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A Review of Master Theses about Mathematical Misconceptions Completed in Turkey between 2000 and 2013

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Abstract: *This research is a general review of theses on mathematical misconceptions completed in Turkey between 2000 and 2013. As a result of the search conducted using key words in thesis search website of Higher Education Authority of Turkey, 35 master theses completed during that period were found. It was observed that usually quantitative research methods and mixed methods were utilized in these theses. Of these, 6 was on numbers, 7 on algebra, 10 on geometry, 6 on probability and 6 on other subjects, and mathematical misconceptions of students, pre-service teachers and teachers were investigated. In this study, the results of the foregoing theses are presented by arranging them according to their subjects.*

Keywords: *Mathematical misconceptions, elementary school students, middle school students, pre-service teachers, teachers*

1. INTRODUCTION

Concept is general or abstract thinking that specifies multiple objects or experiences or describes the relationship between them. Concepts are obtained as a result of abstraction and generalization. Abstraction strips quality from the object, while generalization attributes quality to many objects. Students build these on their previous knowledge while learning new concepts.

Any mathematical concept has a basis, past, and there is a justification of its existence. Every concept defined by mathematicians is the result of a requirement. For example, the curve concept emerges from the concepts of line and circle, the concepts of continuity, limit and derivative emerge from the curve concept and the infinitesimal concept emerges from all these concepts (Nesin, 2007).

Pre-knowledge of students leads to misconceptions in learning new concepts. Misconception can be described as the fact that a person has opinions different from opinions on which experts have reached a consensus (Ubuz, 1999; Zembat, 2008). Students' mathematical misconceptions emerge as forms of perception, causing them to produce mistakes in a systematic way (Smith, diSessa, Roschelle, 1993).

A student with misconceptions will make mistakes on a regular basis while carrying out an operation or solving a problem. For an idea of a student to be considered a misconception, it should fulfill three conditions. These conditions include the fact that the student's idea does not match scientific facts, that s/he maintains this idea and is confident about his/her answers explanations (Eryılmaz, Sürmeli, 2002).

If students have misconceptions in their prior knowledge, they can prevent accurate learning and lead to new misconceptions. It is known that students acquire new knowledge by merging their existing knowledge with new information. Therefore, it is important for the quality of teaching that students' existing knowledge and misconceptions are identified and teaching activities are planned by taking these into consideration (Gilbert, Osborne, Fensham, 1982).

Misconceptions in mathematics education continue by learning concepts wrong from primary education until higher education. In recent years, research and thesis work have been carried out on various kinds of mathematical misconceptions in Turkey. By this article, master thesis studies

conducted on mathematical misconceptions in Turkey between 2000 and 2013 were searched, and it was examined on which subjects research studies on mathematical misconceptions were undertaken.

2. METHOD

This research is a review of documentation. Master theses completed in Turkey between 2000 and 2013 were identified using key word search in thesis search website of YÖK (Higher Education Authority of Turkey). After theses on mathematical misconceptions were identified, individual copies of these were downloaded from the website. Theses full-texts of which are not available on YÖK website were searched in libraries of respective universities, and copies of their relevant parts were obtained. Despite all efforts, it was not possible to obtain a copy of one thesis. Only the abstract of this thesis available on YÖK website was utilized.

A thesis classification and evaluation form was generated before analyzing the contents of master thesis copies obtained in this manner. This form was generated by including the following sections: which mathematical misconceptions the respective thesis investigated, research method, data collection instruments, sampling level, sample size and thesis results. All theses were examined and misconceptions were divided into five different topics, including numbers, algebra, geometry, probability and other topics.

The following were determined with respect to these theses: the method used in the respective theses, i.e. quantitative, qualitative or mixed method; data collection tool, the subjects of the research and the number of participants. Then, thesis results were examined and the results on each sub-topic were evaluated collectively.

3. FINDINGS AND CONCLUSIONS

As a result of key word search conducted on YÖK website, it was found that between 2000 and 2013, 35 master theses investigated the topic of mathematical misconceptions. In that period, no doctoral (Ph.D.) thesis on this topic was found. When the theses were classified by subject, it was seen that 6 of them was on numbers, 7 on algebra, 10 on geometry, 6 on probability and 6 on other topics. It was identified that 23 master theses utilized quantitative method, whereas 12 utilized mixed research methods. It was discovered that 21 theses were conducted on 5^{th} to 8^{th} grade students(primary education), 4 on 9^{th} to 12^{th} grade students(secondary education), 1 on teachers, 4 on subjects from various levels, and that 11 studies, the number of which was the highest, were conducted on 7^{th} grade students. In general, the mean number of samples in studies in which quantitative measurement tools were used was found to be 310. The number of samples and relevant details are given in table 1.

