Journal of Education and Learning; Vol. 5, No. 3; 2016
ISSN 1927-5250 E-ISSN 1927-5269
Published by Canadian Center of Science and Education

The Effect of Manipulatives on Mathematics Achievement and Attitudes of Secondary School Students

Hakkı Kontaş[1]

[1] Faculty of Education, Adıyaman University, Adıyaman, Turkey

Correspondence: Hakkı Kontaş, Faculty of Education, Adıyaman University, Adıyaman, 02040, Turkey. Tel: 90-532-285-8363. E-mail: hakkikontas@hotmail.com

Received: February 19, 2016 Accepted: March 24, 2016 Online Published: April 13, 2016

doi:10.5539/jel.v5n3p10 URL: http://dx.doi.org/10.5539/jel.v5n3p10

Abstract

The purpose of this study is to investigate the effect of manipulatives (concrete learning materials) both on the academic achievement of secondary school students in mathematics and on their attitudes towards mathematics. Pretest-posttest control group experimental model, which is one of the quasi-experimental research designs, was used in the study. The study group consisted of 48 seventh grade students (24 in experiment group and 24 in control group) studying in a state school in the Southeastern Region of Turkey in 2014-2015 school year. The ages of students range between 13 and 14. Mathematics achievement test and mathematics attitude scale were applied in order to collect the research data. As a result of the research, posttest mathematics academic achievement scores of experiment and control groups were found to differ significantly in favor of posttests in both groups. The scores of attitude towards mathematics for experiment and control groups were significantly different in posttests in favor of the experiment group.

Keywords: manipulative, mathematics achievement, secondary school students

1. Introduction

"Teacher! What is this of use for us in daily life?" is one of the most frequent questions that secondary school mathematics teachers are confronted with. One reason why students are right to ask this question is the fact that mathematics is a discipline mainly related to abstract concepts (Hartshorn & Boren, 1990; Laski, Jor'dan, Daoust, & Murray, 2015; Tuncer, 2008). Piaget, one of the founders of constructivism, emphasizes that abstract aspect of mathematics as well. Constructivism, which underlies the mathematics curriculum for elementary education revised in 2005-2006 school year, is a student-focused approach based on construction of complex structures of knowledge by students through active interrelation with concrete materials and on interpreting abstract mathematical concepts by means of concrete experiences (Bruner, 1977; Dienes, 1971; Piaget, 1965; White, 2012), as opposed to traditional mathematics instruction. According to Piaget (1965), students cannot understand and learn the abstract mathematical concepts presented in form of words and symbols solely by way of direct explanation; they do not have the necessary cognitive maturity for it. That is why, he argues that it is possible for students to learn abstract mathematical concepts as a result of their experiences with concrete objects and concrete materials.

Another reason why students ask questions as to the use of abstract mathematics concepts in daily life is the fact that the students in elementary level are in a phase between concrete operational (ages 7-11) and formal operational stages (ages 11-15) according to Piaget's theory of cognitive development (1965). In the concrete operational stage, children acquire the skills to reason and drive generalizations through concrete experiences. Abstract thinking of the child mostly depends on concrete experiences in that stage. Children in formal operational stage, on the other hand, can make assumptions and form hypotheses about abstract concepts by using the reasoning skills they now possess. Considering the developmental properties of students of that age group together with the features of mathematics as a discipline, it would be easier to appreciate the importance of employing concrete learning materials, in other words the manipulatives, in mathematics instruction.

1.1 Literature Review

The word "manipulate" originates from the Old French word "manipüle", meaning "handle". In English it means "to move or control, to operate, to manage with one's hands". When the literature is reviewed for the definition of "manipulative" as a mathematical concept, several definitions which present the features of the manipulatives are found.

Manipulatives are concrete learning materials that allow students to comprehend abstract concepts through concretizing them (Boggan, Harper, & Whitmire, 2010; Cope, 2015; Hartshorn & Boren, 1990; Laski, Jor'dan, Daoust, & Murray, 2015; McClung, 1998; Moyer, 2001; Ojose & Sexton, 2009; White, 2012), thus help them to establish a relation between the manipulatives and abstract mathematical concepts by offering concrete experiences (Holmes, 2013) and eventually, provide long-term permanence of mathematical skills (Cass, Cates, Smith, & Jackson, 2003).

