffman (2004) study that found that guidance through questioning enhances task / problem representation and improves conceptual understanding. The metacognitive questions within the cooperation setting have provided learners with cues to important aspects of the task / problem and helped them to identify the task / problem and identify relevant and important information. While conceptual understanding is enhanced by constructing relationships between the previous and the new knowledge (Kilpatrick et al, 2001), metacognitive questions (e.g., what are the similarities and differences between the current task / problem and previous task / problem I solved?) encouraged students to identify the similarities and differences between the task / problem at hand and the task / problems solved in the past, and then may helped them to solve tasks and problems which, in turn, have done well in the test. These findings are consistent with the study of Xun (2001) that found that questioning strategies enabled learners to compare similarities and differences of what they learned with their current learning situation, which helped them to make connections between different factors and constraints and link to the solutions. In this regard, metacognitive questions could assist learners to improve their conceptual understanding.

Flexibility, accuracy, and efficiency are fundamental components of procedural fluency (Kilpatrick et al, 2001). Learners in the CLMS group were provided with the opportunity to execute their mathematical procedures fluently. Working cooperatively and using the metacognitive questions provided the students with more than one approach to solve the task / problem. Metacognitive question such as “what is the appropriate approach to …?” might help learners to select the appropriate approach from many approaches to solve the task / problem. Because learner asked questions such as “am I on the right track?” he was able to keep track of sub-tasks / problems and make use of intermediate results to solve the task / problem, and therefore to be more accurate and more efficient learner. Thus, cooperative learning with metacognitive scaffolding method enabled learners to modify and adapt procedures to make them easier to use.

Metacognitive questions comprise of planning, monitoring, and evaluation questions. Learners in the CLMS group were trained to plan, monitor, and evaluate their learning strategies and solutions. Planning questions enabled students to formulate, identify, and to define the task or the problem and then build the relationships among its concepts and procedures. Monitoring questions enabled students to regulate or monitor their problem performance by self-generating feedback which enabled them to select the appropriate strategies. Evaluation questions enabled students to reflect on their solutions or alternatives so as to direct their future steps. So CLMS learners could have better conceptual understanding and procedural fluency and therefore could perform higher in the test. Specifically, the use of metacognitive questions may guide learners about the knowledge of when, where, and why to use the strategies, which may improve their ability to solve problems. Additionally, metacognitive questions directed learners to analyze the entire situation described in the task or in the problem and thereby did not only enhance their understanding, but also enabled them to replace their earlier inappropriate strategies with a new virtually errorless process. This strategy could help learners to do well in both conceptual understanding and procedural fluency questions and problems. These findings are consistent with the studies of Desoete et al., (2006); King (1991a, 1994); Kramarski and Mizrachi (2006); Mevarech and Kramarski (1997); Kramarski et al., (2002); and Xun (2001) that found a positive effect of metacognitive questions on achievement.

The findings of this study suggest that there were certain conditions in which the use of cooperative learning fully worked to facilitate learning. There may be times when group members do not know how to ask questions or how to elaborate thoughts, or there may be times when group members are not willing to ask questions or respond to others' questions, or there may be times when group members do not see the need for cooperation. Learners in the CLMS group were trained to ask metacognitive questions which may guide their cooperation and may produce responses from group members, and the responses may invoke further questions from other learners who may require elaboration or explanation from their peers. This guided and interactive learning environment could help learners to construct their effective learning strategies which, may assist them to easily remember and retrieve math concepts and solution's procedures, and therefore perform better in terms of tasks and problems that request conceptual understanding and procedural fluency strands .

A possible reason that learners in the CLMS group outperformed their counterparts in the other two groups in the achievement test is that the production of metacognitive questions, responses, and feedback during the cooperative setting may promote higher level thinking and understanding for participating learners. High level thinking leads learner to learn and process knowledge and skills more effectively, and helps learners to remember mathematics concept and procedures longer and more clearly. In this regard, working cooperatively and asking metacognitive questions require learners to be high level thinkers, and then not to memorize knowledge and skills but to build them, which may enable learners to easily response and solve correctly mathematics tasks and problems. These conclusions are consistent with Webb's et al. (2009) and Kramarski & Mizrachi's (2006) findings that confirmed the importance of learning strategies that used cooperative learning and questioning activities in helping learners to monitor their own comprehension and to think about thinking and therefore to produce high level thinking questions.

While the CLMS learners significantly outperformed their counterparts in the CL group in conceptual understanding and procedural fluency, it is worthwhile to acknowledge that CL learners have done very well in the achievement test. It can be interpreted that learners in the CL group could benefit from their learning environment as same as the learners in the CLMS group, except the advantage of the metacognitive scaffolding, which contributed in making the differences statistically significant.

