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How Realistic Mathematics Education approach influences 6th grade students’ statistical thinking

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Using Mooney’s (2002) framework describing four levels of middle school students’ statistical thinking across four different statistical thinking processes, this study aims to investigate the effectiveness of the use of Realistic Mathematics Education (RME) approach on 6th grade students’ statistical thinking levels. A quasi-experimental with pretest-posttest comparison group research design was used. In the experimental group the unit on ‘data handling and analyses’ was taught using RME approach while in the control group it was taught traditionally using the textbook. The data analysis showed that although there was no statistically significant difference between the two groups with regard to their statistical thinking scores, 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.

Keywords: Realistic mathematics education, statistical thinking, middle school students.

Introduction

We are surrounded by a huge amount of information in our daily lives and it is becoming more important to make sense of the information. To do so, individuals need higher order thinking skills such as questioning, making interpretation and estimation, drawing inference, critical thinking and reasoning. Curricular reforms emphasize these skills in students’ learning. For example, the Turkish National Mathematics Curriculum (MEB, 2018) aims to develop students’ understanding of mathematical concepts and their use in the daily life, reasoning skills in problems and ability to detect inadequate reasoning, metacognition, making mental calculations and estimations. Similarly, earlier in the Netherlands such reform aimed to change the education system which was based on memorizing (Van den Heuvel-Panhuizen, 1996). In 1971, Freudenthal and his colleagues laid the foundations of Realistic Mathematics Education (RME) with the aim of teaching the connection between real life and mathematics (Van den Heuvel-Panhuizen, 1996). For Freudenthal (1991), two key points in RME are: (1) mathematics should be close to students’ everyday lives and (2) mathematics is a human activity.

In daily life, we encounter with various data on newspaper, television and social media. Statistical concepts enable us to make decisions and solve real-world problems using data. However, students’ difficulties in learning of statistics and probability can hinder these. Some of the sources of these difficulties in Turkish middle school students appear to be the teaching of statistical concepts and procedures without connections, memorization rather than conceptual understanding, and learning without concrete examples (Çakmak & Durmuş, 2015). This implies that statistics must be relevant to students’ experiences and real life situations. The use of RME approach in teaching can support making the statistical problem situation become real for students since the context plays an important role in statistics.
While there are studies on the effective use of RME in learning of other mathematical topics, such as percentages (Van den Heuvel-Panhuizen, 2003) and integers (Ünal Aydın & İpek, 2009), there is a scarce of research in teaching statistics using RME. Therefore, this study, which is part of the first author’s master’s thesis work, sought to examine the effectiveness of RME approach on 6th grade students’ statistical thinking. The research questions addressed in this paper are: 1) Is there a significant difference in students’ statistical thinking posttest scores using the RME approach compared to traditional method? 2) What are the students’ thinking levels with respect to the statistical thinking processes before and after the intervention in each group?

**Statistical thinking**

Statistical thinking refers to comprehending the meaning of statistical concepts and understanding where, why and how they are used (Garfield & Ben-Zvi, 2008). That is, statistical thinking is not just calculating something or defining it. It is also about reasoning, making interpretations, predictions and inferences about data. Statistical thinking is important in solving a statistical problem about a real-world phenomenon through an inquiry cycle, called PPDAC (Problem-Plan-Data-Analysis-Conclusion) (Wild & Pfannkuch, 1999). The PPDAC cycle starts with understanding and defining a problem. Then what to measure and how to collect data are planned. Data collection phase is followed by analyzing data through looking for patterns and constructing tables and graphs. Finally, data are interpreted and conclusions are made and communicated.