Manipulatives enable students to integrate their knowledge and associate them with their thoughts in order to understand mathematical concepts thoroughly (Boggan, Harper, & Whitmire, 2010; Kelly, 2006); they contribute to students' communication with their own mathematical thinking and to bringing their mathematical ideas to a higher cognitive level (Balka, 1993; Ojose & Sexton, 2009; O'Shea, 1993). They also evoke amusement in the teaching process by providing active participation of both students and teachers (Boggan, Harper, & Whitmire, 2010; Ojose & Sexton, 2009) and in this way, lead to permanent learning through creating equality of opportunity among students (Şahin, 2013). As stated by Tunç, Durmuş and Akkaya in their research in 2011, manipulatives are instruction materials which facilitate teaching and learning (Tunç, Durmuş, & Akkaya, 2011), and make positive contributions to conceptualization and interpretation processes of students (Ross & Kurtz, 1993). However, manipulatives do not only contribute to the cognitive aspect of the learner, they also enhance the development of psychomotor skills (Cope, 2015; Kocaman, 2015) by addressing several senses of the learner such as sight, touch or hearing (Hynes, 1986; Kennedy, 1986; McClung, 1998; Perry & Howard, 1997), inside and outside the class. As stated by Kocaman (2015), manipulatives should not be thought of as a remedy providing an advantage against every difficulty that students face in mathematics. Instead, as underlined by Gökmen (2012), teachers and students need to make a common sense out of the manipulatives they will use. Otherwise, manipulatives would not go beyond being a means of entertainment alone and cannot help the learner to comprehend any concepts. That is why, it was emphasized in many studies that manipulatives should be understood and applied properly especially during the teaching-learning process (Ball, 1992; Clements & McMillen, 1996; Moyer, 2001; Thompson, 1992). At this point, Kelly (2006) underlines the need to provide the teachers with a sound basis of information about when, why and how to use manipulatives. It was also stated that teachers need to explain the objectives to the students explicitly and introduce the manipulatives, giving the necessary information, during the process of teaching. Thus, the manipulatives will go beyond being instruments of play and entertainment from the perspective of the students and will be transformed into materials contributing to their learning. Nevertheless, Kelly (2006) emphasizes that manipulatives should be used not occasionally but all along, as they enhance the conceptualization process of the students positively. As Ojose and Sexton (2009) put it, long-term application of manipulatives leads to assimilation of abstract mathematical concepts through observation of models and thus, to an increase in the achievement of students. Therefore, in order for teachers to develop and use relevant, effective and productive manipulatives, they firstly need to be well informed about the features of manipulatives in educational environments, principles of preparing manipulatives, their advantages and limitations and to have the capability to explain those materials clearly to the students (Akkan & Çakıroğlu, 2011; Tutak, Kılıçarslan, Akgül, Güder, & İç, 2012). It was revealed that the application of manipulatives effectively in the course of teaching process, as stated above, contributes to increasing the mathematics exam grades of students, creating an outstanding performance of students in classes, decreasing anxiety against mathematics, rising cognitive flexibility and positively affecting their attitudes towards mathematics (Bullmaster, 2013; Clements, 1999; Driscoll, 1983; Ojose & Sexton, 2009; Raphael & Wahlstrom, 1989; Sowell, 1989; Suydam, 1986).

Though continuous use of manipulatives was emphasized by various researchers in the studies mentioned above (Aydoğdu İskenderoğlu & Taşkın, 2015; Bozkurt & Akalın, 2010; Bozkurt & Polat, 2011; Bruner, 1977; Bulut, Çömleklioğlu, & Seçil, 2002; Dienes, 1971; Gökmen, 2012; İpek & Baran, 2011; Kaplan, Baran, Işık, Kal, & Hazer, 2013; NCSM, 2014; Parham, 1983; Piaget, 1965; Raphael & Wahlstrom, 1989; Sowell, 1989; Suydam, 1986; Tunç, Durmuş, & Akkaya, 2011; Tutak, Kılıçarslan, Akgül, Güder, & İç, 2012), teachers employ traditional methods in mathematics classes due to their biases regarding manipulatives (Holmes, 2013), including those prejudices such as that they do not know how to use the manipulatives, the manipulatives are not economical in terms of time and money, that the duration of the classes is inadequate (Holmes, 2013), manipulatives cause some kind of cognitive confusion (McClung, 1998) or they do not serve attainments of teaching (Aydoğdu İskenderoğlu & Taşkın, 2015). All of those prejudices of teachers about manipulatives lead to a decrease in the employment of manipulatives in the higher levels of education where the students have acquired abstract thinking skills, as opposed to the first years of education, when the manipulatives are used more often (McClung, 1998; McNeil & Jarvin, 2007). Marshall and Swan (2005) suggest it is the teachers' lack of information about how to use and manage the manipulatives that causes the decline in post-primary education.