Table 1. *Number of samples in the theses*

Number of samples	Frequency	Percentage
1-25	3	0,086
26-100	8	0,228
101-250	9	0,257
251-500	9	0,257
501-750	1	0,029
751-1000	2	0,057
Higher than 1000	3	0,086
Total	35	1,000

The results obtained in the master theses were examined by grouping them as those misconceptions conducted on the subjects of numbers, algebra, geometry, probability and other topics.

3.1. Misconceptions about Numbers

Master theses conducted on misconceptions on the subject of numbers investigated misconceptions associated with sub-topics, including natural numbers, integers, decimals, numbers with square root, rational and irrational numbers.

Özdeş (2013) investigated 9th grade students' misconceptions associated with natural numbers by a study on 321 students and used an open-ended diagnostic test of 26-items. According to the results of this study, it was observed some of the 9th grade students think 1 is a prime number and they do not know the correct definition of natural numbers. In addition, the students were found to confuse real and rational number sets with each other.

In another thesis study conducted on the subject of integers with 38 elementary pre-service mathematics teachers (Kubar, 2012), these participants were asked two open-ended questions using mixed method. In addition, semi-structured interviews were conducted with four volunteer pre-service teachers. According to the results of this study, pre-service teachers followed 3 ways to define the concept of integer: "core concepts", "representation", and "other definitions". The results of the study indicate that some of the definitions made by pre-service teachers have shortcomings and mistakes.

The thesis by Yılmaz, 2007, which investigated 7^{th} and 8^{th} grade students' misconceptions about decimals, was a quantitative study conducted on 1,024 students from a total of 35 different schools. The results of this study showed that 8^{th} grade students make fewer mistakes than 7th grade students. It was understood that the students generalize some of the rules applicable to integers to decimal numbers, which is incorrect, Such as thinking that the longer the number the higher it is, that the product should be higher than multipliers, that the result of division should be smaller than the number which is divided , etc. Other than that, further mistakes such as placing decimals on the number line incorrectly and thinking that zeroes placed on the far right after the point change the value of the number (e.g. $2.75 < 2.750$) were discovered.

In other master theses conducted on the concept of numbers, 7^{th} and 8^{th} grade students' and pre-service teachers' misconceptions on the concept of numbers were investigated. In these studies, it was observed that some participants confuse irrational numbers with rational numbers, irrational numbers with complex numbers and think that any number with square root is an irrational number. In addition, they were found to have difficulty in writing rational numbers as decimal numbers (Adıgüzel, 2013; Alkan, 2009; Özcan, 2004).

3.2. Misconceptions about Algebra

In the master theses which studied misconceptions on algebra; topics of fractions, equations, ratio and proportion were investigated. It was clear that all of these studies were conducted on 4^{th} to 9^{th} grade students. Two of these studies, one of which investigated how activity-based education affect students' misconceptions about algebra (Akkaya, 2006), while the other, how computer-aided education affect students' misconceptions about algebra (Nasr, 2008), were experimental studies. In both studies, pre-and post-tests were applied to study participants' development and misconceptions.

In his thesis, Akkaya (2006) divided subjects into two groups and designated one group as the test group and the other as the control group. The test group was taught activity-based mathematics prepared to resolve misconceptions on 6th grade algebra topics, whereas the control group was taught in a traditional way. The results of this study showed that the students who received activity-based education had less misconceptions compared to those who received traditional education.

In the other study, which was an experimental study conducted on 6th grade students; computer-aided teaching of algebra was compared with traditional teaching (Nasr, 2008). The results of this study revealed that students who received computer-assisted education had fewer misconceptions than other students.

One of two thesis studies conducted with students from various grades by stratification method recruited 1035 7^{th} and 9^{th} grade students (Çetin, 2009), while the other recruited 1,051 4^{th} and 8^{th} grade students (Kocakaya Baysal, 2010). Both studies showed that as the grade level increases, students' mathematical misconceptions are reduced. Çetin's (2009) study also indicated that some of the students have the misconception that any fraction is a proportion. Results of other studies further showed that students have misconceptions, including that the order of operations is not

important in algebra, mathematical operations should be done from left to right, and any variable should only have one value (Kocakaya Baysal, 2010).

Other studies investigating students' misconceptions about algebra were conducted on sub-topics of fractions, equations and linear equations. In a thesis study conducted on 151 5th grade students, it was determined that the students had difficulty in arraging fractional numbers in decreasing order or marking them on the number line (Tarkan Yurtsever, 2012).

