Effect of Cooperative Learning Method on Prospective Teachers’ Non-routine Problem-Solving Skills and Their Views About the Method

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The aim of this study is to investigate the opinions of the prospective teachers about the effect of cooperative learning method on non-routine problem-solving levels and on solving problems by means of this method. For this purpose, one experimental group and one control group were randomly formed. Ninety-nine prospective teachers participated in the study. A problem-solving test consisting of non-routine problems was used as a pre-test and a post-test. Covariance analysis was conducted on the data obtained from the problem-solving test to determine whether the difference between the experimental group and the control group was statistically significant. It was concluded that the problem-solving performance of the prospective teachers in the experimental group was better than that of the prospective teachers in the control group. The collated interview findings showed that the prospective teachers mentioned positive effects of working on non-routine problems in a cooperative learning group.

Keywords: cooperative learning, prospective teachers, non-routine problems, problem-solving, mathematics teaching

Introduction

Problem-solving underlies in the center of mathematics curriculum. During the studies of problem-solving, students learn to solve a problem systematically and present their way of thinking while solving a problem. In addition to this, students find new ways of thinking by solving problems and all these provide them with self-confidence which they need when faced with unfamiliar problems in their lives (National Council of Teachers of Mathematics [NCTM], 2000). Charles (n.d.) stated that mathematical reasoning improves through problem-solving and thus strong connections are built between mathematical concepts. According to Polya (1988, p. v), the experience of problem-solving is as follows:

A great discovery solves a great problem, but there is a grain of discovery in the solution of any problem. Your problem may be modest; but if it challenges curiosity and brings into play your inventive faculties, and if you solve it by means, you may experience the tension and enjoy the triumph of discovery.

When the resources about problem and problem-solving were analyzed, it was seen that they were classified into two as routine and non-routine problems (Schoenfeld, 1992; Billstein, Libeskind, & Lott, 1993;
EFFECT OF COOPERATIVE LEARNING METHOD

Orton & Wain, 1994; Reusser & Stebler, 1997; Van De Walle, 2001; Buschman, 2003). Routine problems are generally, the problems which are similar to the ones which have been solved before or they require applying a formula which was learnt before onto a new situation (Polya, 1988).

Non-routine problems, on the other hand, cannot be solved by means of a known method or formula. Solving these problems requires students’ careful analysis of data and creative attempt and usage of one or more strategies (prediction, controlling, searching for patterns, making a systematic list, etc.). Polya (1988) expressed that it is important to teach to solve routine problems in order to improve problem-solving skills but this should not be considered as satisfactory. Polya (1988) added that non-routine problems must also be included in mathematics teaching in order to improve critical thinking and creativity. In addition to this, Clarke and McDonough (1989) stated that students left non-routine problems aside while working individually as they generally found them difficult, but they could carry out the requirements of problem-solving process better while working in cooperation-based groups.

Cooperative learning is a teaching method in which students work in small groups to maximize their own and their classmates’ learning (Johnson, Johnson, & Simith, 1998, 2013; Slavin, 2015). Each group activity does not address cooperative learning. According to Johnson (1984), cooperative learning does not mean that students sit next to each other and talk to each other in group work. In addition, cooperation does not imply that the one who finishes the work earlier than the other group members help the others or that one in the group prepares the group report and writes the names of all members.

In order to be able to label a group activity as a cooperative learning activity, it is essential that each group member aims to increase his/her own and his/her group members’ learning at a maximum level and he/she must be interested in such an activity. Group activities should be arranged in such a way that each should know that his/her own achievement is, at the same time, attached to his/her group, itself. Each group member should know that the real achievement can be attained only if this condition is guaranteed, and therefore, each member should also work for the other’s performance.

Cooperative learning has many different forms, such as Jigsaw, Cooperative Integrated Reading and Composition (CIRC), Teams-Games-Tournament (TGT), Learning Together (LT), Team Assisted Individualization (TAI), Academic Controversy (AC), Group Investigation (GI), Student Teams-Achievement Divisions (STAD), etc. (see Kagan [1992] for more details).