Learners in the CL group were provided with the opportunities to stretch and extend their thinking, to talk aloud, to challenge and defend a point of view, and to focus on the problem-solving process rather than the answer. Also Leikin and Zaslavsky (1997) stated that while learning mathematics in certain cooperative learning settings, students often improve their problem solving abilities, solve more abstract mathematical problems and develop their mathematical understanding. The cooperation situation usually helps learners to learn how to take different points of view into account. And when learners at different development levels work together to explore differences of opinion, they all improve their thinking skills. Similarly, Piaget (1970) confirmed that when learners share a goal, the result of trying to reach it can, because of different perspectives, lead to cognitive conflict. Resolving that conflict leads directly to cognitive development. Learners in the CL group were exposed to many of these activities, and these activities could be considered to have an effect on learners' mathematics conceptual understanding and procedural fluency. This study findings of the effectiveness of cooperative learning in some way is consistent with the results of some other research ((Acar & Tarhan, 2008; Doymus, 2008; Kirschner et al., 2004b; Kramarski & Mizrachi, 2006; Mevarech & Fridkin, 2006; Tarım, 2009; Tarım, 2003; Tarım & Artut, 2004; Webb et al.,2009). The findings also show that the cooperative learning method can be applied successfully in teaching mathematics conceptual understanding and procedural fluency to young learners.

While the CLMS and CL learners significantly outperformed their counterparts in the T group in conceptual understanding and procedural fluency, it is valuable to admit that T learners have done good in the achievement test. The teacher of the T group stated that he applied some group work during the experiment. This group work may explain the good performance of learners in group T. However, learners in group T could not significantly reach to their counterparts' levels in the other two groups. The explanations for the not very well performance of the learners in T group may refer to the poor organization of the learning environment during the experiment. The teacher of T group deemed that he applied cooperative learning method, however, his application did not meet the cooperative learning standards. Johnson and Johnson (2007) emphasized that not all groups are cooperative groups. According to them, many teachers who believe that they are using cooperative learning are, in fact, using traditional classroom groups. Cooperation is not having learners sit side by side at the same table to talk with each other as they do their individual assignments. In this learning environment, T learners many not taught the appropriate strategies, could not self-regulate the study strategies, and did not understand how to apply these strategies. This is consistent with what the teacher of T group reported that some of learners were confused when they encountered a mathematical problem, and they were unable to explain the strategies they employed to find the correct solution. The teacher also mentioned that some learners immediately started the computations when the tasks / problems were given to them.

From these findings, it can be concluded that the use of metacognitive scaffolding method helped students to fully benefit from cooperative learning. When students are actively engaged in activities such as planning, monitoring, questioning, explaining, elaborating, negotiating meanings, constructing arguments, and evaluation, they benefit much from the cooperative learning process. Therefore, the cooperative learning method is inadequate without metacognitive scaffolding or, cooperative learning with metacognitive scaffolding method is superior to cooperative learning method alone. It follows that the cooperative learning process should be scaffolded appropriately, and modeling through metacognitive scaffolding. Therefore, metacognitive scaffolding and cooperative learning can be integrated in instructional design, curriculum design, computer based design, or web-based design to develop mathematics conceptual understanding and procedural fluency facilitate self-regulated learning.

Implications and Future Research

A close examination of the results revealed that cooperative learning alone is insufficient as a form of scaffolding. Therefore, metacognitive scaffolding can be integrated in instructional design, curriculum design, computer based design, or web-based design to develop mathematics conceptual understanding and procedural fluency. Furthermore, the effectiveness, the high learn ability level and the cost effectiveness of this method make this method a good candidate for inclusion in the development of the pedagogical approach.

No purposive observations and / or interviews were conducted in this study. This calls for future research that investigates the nature and the quality of the students' interaction in CLMS and CL methods. Students' motivation and attitudes are interesting areas for future research. An interesting question raised in this study relates to the effects of individual learning with metacognitive scaffolding (MS) versus cooperative learning alone (CL) on mathematics conceptual understanding and procedural fluency. To address the issue, students who work individually and are provided with metacognitive questions cards by the teacher should be compared with students who work cooperatively alone without using metacognitive questions cards. Finally, the findings of this study raise an important question regarding the teachers' willing to implement the CLMS instructional method. Therefore, teachers willing, proficiencies, experiences, teaching skills, and attitudes toward CLMS method may be investigated in future research.

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