On the other hand, there are also some other researches putting forth that there is not a positive correlation between the manipulatives and mathematics achievement due to the prejudices of teachers against manipulatives (Drickey, 2006; McClung, 1998), and that manipulatives do not facilitate learning in mathematics instruction (Fuson & Briars, 1990; Sowel, 1989; Wearne & Hibert, 1988), which have given way to studies that do not support the use of manipulatives in mathematics instruction (Ball, 1992; Thompson P. & Thompson A., 1990; Winograd & Flores, 1986). Thus, studies have emerged in literature, which drove inconsistent conclusions as to the effects of using manipulatives upon the achievement of students, especially with the students at higher levels of education, who have gained abstract thinking skills. This situation indicates to us that the effects of manipulatives on the achievement and attitude of students have yet not been explicitly clarified.

1.2 Purpose of the Study

The purpose of this study is to investigate the effect of manipulatives used for the subject of circles and spheres in the seventh grade mathematics course upon the achievement and attitudes of students. To this end, answers to following questions were sought.

1) Is there a significant difference between

 a. Pretest scores of experiment and control groups

 b. Posttest scores of experiment and control groups

 c. Pretest-posttest scores of either group

 in terms of academic achievement in mathematics lesson?

2) Is there a significant difference between

 d. Pretest scores of experiment and control groups

 e. Posttest scores of experiment and control groups

 f. Pretest-posttest scores of either group

 in terms of their attitudes towards mathematics course?

2. Method

2.1 Research Design

In this study investigating the effect of manipulatives on academic achievement and attitude towards mathematics course, pre-test/post-test control group model which is one of the quasi-experimental designs, was used. In pre-test/post-test control group model, one of the groups, formed previously for some other purpose, is randomly selected as the experiment group, whereas the other group is taken for the control group. The groups are evaluated once before the experiment and once after it. The model allows controlling errors originating from sources such as date, maturity, testing and instrument considerably, as the effects of those variables on experiment and control groups are expected to be the same (Kaptan, 1998, p. 85). In experimental method, the researcher is able to control certain influences, paths or environmental conditions and thus, to observe and understand how objects or the behaviors of the individuals (the subjects) are affected and change. Experimental method is also the ideal method for finding out the cause and effect relations in the research (Kaptan, 1998, pp. 74-75).

2.2 Study Group

The study group of this research consists of 48 seventh-grade students (24 in experiment and 24 in control groups) studying at classes 7-B (experiment group) and 7-G (control group) at a state school in the Southeastern Region in Turkey in the spring semester of 2014-2015 school year. The students in experiment group (11 female, 13 male) and control group (10 female, 14 male) are between 12-13 years of age. Since the study group was selected from among groups that had already been formed, convenience sampling was used (Creswell, 2013). As the mathematics lesson academic achievement scores and attitude towards mathematics lesson scores were equivalent between the two groups, one of the groups was randomly assigned as the experiment group, and the other one as the control group.

2.3 Data Collection Tools

Mathematics achievement test and attitude towards mathematics lesson scale were used for collecting the research data.

2.3.1 Mathematics Achievement Test

A multiple choice test consisting of 25 items and oriented to "Circle and Sphere" subject in the "Geometry" learning domain of seventh grade mathematics lesson in secondary school was developed. At least 2 questions assessing each of the acquisitions appeared in the test. The test was checked by a mathematics teacher, an expert in mathematics instruction, an expert in assessment and evaluation and a Turkish teacher. It was given its final form after the pilot scheme. KR-20 reliability coefficient of the achievement test was calculated as .82. This value demonstrates the reliability of the test as an assessment tool.

