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THE EFFECT OF REALISTIC MATHEMATICS EDUCATION ON SIXTH GRADE STUDENTS' STATISTICAL THINKING[1]

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Abstract: Purpose of the study is to investigate the effectiveness of the use of Realistic Mathematics Education (RME) approach on sixth grade students' statistical thinking levels. Mooney's (2002) statistical thinking framework describing four thinking levels across four different statistical thinking processes was used. This study utilized a quasi-experimental pretest-posttest design. In the experimental group, the data handling unit was taught using RME approach whereas in the control group lessons were taught traditionally using a mathematics textbook and direct instruction. A statistical thinking test composed of seven open-ended questions was prepared and applied to both groups as pretest and posttest. The change of students' statistical thinking levels in pretest and posttest were analyzed and compared in both groups as well as between groups. The data analysis showed that the overall growth at Level 4 across statistical thinking processes was higher for the students who were taught using the RME approach than for those taught traditionally.

Key words: Statistical thinking, realistic mathematics education, middle school students.

1. Introduction

Due to the rise of information and communication technologies in today's modern life, we are exposed to a huge amount of information on a daily basis and need higher-order thinking skills to use data beneficially. Some of the higher-order thinking skills are questioning, making interpretation and estimation, reasoning, critical thinking, drawing interference, metacognition, ability to detect inadequate reasoning, reasoning skills in problems and making mental calculations and estimations etc. Educational reforms have been made to equip students with these skills. For instance, the Turkish National Mathematics Curriculum (2018) emphasizes students' understanding of mathematical concepts and their use in the daily life by giving particular importance to higher-order thinking skills rather than memorizing facts with no connection to how they are used in real life. Such reforms with the same aims also took place in the Netherlands (Van den Heuvel-Panhuizen, 1996) many decades ago. Freudenthal and his colleagues came up with the idea of teaching the connection between real life and mathematics, named Realistic Mathematics Education (RME) approach in 1971 (Van den Heuvel-Panhuizen, 1996). According to Freudenthal (1991), mathematics is a human activity and so it should be close to students' daily lives.

In daily life, we are frequently exposed to statistical information on television, social media, newspaper etc. Statistical knowledge helps us in decision-making processes and solving real-world problems involving data. However, students may have difficulties in learning of statistics. According to the prior research, the sources of these difficulties among middle school students appear to be teaching of statistical concepts and procedures without connections, learning without concrete examples and memorization rather than conceptual understanding (Çakmak and Durmuş, 2015; Garfield and Ben-Zvi, 2008). It is getting important to learn mathematics via realistic examples from daily life. According to Garfield and Ben-Zvi (2008) conceptual learning is needed for development of staticical thinking. In statistics, conceptual learning involves understanding and interpreting data as well as making inferences from the data. Because the RME approach gives particular attention to

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conceptual understanding, it is important in today's educational setting to investigate the effect of RME approach on students' statistical thinking.

1. 1. Statistical Thinking

Statistical knowledge is widely used by people to make decisions and predictions in many areas of daily life from consumer goods to sports, weather forecasts and so on. To do so, statistical thinking becomes an essential skill for all citizens. Statistical thinking is not just doing statistical computations or defining concepts; it entails interpreting, reasoning, deducing and making generalizations about the data (Mooney, 2002; Garfield and Ben-Zvi, 2008). Therefore, statistical thinking requires more than just knowing concepts and procedures and performing calculations. Given that statistical data take a huge part of modern daily life, it is essential to develop statistical thinking during school mathematics education.

As part of developing such statistical thinking, Wild and Pfannkuch (1999) describe an investigative cycle, called PPDAC (Problem, Plan, Data, Analysis, Conclusion) model, for solving statistical problems in real-life contexts. As seen in Figure 1, this statistical investigation cycle has five iterative stages: problem, plan, data, analysis and conclusion. The cycle progresses through arrows. The problem stage is about defining and understanding the problem. The plan stage involves deciding on what entitites to collect data and how to measure them. The data stage is then collecting and organizing data. The analysis stage includes anaylzing the data and the following conclusion stage is about making interpretations and generalizations to form conclusions and communicating what has been learned. Via this statistical investigative cycle, students reflect upon all parts of formulating questions, data collection, data analysis and data interpretation (Franklin, Kader, Mewborn, Moreno, Peck, Perry and Scheaffer, 2005). Due to the iterative nature of this investigative cycle, these conclusions and new ideas can lead to new problems and more analysis next.