It is possible to use STAD in many themes including mathematics. It is efficient for student’s mutual interaction, peer teaching, and improving many other skills. In this method, after a lesson is given by the teacher, students are supposed to work in their teams to try to do their works themselves and make sure that the other members in their team also do their best to accomplish the task assigned. In the last phase, students take individual quizzes in which they are not allowed to help other team members (Slavin, 1990).

A revision of the related studies showed that according to Trudge and Caruso (1989), one of the good ways for learners to acquire a different point of views is that learners work effectively and actively and participate in problem-solving based group activities. Similarly, Edwards and Stout (1990) said that cooperative problem-solving is beneficial when students are working with a new concept, when discussion and higher order thinking skills are entailed, or when brainstorming in group is required. And also, problem-solving in cooperation-based groups accomplishes the fulfilment of learners’ individual responsibilities for group achievement and works as a reinforcement for the development of positive co-dependency among members (Johnson & Johnson, 1994).
Cooperative learning method is widely used in many subject areas and class levels. One of the reasons of this is its positive effects on academic achievement (Sharan, 1980; Slavin, Madden, & Leavely, 1984; Johnson & Johnson, 1981, 1989; Leikin & Zaslavsky, 1997; Tarım, 2003; Artut & Tarım, 2007; Roseth, Johnson, & Johnson, 2008; Slavin, 2011, 2015). Although the studies about this learning method have focused on primary and secondary education, it is expressed in the discussions about the benefits of this method that it is also applicable at bachelor degree classes (Emley, 1986; Dees, 1991; Garfield, 1993; Kaptan & Korkmaz, 1995; Artut & Tarım, 2007; Johnson et al., 1998, 2013; Van Voorhis, 1995; Slavin, 2015). In the same way, Nebesniak (2007) stated that the transfer of cooperative learning skills depends on the ability level of the students, teacher support, and exposure to problem-solving situations.

In line with the explanations above, it is thought that the prospective teachers’ perception of the importance of non-routine problem types and improvement in skills of solving these problems. Furthermore, it is also believed that prospective teachers will have important opportunities for their future teaching careers since they study this kind of problems while working in cooperation-based groups as both learners and teachers. Accordingly, the research questions were as below:

1. What is the effect of cooperative learning method on prospective teachers’ non-routine problem-solving skills?
2. What are the views of prospective teachers about including non-routine problems in mathematics classes?
3. What are the views of prospective teachers about working with non-routine problems in cooperation-based groups?

Method

The research was conducted in the course of mathematics teaching on prospective teachers studying at the Elementary Education Department of a state university in the south of Turkey. Two groups were formed by random assignment. One of these groups was taken as the experimental group and the other one was taken as the control group. Problem-solving studies were implemented in groups based on cooperation in the experimental group. In the control group, the students studied on the problems individually. The views of the prospective teachers were taken so as to determine how the implementation process worked. In this context, this study was designed according to the mixed method. The mixed method is based on the usage of qualitative and quantitative research methods together or mixed (Creswell & Garret, 2008).

Subjects

Two groups were selected as one experimental group and one control group from among five groups randomly. The experimental group consisted of 50 students (female: 35 and male: 15) and the control group consisted of 49 students (female: 30 and male: 19), and totally 99 students participated in the research. The socio-economic levels, academic achievement levels, and parents’ educational levels of the prospective teachers in the experimental and the control group were similar. Therefore, it can be said that the experimental and the control groups were equal in terms of many variables.

Data Collection Tools

Problem test. A problem test was used as a pre-test and a post-test in order to define the problem-solving levels of the prospective teachers. The problems used in this test were developed by making use of Söğütlu (2006), and Altun, Memnun, and Yazgan (2007). All prospective teachers took a problem test consisting of 10
verbal problems. Six of the problems in this problem test were non-routine problems (experimental items) and four of them were routine problems as buffer item. These four items were not evaluated. The test which was prepared was given to both groups as a pre-test at the beginning of the research. As it was believed that the prospective teachers would want to know and they would learn the solutions of the problems after the implementation of the test, it was decided to give a different test consisting of similar problems as a post-test.

Two of the problems in the test are as follows:

Four warriors have to walk across a narrow bridge at nightfall. They have a torch and 17 minutes. Some of them are injured and they can walk across the bridge in 10, 5, 2, and 1 minutes, respectively. Maximum two people can walk across the bridge at the same time and they have to use a torch. In which rotation can all of the warriors walk across the bridge in 17 minutes?