2.3.2 Attitude towards Mathematics Lesson Scale

Attitude Towards Mathematics Lesson Scale (ATMLS): "Mathematics Attitude Scale" developed by Baykul (1990) in order to assess the attitudes of students towards mathematics lesson was used in the study. The scale was devised for the study named "Changes in Attitudes towards Mathematics and Science Lessons from the Fifth Grade of Primary School until the Last Grade of High-Schools and Equivalent Schools and Some Factors Believed to be related to Success in University Entrance Exams". There are 30 items in the scale, 15 of which are positive and 15 are negative. According to the results of factor analysis carried out on the scale, the variance ratio was found .56. Cronbach alpha reliability coefficient of attitude towards mathematics lesson scale was calculated as .96. The items of the scale are in five-point Likert type, with choices as "strongly agree, agree, neither agree nor disagree, disagree, strongly disagree". The calculated reliability value of the attitude scale in this study was .94, which indicates the scale is reliable.

2.4 Analysis of the Data

In order to test whether the distribution of the scores obtained from the attitude scale are normal, Shapiro-Wilk test is used if the sample size of the group is less than 50 and Kolmogorov-Smirnov (K-S) test is used if it is larger than 50 (Büyüköztürk, 2014, p. 42). Shapiro- Wilk test was applied in this study, as the sample size was less than 50 and it was found that the observation values did not display normal distribution (Table 1). Since the distribution was not normal, Wilcoxon Signed-Rank Test and Mann Whitney U-Test, which are nonparametric tests, were applied for the evaluation of scores of the mathematics achievement test and attitude towards mathematics lesson scale.

Table 1. Normality test results for the attitude scale

		Shapiro-Wilk		
		Statistic	df	Sig.
Experiment	Pretest	.967	24	.603
	Posttest	.774	24	.000
Control	Pretest	.942	24	.183
	Posttest	.948	24	.247

2.5 Experimental Procedure

The research was carried out in two separate seventh-grade classes of a state school. Attention was paid that the classes would feature similar qualities in terms of their potentialities, during the selection of the classes. To this end, the former mathematics achievement mean scores of the classes were compared and two classes which had equivalent mathematics achievement were included in the study. One of the classes was assigned as the experiment group and the other as the control group randomly. Both of the groups were applied the mathematics achievement test and attitude towards mathematics lesson scale. During the study, the experimental procedure of which took 4 weeks (5 classes per week, 20 classes in total), manipulatives designed in accordance with the topics of "length in circle and sphere" and "angles" were used with the experimental group by the researchers, whereas the lesson was conducted by means of traditional methods in the control group. Designed teaching materials were tangible and allowed the students to practice and revise sufficiently.

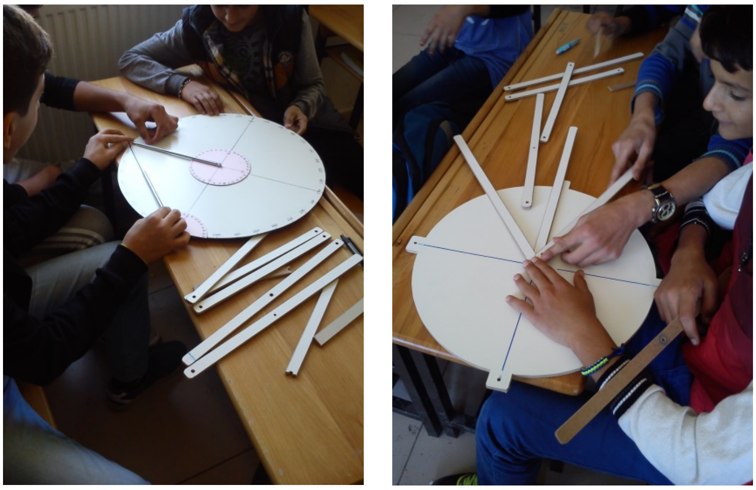

Figure1. The manipulatives used in the study

3. Findings

Is there a significant difference between pretest scores of experiment and control groups before the application?