Erek's (2008) thesis study conducted on 18 7^{th} grade students revealed that students had misconceptions about exponential numbers and adding up fractions. For example, some students think that $x^5=5x$ or $\frac{1}{a}+\frac{1}{b}=\frac{1}{a+b}$. Other than these studies, it was not possible to obtain a copy of the thesis by Çavuş Erdem (2013), who determined 7th grade students' mistakes and misconceptions on equations and investigated teachers' opinions on such mistakes and misconceptions, thus we cannot report our opinions on the results of that thesis.

3.3. Misconceptions about Geometry

With 10 theses on misconceptions about geometry conducted in Turkish universities between 2000 and 2013, geometry was the subject which was studied the most. Of these theses, 8 investigated misconceptions on various sub-topics of students from one level of grade. A majority of these theses were quantitative descriptive research studies, and the highest and lowest numbers of samples used were 581 and 60, respectively.

In this context, three theses were conducted on 5^{th} grade students' misconceptions on the subjects of circles, rectangles, polygons, perimeter, area and volume (Başışık, 2010; Dağlı, 2010; Kaygusuz, 2011). Some of 5^{th} grade students' misconceptions on these subjects can be summarized as follows: The fact that students have difficulty in calculating areas and volumes of complex two- and three-dimensional shapes (Dağlı, 2010); the fact that some of the students cannot perceive irregular polygons as polygons, and that they think that polygons whose side lengths are the same should also have diagonals whose lengths are the same (Başışık, 2010). It was revealed that 5th grade students were mistaken the most on the subject of circle and the least on the concept of center, and that there was no significant difference between female and male students on making sense of the concepts (Kaygusuz, 2011).

Four different thesis studies conducted on various levels of grade about sub-teaching areas of geometry, including point, line, plane and other geometric objects were identified. In one of these theses, Başkurt (2011) applied a measurement tool of 12 open-ended questions to 461 participants from 6th, 7th, and 8th grade and investigated the students' misconceptions on point, line and plane. According to Başkurt's results, it was discovered that some of the students cannot perceive point as a region on a plane, that they confuse line with line segment, ray with line and draw finite geometric shapes such as a square or rectangle to define a plane (Başkurt, 2011).

Similarly, in another thesis study conducted on 6th, 7th, and 8th grade students, Baran (2011) investigated students' misconceptions on geometric objects. In this study, a measurement tool consisting of 14 multiple choice, 5 true/false and 6 open-ended questions was applied to 225 students. According to the results of this research, it was observed that some of the students assume that it is enough to know the length of two sides of a triangle to be able to calculate its area. It was further determined that students have difficulty in classifying triangles by side length (Baran, 2011).

In a thesis study by Yılmaz (2011) which investigated the relationship between 7^{th} grade students' misconceptions on the subject of line and angles and Van Hiele geometry levels, 15-question diagnostic test and 25-item test for level of comprehension of Van Hiele geometry were applied to 60 students. The results of this study showed that students' misconceptions decreased with increasing level of their understanding geometry (Yilmaz, 2011).

One of the studies investigating students' misconceptions on geometry in general was the study by Ayyıldız (2010), which compared misconceptions of students who keep a diary of their learning and those who don't. This study was conducted on 78 6th grade students, and its results

showed that students who keep a diary of their learning had less misconception than other students (Ayyıldız, 2011).

The results of Akuysal's (2007) research on 7th grade students showed that students define polygons as shapes with more than four edges and that they do not know the relationship between central angle and inscribed angle. In addition, the thesis by Kiriş (2008), conducted on 487 6th grade students, and the thesis by Doğan (2013), conducted on 98 12th grade students, investigated students' misconceptions on the subject of geometry, and they discovered that students usually cannot perceive infinity of lines, planes and space.

3.4. Misconceptions about Probability

In his thesis study, Mut (2003) investigated misconceptions of students from all grades between 5th and 10th on the subject of probability. A 14-item diagnostic test was applied to 885 students who participated in this study to determine eight different misconceptions about probability. According to Mut's findings, the frequency of students' misconceptions decreases with increasing grade level. In addition, it was revealed that students often have misconceptions of the effect of sample size and the effect of time (Mut, 2003).