To interpret middle school students’ statistical thinking Mooney (2002) considers four statistical processes used in Jones et al.’s (2000) framework for elementary students: describing data (explicit reading of data presented in visual displays), organizing and reducing data (arranging, categorizing, and summarizing data using measures of center and spread), representing data (constructing visual display of data) and analyzing and interpreting data (identifying patterns in data and making inferences and predictions from the data). According to Mooney’s refined framework, 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, student shows no awareness of the given data; gives answers according to his/her own experiences or feelings; cannot use concepts correctly; and cannot read the given situations. In Level 2, student shows little awareness of the problem but it is still not sufficient; the solutions may contain partially correct answers. In Level 3, student shows full awareness of the problem; can correctly use concepts and formulas, and express what they mean and why they are used; can correctly see and explain the relationships between concepts; however his/her solutions or demonstrations may contain some errors. Besides, s/he can use different representations of a given data set and make transitions between them with small errors. In Level 4-analytical, students can do all procedures without any error. That is, s/he can read the given data fully, make connections, use these relationships and necessary computations correctly as well as explain how and why s/he uses them. In addition to these abilities, s/he can display the given dataset with various representations and make transitions between them without any error.

Using Mooney’s framework, Koparan and Güven (2013) examined statistical thinking levels
of 90 Turkish middle school students. They found that 6th grade students’ statistical thinking generally was at Level 1. For example, the proportions of students at Level 1 varied across four statistical thinking processes: 49.3% in describing data, 65.3% in organizing and reducing data, 74.2% in representing data, and 80.8% in analyzing and interpreting data. These results showed that almost half of the students had difficulties in reading of data contained in tables and graphs. Moreover, majority of them failed to both construct a complete and appropriate display of data and compare datasets and make inferences based on data.

**Realistic mathematics education (RME)**

Freudenthal’s (1991) view of mathematics as a human activity indicates that knowledge becomes the individual’s own knowledge only if s/he interacts with and discovers it. To do this, the individual should actively participate in learning situations and deeply understand the meanings of mathematical concepts and their usage. According to Freudenthal, learning mathematics takes place via mathematization, which refers to the process of experiencing the discovery of the mathematics concept. In RME, mathematization is essential; without it, the process of learning mathematics cannot be completed (Freudenthal, 1991). Freudenthal (1991) expresses two forms of mathematizing as follows: Horizontal mathematization is transition from real world to mathematics and the vertical mathematization is doing mathematics in its world. In this study we focus on horizontal mathematization which takes place when the student encounters a mathematical problem and s/he starts to solve it. In this process, student makes drawings, identifies patterns and so on to transfer the real world problem to mathematics.

According to Freudenthal (1991) to learn mathematics, the student actively participate in the process, experience the discovery of mathematical concepts, try to solve the problem, develop ways and then the knowledge becomes his/her own. The teacher guides students when they need. One of the most important parts of RME is the problem situation, which should be concept oriented and make students curious enough to solve the problem.

**Method**

To explore the effectiveness of RME approach on students’ statistical thinking, a quasi-experimental with pretest-posttest comparison group research design was used since random assignment was not possible. The study was conducted in two intact 6th grade classes where the first author taught mathematics at a public school in Aydin, Turkey in the spring of 2018. In the experimental group (n=25), the unit on ‘Data Handling and Analysis’ was taught using RME approach while in the control group (n=24) it was taught traditionally using the textbook determined by the Ministry of Education. Both classes were taught over a three-week period.

**Data Collection and Analysis**

The instrument used in this study was the statistical thinking test with seven open-ended questions, some of which were adapted from Koparan and Güven (2013) while others were written by the authors. The questions were addressing the four statistical thinking processes: describing data (question 5), organizing and reducing data (questions 2 and 3), representing
data (questions 1 and 4), and analyzing and interpreting data (question 6 and 7). After experts’
evaluation of the test items, it was piloted with 75 sixth graders (in other classrooms in the
same school and the same school year as the research) to determine its reliability. The
Cronbach’s alpha coefficient of the test was found 0.76, which is considered acceptable
(Baykul & Güzeller, 2014). Then, the test was administered in both groups to assess students’
statistical thinking levels before and after the intervention.