Table 2. Comparison of achievement posttest mean scores of experiment and control groups

Groups	n	$\bar{X}$	Mean Rank	Sum of Ranks	U	p
Experiment	24	47.79	26.52	636.50	239.500	.314
Control	24	44.13	22.48	539.50		

As shown in Table 2, there was no significant difference between the mathematics achievement mean scores of the experiment and control groups (p>.05). According to this finding, the mathematics achievement levels of the experiment and control groups before the application can be said to be equivalent.

Is there a significant difference between posttest scores of experiment and control groups after the application?

Table 3. Comparison of achievement posttest mean scores of experiment and control groups

Groups	n	$\bar{X}$	Mean Rank	Sum of Ranks	U	p
Experiment	24	77.00	32.69	784.50	91.500	.000*
Control	24	53.75	16.31	391.50		

According to the findings in Table 3, there was significant difference between the achievement posttest mean scores of experiment and control groups (p<.001). This finding indicates that manipulatives are effective in increasing the achievement scores of the experiment group significantly.

Is there a significant difference between the achievement pretest-posttest scores of the experiment and control groups?

Table 4. Results of Wilcoxon test for the academic achievement pretest-posttest scores of experiment and control groups

		n	Mean Rank	Sum of Ranks	Wilcoxon (Z)	P
Experiment Posttest-Pretest	Negative Rank	2	4,25	8,50		
	Positive Rank	22	13,25	291,50	-4.048	.000
	Total	24				
Control Posttest-Pretest	Negative Rank	5	7,30	36,50		
	Positive Rank	19	13,87	263,50	-3.250	.001
	Total	24				

When Table 4 is analyzed, a statistically significant increase (Z=-4.048, p=000<.001) is observed in the achievement posttest scores ($\bar{X}$=77.00) of the experiment group in comparison to its pretest scores ($\bar{X}$=47.79). The increase in achievement posttest scores ($\bar{X}$=53.75) of the control group is also found to be statistically significant (Z=-3.250, p=.001<.05) compared to its pretest scores ($\bar{X}$=44.13).

Table 5. Comparison of attitude scale pretest scores of experiment and control groups

Groups	n	$\bar{X}$	Mean Rank	Sum of Ranks	U	p
Experiment	24	118.00	21.52	516.50	216.500	.139
Control	24	110.00	27.48	659.50		

According to the results of Mann-Whitney U test conducted in order to assess whether there is a significant difference between the attitudes towards mathematics lesson of experiment and control groups before the application, as shown in Table 5, there was no statistically significant difference between mean scores of the experiment and control groups (U=216.500, p>.05). This finding demonstrates that the experiment and control groups had similar attitudes towards mathematics lesson before the application.

Table 6. Comparison of attitude scale posttest scores of experiment and control groups

Groups	n	$\bar{X}$	Mean Rank	Sum of Ranks	U	p
Experiment	24	123.75	15.88	381.00	81.000	.000*
Control	24	98.83	33.13	795.00		

According to the results of Mann-Whitney U test conducted in order to assess whether there is a significant difference between the attitudes towards mathematics lesson of experiment and control groups after the application, as shown in Table 6, there was a statistically significant difference between the attitude mean scores of the experiment and control groups in favor of the experiment group (U=81.000, p<.001). This finding puts forth that manipulative learning materials are substantially effective in increasing the scores of attitude towards mathematics lesson with the experiment group students.

Table 7. Comparison of attitude scale pretest-posttest scores of experiment and control groups

Groups	Tests	n	$\bar{X}$	Mean Rank	Sum of Ranks	U	p
Experiment	Pretest	24	118.00	21.33	512.00	212.000	.116
	Posttest	24	123.75	27.67	664.00		
Control	Pretest	24	110.00	29.06	697.50	178.500	.024*
	Posttest	24	98.83	19.94	478.50		

According to the results of Mann-Whitney U test conducted in order to assess whether there is a significant difference between the attitude towards mathematics lesson pretest-posttest scores of the experiment group, as shown in Table 7, there was no statistically significant difference, though the pretest mean scores of the experiment group were higher than the posttest scores ($U=212.000$, $p>.05$). This finding indicates that manipulative learning materials increase the scores of attitude towards mathematics lesson in students of the experiment group, but the effect is not significant.

According to the results of Mann-Whitney U test conducted in order to assess whether there is a significant difference between the attitude towards mathematics lesson pretest-posttest scores of the control group, posttest mean scores were observed to decrease significantly compared to the pretest mean scores ($U=178.500$, $p<.05$). This finding shows that there was a significant decrease in the attitude of control group students towards mathematics lesson after the application.