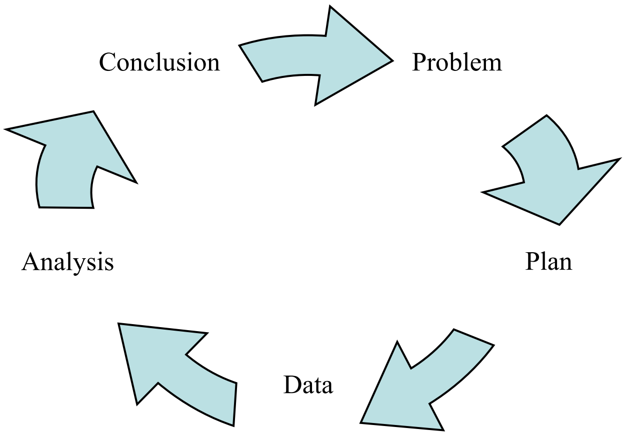

Figure 1: *Statistical investigation cycle*

In the study, Mooney's (2002) statistical thinking framework for middle school students was used. This validated framework is modeled based on Jones, Thornton, Langral and Mooney's (2000) framework developed for primary school students. Mooney (2002) revised this framework for middle school students. In this framework, there are four statistical processes that are aligned with the statistical investigation cycle (Figure 1) for developing statistical thinking: 'describing data', 'organizing and reducing data', 'representing data', and 'analyzing and interpreting data'. 'Describing data' process is the ability to read data in different visual displays; 'organizing and reducing data' refers to arranging data using meausures of center and spread; 'representing data' is the capacity to construct different visual displays of the same data; and 'analyzing and interpreting data' involve making inferences and predictions about statistical data (Mooney, 2002). According to Mooney (2002), students progress through four levels of thinking in each of these processes: Level 1-idiosyncratic, Level 2-transitional, Level 3-quantitative and Level 4-analytical. In Level 1, students cannot give answers related to context; they give answers according to his/her feelings or personal experiences and show limited awareness of the problem. In Level 2, students can show little awaneress of the context, give partially correct answers but it is still not sufficient at this level. In Level 3, students show awaneress of the context; they are aware of the relations, reasons, different displays of the same data and calculations; but their demonstrations may involve some mistakes. In Level 4, students can carry out all procedures without any error; they can fully read the data, make calculations and connections correctly as well as explain the aim of using different data displays, make transitions between them, draw meaningful conclusions and make generalizations from the data.

There are studies investigating middle school students' statistical thinking via different methods. Koparan and Güven (2013) used Mooney's (2002) statistical thinking framework to determine the levels of middle school students' statistical thinking levels. In the study, there were totally 90 students from sixth, seventh and eight grades. A statistical thinking test with 26 questions was prepared by the authors and applied to students. In the test, 5 questions were related to describing data process, 5 questions were related to organizing and reducing data process, 8 questions were related to representing data and 8 questions were related to analyzing and interpreting data process. At the end of the study, it was found that although students were generally at Level 4 in describing data process, they were mainly at Level 1 in other statistical thinking processes. The study showed that students overall had lower levels of statistical thinking.

McClain, Cobb and Gravemeijer (2000) conducted a classroom-based design study with seventh grade students over 12 weeks. The aim of the study was to examine the development of students' reasoning about data through an instructional sequence. In one of the activities, students were given two datasets about two different brand batteries' lives. One of the batteries had higher values but there was a big difference between its' highest and lowest values; the other battery's values were close to each other. Students' task was to determine the best battery to buy by comparing their battery lives. Students were engaged in both small group and whole class discussions during the instruction. With the whole class discussions, students decided to focus on consistency concept. They thought that the battery with more consistent battery life values would be more durable. So at the end of the activity, they decided to buy the battery which had more consistent battery life values. This study showed that when students were trying to decide which battery was better by comparing two given datasets, the whole class discussions helped them to focus on the idea of consistency in the data for their decision making. Also with whole class discussions, they considered the more consistent data as the one which had a smaller range of values.

1. 2. Realistic Mathematics Education (RME)

RME is a mathematics education approach developed by Freudental and his colleagues in 1971 in Utrecht University (Yağcı and Arseven, 2010). Freudental (1991) describes mathematics as a human activity. According to Freudental (1991) learning mathematics starts in real life and ends with comprehending the mathematical concept. The RME approach is similar to consructivist theory in this perspective. In both approaches, students learn mathematics via examples that make sense to them. Another similarility between these approaches is that learner's active engagement is required. According to the RME approach, the individual acquires the knowledge only if s/he actively engages in the learning process and interacts with it (Freudenthal, 1991). Constructivist theory states that students construct knowledge by themselves, but the theory cannot give satisfactory anwers to the questions of what is constructed and how it is constructed (Gravemeijer, 2008). According to Gravemeijer (2008), the RME approach can address these questions via didactical phenonomology principle. Didactical phenomology advocates that in a class every student perceives the same concept according to their own perception system (Freudenthal, 1991). Hence, the RME approach assumes that every individual learns mathematics with his/her own perceptions.

The fundamental point of RME is that the lesson should begin with a reliastic problem context. RME emphasizes teaching mathematics to students via problems that are real or can be conceived as real in students' minds through constructing meaningful concepts (Van den Heuvel-Panhuizen, 1996). The teaching activity should be initiated with a real context problem and the problem needs to foster learner's curiosity for solving it (Van den Heuvel-Panhuizen, 1996).

Freudenthal (1991) advocated that mathematics can only be learned via mathematization which is a key process in the RME framework. More specifically, mathematization is described as the learning process of the student through his/her own experiences (Van den Heuvel-Panhuizen, 2003). There are three instructional design heuristics of RME to support mathematization: didactical phenomelogy, guided reinvention and emergent modeling (Gravemeijer, 2008). The basic principle of RME is the didactical phenomology (Freudenthal, 1991; Van den Heuvel-Panhuizen, 1996 and Gravemeijer, 2008). Didactical phenomology puts student to the center: Problems should be meaningful for her/him and s/he should actively engage in the learning process.