Students’ responses on pre- and posttests were coded by both authors and scored using the
rubric developed based on Mooney’s (2002) framework for statistical thinking levels. There
was 88% consistency between two coders. Disagreements were discussed and consensus was
reached. The independent samples t-test showed that there was no difference on statistical
thinking pretest scores between the groups initially. In the posttest analysis, Mann Whitney U
test was used to determine the difference between the groups since the control group data
were not normally distributed. Also, descriptive statistics were used for the seven-item test to
examine the change in students’ thinking levels before and after the intervention.

Procedure and Tasks

In the control group, the ‘Data Handling and Analysis’ unit was taught with a traditional
approach using the 6th grade mathematics textbook (Güven, 2014). The teacher followed the
structure and order in the textbook and the problems given in the textbook were solved by the
students. In the experimental group using the RME approach, both low and high ability
students worked in small groups since both weaker and stronger students can benefit when
working in heterogeneous groups (Freudenthal, 1991). Moreover, students first worked in
groups and then the whole-class discussion of students’ work took place. Ground rules for
working together in groups were established with the students and implemented throughout
the lessons. These were the rules to promote effective group work, such as “while someone is
speaking, others must listen” and “in a group every member must work and help each other”.

The Frog Olympics task was adapted from Kazak, Pratt and Gökce (2018) and implemented
using the RME approach in the experimental group over eight class periods (each class
period=40 minutes). The aim of the task was to create a problem situation that can be viewed
real by the students as they engage in all four statistical thinking processes. In the activity
students tried to determine which frog would be the best to go to the Olympics. First, students
made two different origami frogs that could jump. Each group had one big frog and one small
frog. The arithmetic means of these frogs’ jumping distances were very close but the range
values were not. Then the problem situation was introduced and the students were asked to
determine the best jumping frog for the Olympics jumping race. Each group determined a
start line and made each frog jumped 13 times on their desk. For each trial they measured the
distance jumped and recorded the jumping distance in cm by rounding their measurement into
the nearest integer. Next, groups were asked to make a frequency table and each group
presented their data to the whole class. Then they were asked to make a graphical
representation of the data, i.e. bar graph, using their frequency tables. By doing this, they were
expected to make connections between different representations of a dataset. The following
teaching episodes focused on analyzing data and making decision. Using their prior
knowledge from the science classes, they calculated the range and mean of their datasets and
discussed together in their groups to decide which frog was better in jumping. Students already knew how to compute mean and range, but using them to compare two datasets was a new task for them. During the whole-class discussion, some groups thought that the small frog was better while some thought the big frog was better, and the teacher let them argue about their decisions. While groups were presenting their analysis and decisions, they had to explain why it was like that. Therefore, groups began to compare and contrast their ideas and a decision was made by a whole-class at the end of the discussion. In the next task, over the course of four class periods, the students were asked to collect data about their jump distances and record them during their physical education class. In the schoolyard, each group member jumped 13 times like frogs and another student measured the distance jumped. Then they made frequency tables and bar graphs of their data. As seen in the RME tasks students are expected to experience the whole statistical thinking process in PPDAC (Wild & Pfannkuch, 1999) while the textbook used in the control group puts more emphasis on calculations.

Findings

Before the intervention, independent samples t-test results showed no significant difference in the statistical thinking test scores for both groups (t (47) = 0.18 and p=0.986). In the posttest analysis, Mann Whitney U test indicated that although the mean rank of the experimental group (26.44) was higher than that of the control group (23.50), there was no statistically significant difference between the groups (p=0.47). Since the experimental group had the highest rank, descriptive statistical analysis was used to look closely for the changes in students’ thinking levels with respect to the statistical thinking processes for each group.

Figure 1 shows the distribution of the experimental group students’ statistical thinking levels for each question organized by the four statistical thinking processes on the pretest. Each column represents the item on the test and the statistical thinking process measured by that item. Colored sections of each column show the statistical levels of students and the number of students in each level for each question. For example, in Figure 1 the first column at the bottom shows the item on describing data (question 5) and there are 18 students at Level 1, 4 students at Level 2, 1 student at Level 3 and 2 students at Level 4.