4. Discussion, Results and Suggestions

Various researchers have been carried out recently, investigating the effects of manipulatives in mathematics instruction. According to the findings of those studies, it was observed that manipulatives increase the mathematics achievement (Clements, 1999; Kayma, 2010; Sowell, 1989; Tuncer, 2008). Besides, there are also some other researches suggesting that, students are more active, their motivation for learning is higher and they adopt a positive attitude towards mathematics lesson, when manipulatives are employed in mathematics classes (Enki, 2014; Gürbüz, 2007; Sowell, 1989; Yağcı, 2010).

Considering the sample sizes, the models specifications and the methodology, our empirical findings show that the prepared teaching materials increase the mathematics achievement of the students, which can be explained by the function of manipulatives as a bridge concretizing abstract mathematical concepts. That result of the study is similar to the results of previous studies (Akkan & Çakıroğlu, 2011; Boggan, Harper, & Whitmire, 2010; Bullmaster, 2013; Clements, 1999; Cope, 2015; Durmuş & Karakırık, 2006; Goracke, 2009; Gürbüz, 2007; Holmes, 2013; Kayma, 2010; Kocaman, 2015; Laski, Jor'dan, Daoust, & Murray, 2015; Marshall & Swan, 2008; Moyer, 2001; Ojose & Sexton, 2009; Ross, 2004; Sowell, 1989; Strom, 2009; Şahin, 2013; Tuncer, 2008; Tunç, Durmuş, & Akkaya, 2011; Yağcı, 2010; Yeniçeri, 2013; Yıldız & Tüzün, 2011).

In reference to the comparison of achievement posttest scores of the experiment and control groups, the high scores in the posttest of the experiment group indicates that the manipulatives prepared for the "circle" and "sphere" topics contribute considerably to effective learning. However, there exist some studies in literature which suggest that manipulatives are not effective on the mathematics achievement of the students (Boakes, 2009; Boyraz, 2008; Enki, 2014; Kaplan, Baran, Işık, Kal, & Hazer, 2013; McClung, 1998; White, 2012).

Based on our knowledge that the levels of attitudes of the experiment and control groups towards mathematics lesson before the application are similar, it was concluded that manipulatives are effective in increasing the scores of attitude towards mathematics lesson for the experiment group. There are other studies demonstrating that manipulatives are effective upon the attitudes of students towards mathematics lesson (Enki, 2014; Sowell, 1989). In the study by Enki (2014), the students pointed out that, as opposed to former traditional instruction methods, learning through activities including the use of manipulatives gave them pleasure and increased their motivation and allowed them to learn while having fun. Positive feedbacks of this kind are indicators of a positive attitude towards the mathematics lesson and the usage of manipulatives in mathematics instruction.

Comparing the pretest-posttest scores of attitude towards mathematics lesson of the control group, it can be seen that posttest mean scores were less than pretest mean scores at a statistically significant level, which shows that there was a significant decrease in the attitude of control group students towards mathematics lesson after the application. The underlying reason may be the diminishing of students' attention towards the mathematics lesson delivered by means of traditional methods, or the change in students' attitudes due to abstract topics. It can also be inferred from the data that the scores of attitude might have decreased because the topics selected for the study are the last ones in the mathematics curriculum before the end of the semester.

In conclusion, with reference to the idea that usage of manipulatives is beneficial for concretizing abstract topics, an increased usage of manipulatives in teaching-learning processes can be suggested. The retention test could not be applied, as the topic selected for the study was the last one before the holiday. The effects of manipulatives upon retention may be investigated by longer-term studies.

References

Akkan, Y., & Çakıroğlu, Ü. (2011). Farklı branşlardaki öğretmen ve öğretmen adaylarının matematik öğretiminde sanal-fiziksel manipülatiflere bakış açılarının karşılaştırılması. In *5th International Computer & Instructional Technologies Symposium* (pp. 1-7). Elazığ: Fırat University.