In RME, didactical phenomology takes place through horizontal mathematization and vertical mathematization. Treffers (1991) suggested the idea of horizontal and vertical mathematization but Freudenthal finalized these two processes. Horizontal mathematization refers to transfering a given real world problem to mathematics (Van den Heuvel-Panhuizen and Weijers, 2005). That is, horizontal mathematization is transition from real life to mathematics. On the other hand, vertical mathematization is beyond horizontal mathematization and involves thinking in the world of mathematics without real life context (Freudental, 1991). In vertical mathematization process, students can transfer information in mathematics (Freudenthal, 1991). To achieve vertical mathematization, students firstly complete horizontal mathematization process. This is called progressive mathematization (Van den Heuvel-Panhuizen, 2003).

RME also provides some guidelines for teaching procedures and teachers' roles. For example, guided reinvention focuses on teachers' role by indicating that teachers should prepare high quality problems and guide students' learning (Freudenthal, 1991). Besides, emergent modeling instructional design heuristic advocates that students can learn mostly via mathematical models (drawings, tables, graphs etc.) which are developed by the students themselves (Gravemeijer, 2008). Also, there are six teaching mathematics principles in the RME framework: activity principle, reality principle, level principle, intertwinement principle, interaction principle and guidance principle (Van den Heuvel-Panhuizen and Weijers, 2005). The activity principle indicates that students should actively participate in the learning process. The reality principle advocates that problems used in teaching should be real or can be conceived as real in students' minds. According to the level principle, learning should proceed from simple to hard and concrete to abstract. The intertwinement principle is about relations between mathematical concepts and relations between mathematics and other sciences. The interaction principle is related to social activity and emphasizes the learning mathematics through social interaction. Lastly, the guidance principle suggests that teachers should help students and guide them in their learning.

RME is a mathematics education approach advocating that mathematics should be close to daily life. The aim is to develop conceptual understanding via real-life context problems. Conceptual understanding is also important for statistical thinking. Since the context plays an important role in solving statistical problems (Bakker, Kent, Derry, Noss and Hoyles, 2008), the use of RME approach in teaching statistics can provide an opportunity for making the statistical problem situation real for students. Therefore, this study focuses on the use of RME approach in promoting students' statistical thinking in a sixth-grade classroom.

In related literature, there are many studies that investigate the effectiveness of RME approach on learning of various mathematics topics at different grade levels. In these studies, it is generally found that the RME approach can improve students learning on different mathematics topics, such as probability (Akkaya, 2010), geometry (Bıldırcın, 2012; Özdemir ve Üzel, 2013) and algebra (Van den Heuvel-Panhuizen, 2003; Althauser and Harter, 2016) However, there is a scarce of research in teaching statistics using RME approach. Therefore, this study contributes to the existing literature by focusing on the use of RME approach in relation to 6th grade students' statistical thinking.

1. 3. Aim and Research Problems

The aim of this research is to investigate the effectiveness of RME approach on developing sixth grade (age 11) students' statistical thinking. Accordingly, four research questions are examined:

1) Does RME approach contribute to significant development of the statistical thinking for sixth grade students?

2) Does RME approach is more effective in developing statistical thinking than traditional teaching for sixth graders?

3) What is the level of statistical thinking of sixth grade students?

2. Method

A quasi-experimental design with pretest and postest was used in the study in the spring of 2018 in Aydın, Turkey. Two intact sixth grade classes where the first author taught mathematics were selected. Statistical thinking test was applied to both groups at first and the groups were found equal in the pretest scores. In the experimental group, lessons were taught via RME approach whereas in the control group lessons were taught traditionally using a mathematics textbook and direct instruction for three weeks. At the end of a three-week instruction, statistical thinking test was applied to both groups again as a postest.

2. 1. Participants

The subjects in the study were 49 sixth grade students: 25 students (9 males and 16 females) were in the expemential group and 24 students (10 males and 14 females) were in the control group. The students in both groups had similar socioeconomic and educational background. In terms of their statistical knowledge, the sixth graders already had known how to calculate arithmetic mean and range from their science classes and how to make a bar graph; but comparing two data sets was new to them as it was thought in the sixth-grade mathematics.

2. 2. Instrument

In this study, the data collection instrument was a statistical thinking test constituted of seven open-ended questions some of which were adapted from previous studies (Kazak, 2016; Koparan & Güven, 2013). The questions focused on the four statistical thinking processes described in Mooney's (2002) statistical thinking framework: describing data (question 5), organizing and reducing data (questions 2 and 3), representing data (questions 1 and 4) and analyzing and interpreting data (questions 6 and 7). Before the experiment, the test initially piloted with 75 sixth grade students and its Cronbach's alpha coefficient was found 0.76, which is acceptable (Baykul & Güzeller, 2014). The test applied to both groups as pretest and posttest and then students' statistical thinking levels were determined.

2. 3. The Procedure and Data Collection

In the control group, each lesson on 'Data Handling' unit was taught traditionally using the 6th grade mathematics textbook (Güven, 2017). The teacher followed the sequence of content in the textbook. The direct instruction involved providing students with explanations and examples of knowledge being taught with the use of the whiteboard and the students wrote them to their notebooks. Problems were written to the whiteboard and some time was given to the students to solve the problem on their own. After the teacher checked students' solutions, the problem was solved by a voluntary student on the whiteboard. After the student solved the problem, the teacher explained the solution to the whole class.