Your company pays a certain sum of money to service firm for the maintenance of the photocopy machine. Your company pays 200 Turkish Liras (TL) to the service company after the first 60,000 copies. Your company spares a budget of 600 TL for the next level which is expected to copy 180,000. As the manager, can you say that this amount of money is enough?

Interview form. An interview form was used in the research to determine the views of the prospective teachers about the problem-solving studies in the cooperation-based groups. Here are some of those questions:

- Have you ever come across non-routine problems in mathematics classes?
- What do you think about including non-routine problems in mathematics classes?
- Could you please write your reflections about the positive and negative aspects of problem-solving studies in cooperation-based groups?
- If you used problem-solving studies in cooperation-based groups in your future teaching career, what do you think its positive or negative contributions to your students would be?

The form was given to the experimental group at the end of the study.

Teaching Methods and Implementation

One of the purposes of the course of mathematics teaching is to instruct the prospective teachers how the problem-solving education should be carried out at the elementary level. In the scope of this purpose, the instruction of verbal problems is included at the elementary level. Non-routine problems which are generally ignored in the teaching process are the focus of this study. The courses of mathematics teaching were given by the researcher in the experimental and control groups with the same problems.

Experimental group. In this research, cooperative learning method was used in the experimental group. The prospective teachers worked in cooperation-based groups on non-routine problems for nine weeks two hours for each. In this group-work, the STAD, one of the cooperative learning techniques, was used.

Groups. Heterogenous groups of four were formed by considering the gender and achievement variables. The students’ demands were not taken into consideration while forming the groups and it was emphasized that all of the students were at different levels and could study together. The groups were requested to find names, slogans, and logos for themselves as a preparation for group work and it was aimed to bring them in group consciousness by this way. “Group Work Guide” was given to every group. In the Group Work Guide, there was information about how to work together effectively for the group members. In terms of preparation for working together, some activities, such as “turns toss,” “valuing differences,” and “brainstorming” were carried out (Kagan, 1992).
Steps 1 (Teacher instruction). Teacher candidates were given one-hour training about non-routine problems as a whole class teaching activity.

Step 2 (Worksheets). In line with the teacher’s instructions, prospective teachers were given worksheets designed appropriately according to non-routine problems (see Appendix). There were two columns in the worksheets. The worksheets including 2-3 non-routine problems. During the pair work while one prospective teacher solved the first question of the first cell in his/her column by telling aloud, the other prospective teachers followed him/her and if needed ask some questions and provided support. Later, other prospective teachers followed the same way. After completed all the problems, the pairs in the groups exchanged their worksheets. Then, they checked each other’s solutions. The researcher gave the answer key to all groups. All group members congratulated each other, if all problems in the worksheet were solved correctly. If an answer of a question did not approve by the pairs, that question was discussed with other pairs of the group. If there was no agreement by the pairs, they applied to teacher for help. The teacher participated the group, which demanded help and solved the problem together with the prospective teachers. Next, each group’s solutions were shared in the class by means of various ways. Sometimes, they gave their response papers to each other or sometimes they solved the problem on the board and told their solutions to other groups.

Step 3 (Quizzes). Prospective teachers were individually tested on the non-routine problems. During the experimental process, they were tested four times, once in each two weeks.

Step 4 (Evaluation). The team achievement scores were also considered by individual improvement scores in line with Slavin’s suggestions (Kagan, 1992, p. 16:2).

Control group. The prospective teachers in this group worked on non-routine problems for seven weeks, two hours for each individually. They were given a whole class teaching about non-routine problems for an hour every week. In the following lesson, they worked on the worksheets given to them individually. When needed, they were helped. Then, the answers were given and explained by the teacher.

In other words, the teacher presents the problem to the prospective teachers and wants them to solve the problem. Later, the problem is solved on the board. No structured group work was included in the control group. The prospective teachers of the control group took quizzes as in the experimental groups, and were evaluated individually.