According to Figure 1, before the intervention students in the experimental group mostly exhibited Level 1 thinking with regard to describing data (question 5), representing data (question 1 only) and analyzing and interpreting data (question 6 and 7). For organizing and reducing data (questions 2 and 3), they generally demonstrated Level 3 thinking. Only a few students exhibited Level 4 thinking overall. Similar to Koparan and Güven’s (2013) findings, students’ levels of thinking initially were generally at Level 1.
Figure 1: Experimental group students’ statistical thinking levels with respect to statistical thinking processes (by questions) on the pretest

Figure 2 shows the experimental group students’ statistical thinking levels on the posttest. Overall, most development was seen in students’ thinking levels with regard to representing data and organizing and reducing data as almost half of them were at Level 4. In addition, about half of the students demonstrated Level 3 or Level 4 thinking for analyzing and interpreting data. However, slightly more than half of the students still exhibited Level 1 thinking with regard to describing data.

Figure 2: Experimental group students’ statistical thinking levels with respect to statistical thinking processes (by questions) on the posttest

Figure 3 displays the control group students’ statistical thinking levels for the statistical thinking processes on the pretest. While slightly less than half of the students exhibited Level 1 thinking with regard to describing data, majority of them demonstrated Level 1 thinking for representing data and analyzing and interpreting data. There were very few students demonstrating Level 4 thinking for each process.

Figure 3: Control group students’ statistical thinking levels with respect to statistical thinking processes (by questions) on the pretest

Figure 4 shows the control group students’ statistical thinking levels for the statistical thinking processes on the posttest. Students mostly exhibited Level 1 thinking for describing data and Level 3 thinking for organizing and reducing data, and analyzing and interpreting data. On the other hand, students’ levels of thinking tended to be at Level 1 and Level 2 with regard to representing data. Overall, there was a growth in the development of students’ thinking after instruction, but less compared to the experimental group.
Conclusions

In this study, there was no statistically significant difference in the students’ statistical thinking posttest scores between the experimental group and control group. However, our descriptive statistical analysis of the change in students’ thinking levels with respect to the statistical thinking processes revealed further insights about the development of students’ thinking during the RME activity and the traditional instruction.

After the instruction, the least development in students’ thinking levels was seen for describing data process both in the experimental group and the control group. With regard to organizing and reducing data process, there was usually development from Level 1 to Level 3 or Level 4 in the experimental group while many students’ thinking levels shifted from Level 1 to Level 3 in the control group. The most development was seen in representing data process with the positive shifts in almost all students’ thinking in the experimental group and with many of these was at Level 4. There were also a few shifts in student’s thinking for representing data from Level 2 and Level 3 to Level 4 in the control group. While the control group students’ thinking levels were mostly at Level 3 and Level 4 for analyzing and interpreting data process after the instruction, the experimental group students’ thinking levels tended to shift slightly to Level 3 and Level 4. This could be due to the emphasis given to calculating statistical measures in the textbook used in the control group.

Overall, our findings suggested that the instruction using the RME approach helped students to develop their statistical thinking mainly for representing data and organizing and reducing data processes. For these two processes there was a noticeable increase in the number of students demonstrating Level 4 thinking while there was a corresponding decrease in the number of students exhibiting Level 1 thinking after the instruction. For analyzing and interpreting data process, the increase in the number of students was mainly at Level 3 thinking with a corresponding decrease at Level 1 thinking after the instruction. However, the findings indicated that students would need more experience in describing data when engaging in the RME activity as well as using the textbook. These results are consistent with previous research (e.g. Mooney, 2002) showing low student scores in describing data but high scores in analyzing and interpreting data, organizing and reducing data or representing data processes.
The non-significant statistical test results can be due to the sample size, which is comprised of about 25 students in each group. A study with larger sample size would give more reliable results. The present study is limited to quantitative methodology of data collection. In future a qualitative method can be undertaken for a deeper study of the change in students’ statistical thinking after an intervention using the RME approach.

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