RME approach was used in the experimental group where low and high ability students worked in pairs. According to Freudenthal (1991), if low and high ability students worked together, both of them would benefit from the work maximally. There were 12 groups in total. The group work was followed by whole class discussions. At the beginning of the study, classroom ground rules regulating how students work in groups and how they do classroom discussions were established together with students and the teacher. Some of the rules were: "While someone is speaking, others must listen" and "In a group every member must work and help each other".

In the experimental group, two RME activities for the 'Data Handling' unit were implemented using the PPDAC investigative cycle steps (Wild & Pfannkuch, 1999). While there are several other versions of the frog task in the literature, the Frog Olympics task was adapted from Kazak, Pratt and Gökce (2018) using the RME approach. The task took eight class periods each of which lasted 40 minutes. A problem situation that can be viewed real by the students when engaging in statistical thinking was created in the task. There were two different sized frogs which were done by the students via origami (see Figure 2). The aim of making two types of frogs was to get two datasets to compare; because frogs' sizes were different, their jumping distances would be different. The students tried to determine the best jumping frog to go to the Olympics by investigating each frog's jumping distances. Students made each kind of origami frogs jump 13 times on their desk and recorded the results (i.e., the jumping distances in cm rounded into the nearest integer). After the data gathering part, students made frequency tables and bar charts to organize and represent their data to analyze them. Each pair presented their findings to the whole class. Lastly, via whole class discussion they determined the most appropriate frog to go to the Olympics.

Figure 2: *The two types of origami frogs, big and small, used in the Frog Olympics task*

Students used aritmetic mean and range for each frog's jumping distances based on the group's data while deciding which frog should go to the Olimypics. In the whole class combined data, the big frog's aritmetic mean was 22,46 cm and its range was 14 cm; the small frog's aritmetic mean was 23,46 and its range was 35 cm. The best candidate for the olympics was the big frog since both frogs' jumping distance aritmetic means were close to each other but the big frog had more consistent jumping distances. Students came to this decision during a whole class discussion under the teacher's guidance.

The second RME activity was conducted during three lesson periods. As part of the physical education class, students collected their own long jump distances like the frogs. They jumped 13 times and measured the distance in one long jump. Then they tried to decide which one was the best to go to the Jumping Olympics. They again created frequency tables and bar charts from their data, did calculations to interpret the data, presented their results and had whole class discussions. Figure 3 showsone group's bar chart as an example. The students as a class appeared to determine the best candidate more rapidly in this activity. According to the PPDAC investigative cycle described by Wild and Pfannkuch (1999), in this RME activity students firstly defined the problem, and then developed a plan to solve it based on their experience during *the Frog Olympics task*. In the data stage, students made frequency tables and bar charts to display the data. In the analysis stage, they calculated measures of center and spread for the dataset. Finally, in the conclusion stage, they reached a solution about the best candidate for Jumping Olympics through whole class discussions.

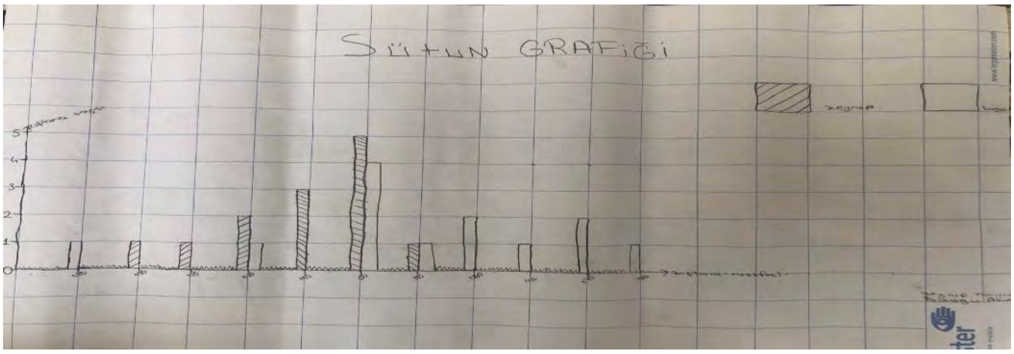

Figure 3: *Bar Chart of Students' Jumping Distance*

In these instructional activities, RME teaching principles were utilized. Students were active in the whole process (activity principle), problem contexts were close to real life (reality principle), activities were designed through simple to hard (level principle), relation between mathematics and other sciences were emphasized during activities (interwinement principle). Students also used statistical calculations learned in their science class, so relations could be more visible. Interaction principle was used through small group work and whole class discussions. During the instruction process, the teacher guided students according to guidance principle and guided reinvention. From didactical phenomology principle perspective, students constructed their own models related to emerging modeling heuristic and made connection between real life and mathematics world according to their own perception system.