Data Analysis

In the research, an independent t-test was conducted, so as to find if there was a statistically significant difference between the pre-test achievement scores of the experimental and the control groups. Covariance analysis was made in order to determine whether the cooperative learning method was effective on the prospective teachers’ non-routine problem-solving skills. Descriptive analysis, a qualitative research method, was used for defining the views of the prospective teachers about non-routine problems and working on this kind of problems in cooperation-based groups. Interviews were transcribed and transferred to the computer. The transcribed texts were read question by question and were evaluated in line with the codes and themes.

In the presentation of the findings, the quotations from the prospective teachers were given by using the codes of S1, S2, ..., S50 instead of using real names.

Findings

The results of descriptive statistics for both groups were presented in Table 1.
Table 1
Descriptive Statistics About Pre-Test and Post-Test Scores of the Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Pre-test M</th>
<th>Pre-test SD</th>
<th>Post-test M</th>
<th>Post-test SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>50</td>
<td>2.04</td>
<td>1.04</td>
<td>4.24</td>
<td>1.17</td>
</tr>
<tr>
<td>Control</td>
<td>49</td>
<td>1.91</td>
<td>1.01</td>
<td>3.55</td>
<td>1.62</td>
</tr>
</tbody>
</table>

As seen in Table 1, average pre-test scores of both groups are close to each other. An independent $t$-test was conducted to determine if there was a statistically significant difference between the scores of the groups. The results of $t$-test revealed that there was not a significant difference between the average pre-test scores of both groups ($t(97) = 0.58; p > 0.05$). Furthermore, the significance in the post-test was analyzed by covariance analysis since average pre-test scores of the prospective teachers in the experimental group were a bit higher than that of the prospective teachers in the control group. The results of the covariance analysis showed that there was a statistically significant difference between the groups’ average post-test scores when the pre-tests were taken under control ($F(1, 96) = 5.57; p < 0.05$). It was also observed that the problem-solving performance of the prospective teachers in the experimental group in which cooperative learning method was implemented was better than that of the prospective teachers in the control group.

**Interview Findings**

When the views of the prospective teachers about working on non-routine problems were taken into account, it was seen that none of the prospective teachers had come across this kind of problems in mathematics classes before. Some of the prospective teachers’ views are as follows:

- I have never come across this kind of problems in mathematics classes, but I remember that this kind of problems were sometimes used among friends for fun outside the school environment. (S15)
- I do not remember this kind of problems was asked at school. My father used to ask such problems to me to understand my intelligence level when I was a kid. (S22)

When the views of the prospective teachers about including non-routine problems in mathematics classes were considered, it was observed that the prospective teachers expressed positive opinions as they support the usage of various strategies ($N = 32$), they help students obtain different perspectives ($N = 18$), and they help cognitive development ($N = 9$). In addition to this, two prospective teachers stated that they find working on non-routine problems exciting, but they could not comprehend their relationship with mathematics completely. Some of the prospective teachers’ views are as follows:

- I wish I had studied on this kind of problems in mathematics classes. I would have liked mathematics more. (S43)
- I could not solve these problems by the ways I knew. I had to think differently. To be honest, I had a lot of difficulty at first. (S22)
- In fact, studying on this problem is exciting but I could not understand how it is related with mathematics. (S5)
- Studying on such problems illuminates us.... (S36)

When the views of the prospective teachers about studying on non-routine problems in cooperation-based groups were analyzed, it was concluded that the prospective teachers thought that working together facilitates seeing the solution ($N = 15$), improves the skills of solving this kind of problems ($N = 39$), makes students focus on the solutions of the problems longer ($N = 43$), the interaction between the groups make them see different ways of solving problems ($N = 18$), working together supports appreciating different ways
of solving problems ($N = 21$), the group members like the support of their friends in group ($N = 32$), working together allows students to study with pleasure ($N = 28$), and contributes in developing positive attitude towards mathematics ($N = 30$). Some prospective teachers ($N = 5$) verbalized that they did not like working in groups and preferred working on problems individually. Some of the prospective teachers’ views are as follows:

I did not use to be able to solve the problems alone, but I managed to solve some of the problems by discussing with my friend in group. This was wonderful. (S16)
I was sometimes surprised when I saw the answers of the other groups. I could not think of that solution. (S11)
I could study on the problems longer without getting bored as I was not alone. (S3)
I think it was very nice to support each other in the group without competition. (S46)
I do not feel myself comfortable while working in groups. I always prefer working alone. (S5)
I think I made a great progress in solving this kind of problems at the end of this study when compared to the beginning of this study. (S27)

When the views of the prospective teachers about using non-routine problems in groups based on cooperation in their future teaching career were taken into consideration, it was seen that almost all of them expressed positive opinions on this issue. A few ($N = 5$) prospective teachers declared that they had some hesitations about using this method in their future teaching career because of the difficulties that might be experienced during the implementation although they believed group work is beneficial. Some of the prospective teachers’ views are as follows:

Certainly, I am going to use this method when I become a teacher. (S27)
I would like my students to solve problems savourily in group work as we did. (S15)
Suggestions of different ideas on the problem by my group friends while working in groups sometimes sparkle and made me catch the solution of the problem. In the future, I would like my students to live the same by using this method. (S23)
It is really difficult to implement this method under the conditions of our country as the classrooms are too too crowded for group work. (S12)
I would like to use this method when I become a teacher, but it might be very noisy in crowded classrooms. That is why I have some hesitations. (S41)

Discussion

In this study, which was conducted in order to determine the effect of the prospective teachers’ working in cooperation-based groups on non-routine problem-solving levels, it was found that working in cooperation-based groups was effective on non-routine problem-solving skills. This finding is consistent with the literature findings (Sharan, 1980; Slavin, Madden, & Leavey, 1984; Leikin & Zaslavsky, 1997; Johnson & Johnson, 1981, 1989; Tarim, 2003; Artut & Tarim, 2007) that suggested cooperative learning method was effective on mathematics teaching. Leikin and Zaslavsky (1999) emphasized that the students generally improved their problem-solving skills while learning mathematics in groups based on cooperation, they could solve more abstract problems and improve their mathematical understanding.

As mentioned by Polya (1988), non-routine problems necessitate critical thinking and creativity more. Edwards and Stout (1990) said that cooperative problem-solving was a useful method to practise on new concepts requiring discussion and higher level thinking skills, so it is possible to deduce that participating in cooperative groups supports solving such problems. Similar to this, the teacher candidates in the experimental group showed better problem-solving performance. This finding is consistent with Heller and Heller’s (2010)
point of view, saying that cooperative learning groups provide more support for solving the content rich problems.

Gilbert-Macmillan (1983) stated that cooperative learning method provided students with the opportunity of thinking aloud, created environments to meet with different ideas and focused on the problem-solving process more than the answer of the problem. In this study, the views of the prospective teachers were also in this direction. The prospective teachers expressed that they exchanged ideas effortlessly while working together, discussed on the questions for long and made effective discussions on especially defining the strategies to use while solving the problem and the appropriacy of the results they obtained. Also, Dimabuyo and Portia (2011) mentioned that in cooperative learning method, students were more engaged in communicating with each other, so their mathematical communication developed.

Adams and Hamm (1990, p. 33) indicated that coming up with different ideas while working for a common purpose caused the students to experience cognitive conflicts and solving these conflicts supported the cognitive development directly. One of the prospective teachers expressed opinion in this study as:

Suggestions of different ideas on the problem by my group friends while working in groups sometimes sparkled and made me catch the solution of the problem. In the future, I would like my students to live the same by using this method. (S23)

This opinion, being able to see the ways of solution by working on different opinions, can be a sample for supporting the cognitive development by cognitive conflict and solving this conflict.

Buschman (2003) recommended that problems in which the students can produce their own strategies and implement them should be presented to the students. In addition to this, it is also underlined that problem-solving opportunities in which the students can also learn from the mistakes which they made in the problem-solving process, they can develop different thinking styles and various ways of solutions are shared. The following two opinions of the prospective teachers complete this finding in the related literature:

While we were analyzing the other groups’ ways of solutions, we noticed our own mistakes. This way, we sometimes took the opportunity to correct our mistakes. (S17)

I was sometime surprised when I saw the other groups’ solutions. I could not think of this solution. (S49)