In a study conducted in order to identify misconceptions of 8th grade students (primary education) on the subject of probability, 349 participants were asked 25 open-ended questions. The results of this study revealed that students confuse dependent events with independent events the most. In addition, students were found to have misconceptions about when to use combinations and when to use permutations while solving a problem (Dereli, 2009). In another thesis conducted on 8th grade students, a 41-item multiple-choice test was administered to 130 students (Hayat, 2009). Similar to what has been just mentioned, the results of this study revealed that students have misconceptions about dependent and independent events. Moreover, it was clear that students cannot comprehend that the probability value should be a value in the closed interval of [0, 1].

On a survey conducted on pre-service teachers and teachers, a total of 72 participants, including 17 pre-service teachers, 22 teachers with less than ten years of experience and 33 teachers with ten years or more than ten years of experience, were asked 9 open-ended questions (Doğucu, 2013). The results of the survey showed that there was no significant difference between experienced teachers' and pre-service teachers' misconceptions on the subject of probability. In another study conducted on pre-service teachers, 18-item diagnostic test, including 9 nine open-ended and 9 multiple-choice questions, was applied to 12 participants. Moreover, semi-structured interviews were conducted with the participants (İlgün, 2013). In this study, all participants were found to have timeline error and misconception on the subject of joint probability. In addition, it was discovered that more than half of the participants have misconceptions on the subjects of conditional probability, the impact of sample space, conflict error and representativeness heuristic (İlgün, 2013).

Sevimli (2010) conducted a thesis study on 102 pre-service teachers studying at graduate program for math teaching at Marmara University, Faculty of Education. In this distinct study, according to a 25-item multiple-choice concept test applied to the participants, it was observed that the participants have misconceptions on the rules of addition and multiplication in probability (Sevimli, 2010).

3.5. Misconceptions about Other Subjects

The results of 6 master theses concerning the subjects other than the above-mentioned four main topics are given here; these theses were conducted on misconceptions on the subjects of trigonometry, radians, graphs, basic math, vector spaces and problem solving.

In a study investigating 6th, 7th and 8th grade students' conceptual error while solving problems, Yılmaz (2007) applied an instrument containing 12 open-ended questions to 960 students. According to the findings of Yılmaz, it was seen that students make mistakes the most when units of the problem change while solving a problem. In addition, conceptual errors made by students decreased with increasing grade level of students. No statistically significant difference was established between the rates of conceptual error and gender of the students.

In a thesis study investigating 10^{th} grade students' misconceptions about trigonometry (Güntekin 2010), two diagnostic tests consisting of 18 multiple choice and 12 open-ended questions were administered to 205 students. According to the results of this study, some of the misconceptions of 10^{th} grade students were: The fact that students think that certain properties applicable to linear functions are also applicable to trigonometric functions, e.g. students assume that $\sin(x + y) = \sin(x) + \sin(y)$. Additionally, it was seen that some students have misconceptions such $\sin^2(x)=\sin(x^2)$ and $\sin^{-1}(x)=1/\sin(x)$. Moreover, in the same study, students were found to have difficulty in expressing angles in radian (Güntekin, 2010). Similarly, in another study investigating 10^{th} grade students' misconceptions on the subject of radian, it was discovered that students have difficulty in converting angle values from radian to degrees or from degrees to radian (Akbaş, 2008).

In a thesis study investigating pre-service classroom teachers' misconceptions in basic math course (Akbaba Dağ, 2009); mathematical misconceptions of 434 pre-service teachers studying at faculty of education were examined. According to the results obtained in that study, pre-service teachers were found to have misconceptions about continuous and discontinuous functions. In addition, it was discovered that the students of the faculty of education have misconceptions on the subjects of analytical examination of the circle and trigonometry.

In a thesis by Kazcı (2008) conducted on university students' misconceptions about vector space, 105 participants were asked 8 open-ended questions. According to the results of that study, students were found to confuse the concept of linear dependence with linear independence the most and have difficulty in deciding whether a given set of vectors is a basis vector or not. Furthermore, it was seen that students memorize vector space axioms, rather than understanding the concept.

Tortop (2011) investigated 7^{th} grade students' misconceptions about graphics, and reported that the mistake the students make the most is placing x and y coordinates incorrectly while drawing a graph. In addition, some students were found to think that the plot of any function should go through the origin (point of (0, 0)).

4. LIMITATIONS OF THE RESEARCH

It is clear that the studies reviewed in this article, in which master theses conducted on mathematical misconceptions of Turkish students and teachers in Turkey between 2000 and 2013 are briefly summarized, were usually conducted on students from a single school. Additionally, the results of diagnostic tests mostly prepared by the researchers as well as the results of semi-structured interviews conducted with several participants selected were consistent with the results of investigations and theses reported in the literature. However, these results are not expected to be generalizable to the entire population of Turkey.

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