2.4. Data Analyses

The data collected from the statistical thinking test (both pretest and posttest) were analyzed using Mooney's (2002) statistical thinking framework. For each item in the test, firstly expected student responses were identified according to the descriptors of statistical thinking levels. Then the authors independently coded student responses on each question using this coding scheme. The authors' codings were 88% consistent. Different codings were dissussed and both authors agreed on a rubric. Students' answers were coded and scored according to this rubric. For example, in describing data process the description for Level 1 idiosyncratic student response included "demonstrates little awareness of display features, not able to recognize or uses irrelevant features or reasons to recognize the same data represented by different data displays". The student response similar to this description got 1 point for that question. Description for Level 4 analytical student response in describing data process included "demonstrates complete awareness of display feautures including which feautures are relevant or irrelevant, uses quantitative relationships between displays to recognize when different displays represent the same data". The student response resembling this descriptor receieved 4 points in this question. Total points were calculated to determine the students' overall statistical thinking test score. These data were analyzed via using SPSS 22.0 programme. To decide which statistical test would be appropriate, normality tests were done first. All tests showed normal distribution. So, aritmetic mean, standart deviation and t tests were used to compare each group's pretest and postest scores as well as groups' posttest scores. Moreover, descriptive statistical analyses were done to examine the change in students' statistical thinking levels from pretest to posttest.

3. Findings

The aim of this research was to investigate the effectiveness of the RME approach on sixth grade students' statistical thinking. Therefore, pretest and postest scores were compared within groups and between groups. Also, changes in students' statistical thinking level were investigated with descriptive statistical analyses.

Table 1 displays the comparison of statistical thinking pretest scores between the experimental group and the control group. There was no significant difference between groups' statistical thinking pretest scores ($p=0.986>0,05$). This finding indicates that the groups were equal regarding statistical thinking.

Table 1. *The comparison of the statistical thinking pretest scores between the experimental group and the control group*

Groups	N	$\bar{X}$	SD	p
Experimental	25	13.56	3.501	0.986
Control	24	13.54	3.753	

Table 2 shows the results of paired t-test on statistical thinking pretest and posttest scores for experimental and control groups. In both groups, students performed better on the postest. The arithmetic mean of the experimental group's posttest scores ($\bar{X}$=18.04) is higher than the pretest arithmetic mean ($\bar{X}$=13.56). Similarly, the arithmetic mean of the control group's posttest scores ($\bar{X}$=16.17) is higher than the pretest arithmetic mean ($\bar{X}$=13.54), but not as much as in the experimental group. According to the t-test results, in each group there was a significant difference between students' pretest and posttest scores ($p=0.003 < 0.05$ for the experimental group; $p=0.000 < 0.05$ for the control group). According to these results, both RME approach and the traditional approach depending on the textbook and direct instruction appeared to be effective on developing students' statistical thinking.

Table 2. *The results of pretest and posttest scores for experimental and control groups*

Groups	Tests	N	$\bar{X}$	SD	p
Experimental	Pretest	25	13.56	3.501	.003*
	Posttest	25	18.04	5.488	
Control	Pretest	24	13.54	3.753	.000*
	Postest	24	16.17	5.088	

Table 3 displays the comparison of statistical thinking posttest scores between the experimental group and the control group. Although the arithmetic mean of the experimental group ($\bar{X}$=18.04) was higher than the arithmetic mean of the control group ($\bar{X}$=16.17), there was no significant difference between groups' statistical thinking posttest scores (p=0.222>0,05). This finding indicates that the effectiveness of both the traditional approach and the RME approach on the students' statistical thinking was similar. Given that the experimental group's posttest scores were slightly higher than the control group's posttest scores, next we closely look at the changes in students' statistical thinking levels (from pretest to posttest) by each group.

Table 3. *The comparison of the statistical thinking posttest scores between the experimental group and the control group*

Groups	N	$\bar{X}$	SD	p
Experimental	25	18.04	5.488	0.222
Control	24	16.17	5.088	

The distribution of the experimental group students' statistical thinking levels for each question organized by the four statistical thinking processes on the pretest is displayed in Figure 4. Each statistical thinking level is shown with different color on the bars and the numbers represent the number of students in each of these levels by the questions. For instance, in the describing data process (question 5 being the related item) there were 18 students at Level 1, 4 students at Level 2, 1 student at Level 3 and 2 students at Level 4. As seen in Figure 4, on the pretest, the majority of the students in the experimental group generally were at Level 1 with regard to describing data (question 5), representing data (question 1 only) and analyzing and interpreting data (question 6 and 7) processes. However, for organizing and reducing data process (questions 2 and 3), they mostly exhibited Level 3 thinking. There were only a few students at Level 4 thinking overall.

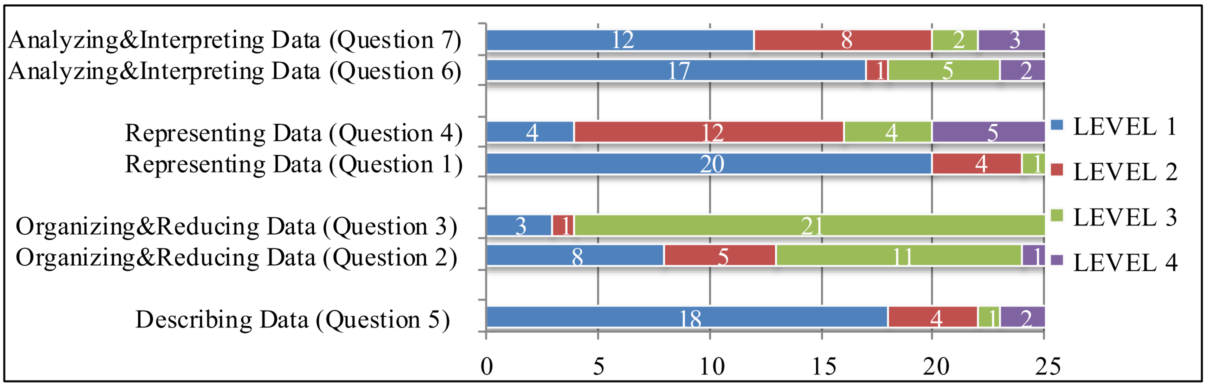

Figure 4: *Experimental group students' statistical thinking levels with respect to statistical thinking processes (by question) on the pretest*

Figure 5 shows the distribution of the control group sudents' statistical thinking levels on the prestest. Similar to the experimental group's results (Figure 4), the majority of the students in the control group initially demonstrated Level 1 thinking for representing data and analyzing and interpreting data. About half of the students exhibited Level 1 thinking with regard to describing data. The students' statistical thinking mostly was at Level 3 for organizing and reducing data process.