There are loads of studies in the literature which show that cooperative learning method improves the attitudes of students towards mathematics class (Gelici & Bilgin, 2012; Gök, Doğan, Doymuş, & Karaçöp 2009; Lazrowitz, Lazarowitz, & Baird, 1994; Nichols & Hall, 1995; Tlusty, 1993; Ural, 2007; Dimabuyo & Portia, 2011; Yıldırım, 2011). In this study, the prospective teachers expressed opinions which say this method will be beneficial in developing positive attitude towards mathematics. A prospective teacher expressed his/her opinion as:

The fear of making mistakes is less in this method as the mistake becomes the mistake of the group and this reduces the anxiety in mathematics. If we use this method for long time, our students may like mathematics more. (S33)

This teacher believed that this method will be effective on developing positive attitude towards mathematics.

Cavanagh (2011) said that participating in cooperation-based group work had positively affected being on task. In this research, the teacher candidates highlighted that they spent more time on focusing on the solutions of the problems in cooperative learning groups ($N = 43$). One teacher candidate said:
I could study on the problems longer without getting bored as I was not alone. (S3).

According to this example by one of the participants and the researcher’s observations, the participants in the experimental group spent more time on problems without giving up. It can be concluded that the finding based on this research is compatible with the related findings in the literature.

**Conclusion**

Consequently, it was concluded that working in cooperation-based groups was effective on the prospective teachers’ non-routine problem-solving skills. A great majority of the prospective teachers stated that they had never come across non-routine problems in mathematics classes before, but using this kind of problems in the classroom environment might contribute in the cognitive development of the students and make the mathematics classes more enjoyable. Furthermore, many prospective teachers mentioned the positive effects of this method such as being able to see different opinions, gaining different perspectives, appreciating differences, and working on problems longer. Therefore, many prospective teachers emphasized that they would use this method in their future teaching career. A few prospective teachers expressed some negative opinions, such as finding non-routine problems unrelated with mathematics and seeing the cooperative learning method inappropriate for themselves.

On the basis of the results which were mentioned above, it can be recommended that cooperative learning method can be used in problem-solving studies during the teacher training. This study was carried out with prospective teachers. Similar problem-solving studies can be done with students from different levels. In order to increase the awareness levels of teacher in terms of the contributions of non-routine problems to their students, a similar study can be conducted with teachers. In line with this, it can also be recommended that some in-service teacher training courses can be held for teachers in collaboration with the Ministry of National Education and related departments of universities.

**References**


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Appendix: Worksheet

<table>
<thead>
<tr>
<th>Name-surname:</th>
<th>Name-surname:</th>
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<tbody>
<tr>
<td>1. There are three containers. One of them is for 10 kg, the other one is for 5 kg and the last one is for 3 kg. The 10 kg container is full of honey. Can you divide the honey into two by using these containers (no other measurement tool is allowed)?</td>
<td>1. Ash, Artun, and Emre are rowing in a boat. They suddenly crash into a rock. Then, the boat starts to sink. In every three minutes, 18 lt water goes into the boat. As they know that the boat will sink, from the third minute, Emre and Artun start to empty the water from the boat and Aslı rows the boat to the beach. Emre empties 3 lt in one minute and Artun 5 lt in one minute. They know that they can reach into the beach if they have 30 minutes. In such a case, will they be able to reach into the beach?</td>
</tr>
<tr>
<td>Solution:</td>
<td>Solution:</td>
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</table>

| 2. Two friends decided to participate in a strange competition. They compete their horses. Which horse the last is will be the winner. They ride their horses and come to the start. However, both of them want that his own horse will be the winner, so they do not start the horse racing. What do you suggest them for a successful horse racing? | 2. A prisoner is sentenced to death penalty. His death penalty is attached to a draw. As the assistant who is supposed to prepare the draw is the prisoner’s enemy, he is normally supposed to write “the death” on both alternatives. The prisoner can also guess that. But, next to the Sultan, he can not accuse his assistant. In what way, can the prisoner save his life? |
| Solution: | Solution: |

| 3. Our school has 102 students and a vehicle which can carry 16 students. How many rounds does this vehicle have to do to transport all students? | 3. In how many seconds can an athlete who can run 100 m in 10 seconds complete 1000 m? |
| Solution: | Solution: |