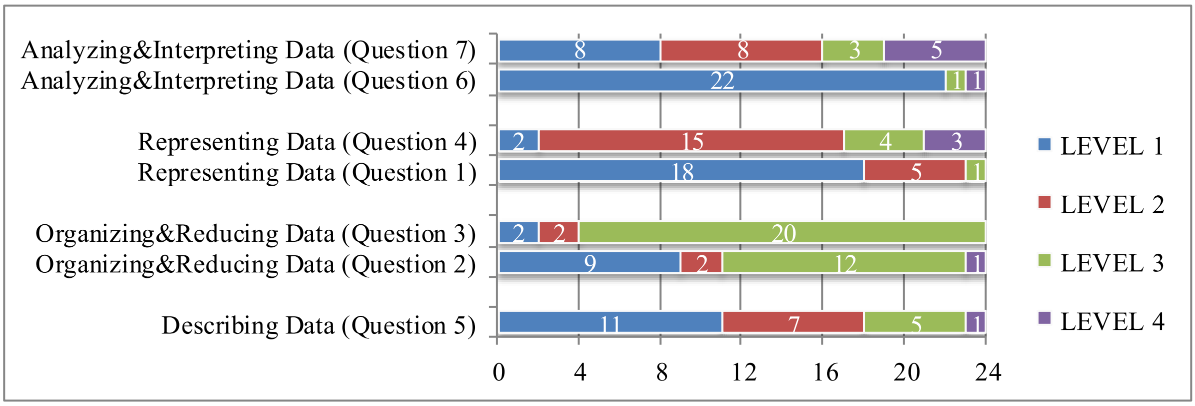

Figure 5: *Control group students' statistical thinking levels with respect to statistical thinking processes (by question) on the pretest*

The distribution of the experimental group students' statistical thinking levels on the posttest is displayed in Figure 6. In the experimental group, the students were generally at Level 3 and Level 4 with respect to the most questions after the intervention. About half of the students or more were at Level 3 and Level 4 with respect to the two statistical thinking processes, namely organizing and reducing data and analyzing and interpreting data. Majority of the students still exhibited Level 1 and Level 2 thinking with regard to describing data. However, overall there were fewer students at Level 1 and Level 2 in comparison to the pretest results.

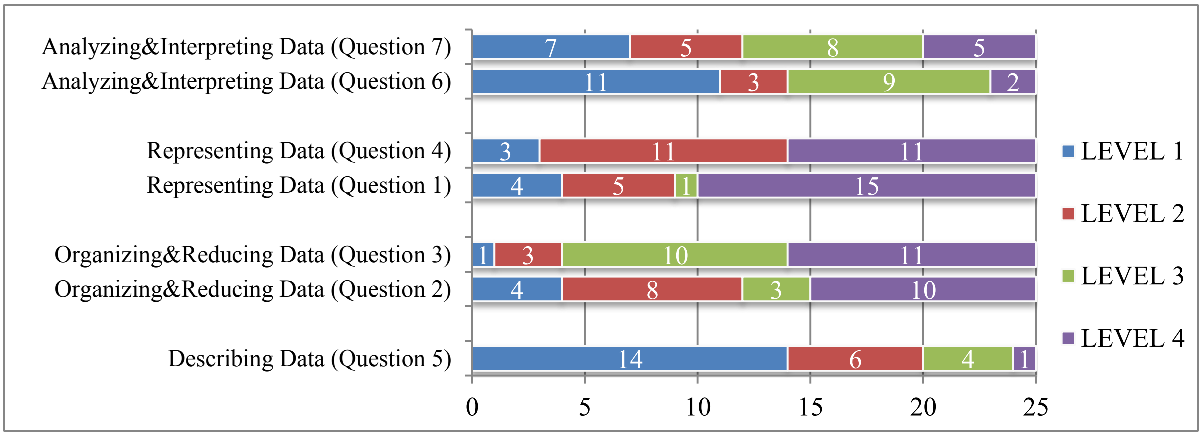

Figure 6: *Experimental group students' statistical thinking levels with respect to statistical thinking processes (by question) on the posttest*

Figure 7 shows the control group students' statistical thinking levels on the posttest. In the control group, there were 13 students in question 1, 10 students in question 2, 20 students in question 3, 10 students in question 4, 9 students in question 5, 17 students in question 6 and 14 students in question 7 at Level 3 and 4. In the posttest, there were more students at Level 3 and Level 4 in the experimental group than the control group. However, there were more students at Level 1 and Level 2 in the control group posttest scores in comparison with the experimental group posttest scores. It can be said that the RME approach promoted higher statistical thinking levels more than the traditional approach.

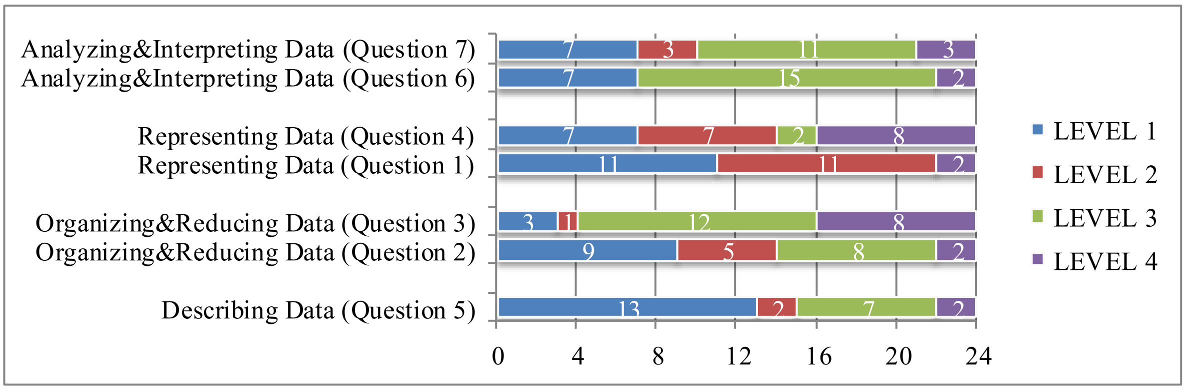

Figure 7: *Control group students' statistical thinking levels with respect to statistical thinking processes (by question) on the posttest*

To examine the changes in students' statistical thinking levels after the instruction in both groups in detail, we summarized the results as positive change (shifts in the number of students from a lower level to a higher one), negative change (shifts in the number of students from a higher level to a lower one) and no change (the number of students remaining in the same level) from pretest to posttest. In the following tables, E represents the number of students in the experimental group, C represents the number of students in the control group and Q represent questions on the test as question 1, question 2 and etc. Columns show the level changes, e.g. "from 1 to 2" means "From Level 1 to Level 2".

Table 4 shows the number of students in both experimental and control groups who had positive change, that is an increase in their statistical thinking level. Of 25 students in the experimental group, 21 in question 1, 13 in question 2, 14 in question 3, 10 in question 4, 10 in question 5, 7 in question 6 and 12 in question 7 increased their statistical thinking levels after the instruction with RME approach. On the other hand, of 24 students in the control group, 9 in question 1, 6 in question 2, 9 in question 3, 6 in question 4, 7 in question 5, 15 in question 6 and 7 in question 7 raised their statistical thinking levels after the instruction with traditional approach. When experimental and control group's results were evaluated together, it was seen that except question 6, there were more students who raised their statistical thinking levels in the experimental group compared to the control group. This suggests that RME approach had more effect on sixth grade students' statistical thinking than the lessons taught via the textbook.

Table 4. *The number of students with positive change in their statistical thinking level from pretest to posttest in experimental (E) and control (C) groups*

Levels/ Questions	From 1 to 2		From 1 to 3		From 1 to 4		From 2 to 3		From 2 to 4		From 3 to 4	
	E	**C**	**E**	**C**	**E**	**C**	**E**	**C**	**E**	**C**	**E**	**C**
Q 1	5	7	1	0	10	0	0	0	4	2	1	0
Q 2	4	3	0	1	1	0	0	0	4	0	4	2
Q 3	1	0	2	1	0	0	0	0	1	0	10	8
Q 4	1	0	0	0	1	0	0	0	5	3	3	3
Q 5	6	1	1	2	0	0	2	3	1	0	0	1
Q 6	3	0	3	14	0	1	1	0	0	0	0	0
Q 7	3	0	3	3	1	1	4	3	0	0	1	0

In Table 5, the number of students in both experimental and control groups who had negative change in their statistical thinking levels was displayed. In the experimental group, none of the students exhibited a decrease in their statistical thinking levels in questions 1 and 6 while only 2-5 students had a lower statistical thinking level in the other questions. The decrease in statistical thinking levels was seen especially from Level 3 to Level 2. However, in the control group, 1 student in question 1, 6 students in question 2, 2 students in question 3, 6 students in question 4, 5 students in question 5 and question 7 showed a decrease in their statistical thinking levels. There was not any student who decreased statistical thinking level in question 6. In the control group, the descrease in statical thinking levels was seen generally from Level 2 to Level 1. Overall, there were fewer students who decreased statistical thinking levels in the experimental group than the control group. That is, the experimental group students were more successful in impoving their statistical thinking.

Table 5. *The number of students with negative change in their statistical thinking level from pretest to posttest in experimental (E) and control (C) groups*

Levels/ Questions	From 2 to 1		From 3 to 1		From 3 to 2		From 4 to 1		From 4 to 2		From 4 to 3	
	E	**C**	**E**	**C**	**E**	**C**	**E**	**C**	**E**	**C**	**E**	**C**
Q 1	0	0	0	0	0	1	0	0	0	0	0	0
Q 2	0	2	1	2	3	1	0	0	0	1	0	0
Q 3	0	1	1	1	2	0	0	0	0	0	0	0
Q 4	1	5	0	0	1	0	0	0	3	0	0	1
Q 5	1	3	1	2	0	0	1	0	0	0	1	0
Q 6	0	0	0	0	0	0	0	0	0	0	0	0
Q 7	2	2	0	0	0	0	0	1	0	0	0	2

Table 6 shows the number of students who had the same statistical thinking level in the pretest and posttest in both groups. In the experimental group, 4 students in question 1, 8 students in question 2 and 3, 12 students in question 4, 11 students in questions 5 and 7 and 18 students in question 6 had no change in their statistical thinking level. The majority of students appeared to be stable at Level 1. Especially in question 5 and 6, almost half of the students' statistical thinking level had no change. In the control group, 14 students in questions 1 and 3, 12 students in questions 2, 4, 5 and 7, and 9 students in question 6 had no change. Of the 24 students in the control group, almost half of the students had no change in their statistical thinking level across all questions.

Table 6. *The number of students with no change in their statistical thinking level from pretest to posttest in experimental (E) and control (C) groups*

Levels/ Questions	From 1 to 1		From 2 to 2		From 3 to 3		From 4 to 4	
	E	**C**	**E**	**C**	**E**	**C**	**E**	**C**
Q 1	4	11	0	3	0	0	0	0
Q 2	3	5	1	0	3	7	1	0
Q 3	0	1	0	1	8	11	0	0
Q 4	1	2	6	7	0	1	2	2
Q 5	11	8	0	1	0	2	0	1
Q 6	11	7	0	0	5	1	2	1
Q 7	5	4	2	3	1	3	4	2

Overall, in the experimental group 87 positive changes, 18 negative changes and 69 no change were observed in students' statistical thinking levels while in the control group, there were 59 positive changes, 25 negative changes and 85 no change. In the experimental group, there were more positive change and no change and fewer negative changes than the control group. These results suggest that the activities done in the experimental group were more effective in developing students' statistical thinking. In both groups, the most development was seen in representing data process and the least development was seen in describing data process. The experimental and control groups' pretest results were similar; students were generally at Level 1 and Level 2. But in the posttest, there were more Level 3 and Level 4 students in the experimental group. It can be argued that the RME approach is an effective way of developing students' statistical thinking.

4. Conclusion

In the study, a pretest-posttest quasi-experimental design was used to investigate whether the use of instruction based on RME approach has an effect on developing sixth grade students' statistical thinking. The RME approach was used in the experimental group while the lessons were taught traditionally using the textbook in the control group over three weeks. There was a significant difference between statistical thinking pretest and posttest scores in each group. Both the RME approach and the lessons taught using the textbook were effective on developing students' statistical thinking. Although there was no significant difference between each group's statistical thinking posttest scores, more detailed descriptive analyses showed that the RME approach helped students to increase their statistical thinking levels more.

When the changes in students' statistical thinking levels were investigated closely, the least development was seen in describing data process in both groups. This result is similar to Mooney's (2002) and Jones et al.'s (2000) findings. According to Shaughnessy (2007), in describing data process in Level 3 and Level 4, it is expected to make proportional reasoning about data and it becomes hard for sixth grade students. In Turkey, students learn the ratio-proportion topic and proportional reasoning in the seventh grade. So, reaching Level 3 and Level 4 in describing data process became difficult for the sixth-grade students in general. The most development in statistical thinking was observed in representing data process in the experimental group. This may be because of the realistic problems used in the RME activies. In the control group, on the other hand, the most development in statistical thinking was seen in analyzing and interpreting data process. Since the textbook involved many problems requiring students to calculate arithmetic mean and range of a given dataset, these practices might have helped the students in the control group. Since there was a significant difference between control group's prestest and posttest scores, it can be suggested that teaching based on the textbook was also succesfull in developing students' statistical thinking. Even though the lessons taught via the textbook were also effective in developing students' statistical thinking to some extend, there was no emphasis on conceptual learning. The textbook just provided the information and posed some problems in which students needed to calculate arithmetic mean and range, rather than to understand their meanings. The study shows that the RME activities can be effective in developing students' statistical thinking. Therefore, the textbooks can be enriched with problems that give emphasis on higher order thinking skills. As Çakmak and Durmuş's (2015) study points out, students need to develop a conceptual understanding, so textbooks can be enriched with more RME activities.

The results of this study were consistent with some other findings in the related literature. Similar to Koparan and Güven's (2013) study, students' statistical thinking levels were generally at Level 1 in both groups' pretests. This shows that students may have difficulties in developing statistical thinking and therefore it is important to focus on development of statistical thinking during the instruction. Morevoer, as seen in Mooney's (2002) and Jones et al.'s (2000) studies, students in this study generally had problems in describing data process since it required proportial reasoning. Therefore, teachers should provide activities related to proportional reasoning skills in statistical problem contexts.

The study is restricted with the two RME activities and the textbook. More RME activities can be done in the experimental group as well as different teaching approaches can be used in the control group. So RME and different teaching mathematics approaches can be compared in teaching statistical thinking to middle school students. In RME activities, there could be more examples related to describing data, analyzing data and interpreting data. By this way, students may be more familiar with these statistical thinking processes. Lastly, classroom ground rules are very important for effective group work and classroom discussions. Therefore, we suggest establishing the classroom ground rules with students before starting the activity.

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