Aydoğdu İskenderoğlu, T., & Taşkın, D. (2015). İlköğretim matematik öğretmeniadaylarinin özel öğretim yöntemleri dersinde somut materyalleri seçme ve kullanma nedenleri. *Dicle Üniversitesi Ziya Gökalp Eğitim Fakültesi Dergisi*, *25*, 215-237. http://dx.doi.org/10.14582/DUZGEF.635

Balka, D. S. (1993). Making the connections in mathematics via manipulatives. *Contemporary Education*, *65*(1), 19.

Ball, D. L. (1992). Magical hopes: Manipulatives and the reform of math education. *American Educator: The Professional Journal of the American Federation of Teachers*, *16*(2), 14-18.

Baykul, Y. (1990). *İlkokul beşinci sınıftan lise ve dengi okulların sın sınıflarına kadar matematik ve fen derslerine karşı tutumda görülen değişmeler ve öğrenci yerleştirme sınavındaki başarı ve ilişkili olduğu düşünülen bazı faktörler*. Ankara: ÖSYM Yayınları.

Boakes, N. (2009). *Origami-mathematics lessons: Researching its impact and influence on mathematical knowledge and spatial ability of students*. New Jersey, United States.

Boggan, M., Harper, S., & Whitmire, A. (2010). Using manipulatives to teach elementary mathematics. *Journal of Instructional Pedagogies*, *3*(1), 1-6.

Boyraz, Ş. (2008). *The effects of computer based instruction on seventh grade students' spatial ability, attitudes toward geometry, mathematics and technology*. Ankara: Middle East Technical University.

Bozkurt, A., & Akalın, S. (2010). Matematik öğretiminde materyal geliştirmenin ve kullanımının yeri, önemi ve bu konuda öğretmenin rolü. *Dumlupınar Üniversitesi Eğitim Fakültesi Dergisi*, *27*, 47-56.

Bozkurt, A., & Polat, M. (2011). Sayma pullarıyla modellemenin tam sayılar konusunu öğrenmeye etkisi üzerine öğretmen görüşleri. *Gaziantep Üniversitesi Sosyal Bilimler Dergisi*, *10*(2), 787-801.

Bruner, J. S. (1977). The process of education. In D. B. Aichele, & R. E. Reys (Eds.), *Readings in secondary school mathematics* (pp. 170-181). Boston: Prindle, Weber, & Schmidt.

Bullmaster, M. L. (2013). A synthesis of research on effective mathematics instruction. *Touro College Graduate School of Education*, 1-15.

Bulut, S., Çömleklioğlu, G., & Seçil, S. Ö. (2002). Matematik öğretiminde somut materyallerin kullanılması. *V. Ulusal Fen Bilimleri ve Matematik Eğitimi Kongresi Dergisi*, 188.

Büyüköztürk, Ş. (2014). *Sosyal bilimler için veri analizi el kitabı* (20 b.). Ankara: Pegem Akademi.

Cass, M., Cates, D., & Smith, M. (2003). Effects of manipulative ınstruction on solving area and perimeter problems by students with learning disabilities. *Learning Disabilities Research & Practice*, *18*(2), 112-120. http://dx.doi.org/10.1111/1540-5826.00067

Clements, D. H. (1999). Concrete manipulatives, concrete. *Contemporary Issues in Early Childhood Ideas*, *1*(1), 45-60. http://dx.doi.org/10.2304/ciec.2000.1.1.7

Clements, D. H., & McMillen, S. (1996). Rethinking concrete manipulatives. *Teaching Children Mathematics*, *2*(5), 270-279.

Cope, L. (Spring 2015). Math manipulatives: Making the abstract tangible. *Delta Journal of Education*, *5*(1), 10-19.

Creswell, J. W. (2013). *Nitel, nicel ve karma yöntem yaklaşımları araştırma deseni* (S. B. Demir, Trans.). Ankara: Eğiten Kitap.

Dienes, Z. P. (1971). An example of the passage from the concrete to the manipulation of formal systems. *Educational Studies in Mathematics*, *3*, 337-352. http://dx.doi.org/10.1007/BF00302302

Dienes, Z. P. (1973). *Mathematics through the senses, games, dance, and art*. Windsor, UK: The National Foundation for Educational Research Publishing Company Ltd.

Drickey, N. (2006). Learning technologies for enhancing student understanding of mathematics. *International Journal of Learning*, *13*(5), 109-116.

Driscoll, M. J. (1983). *Research within reach: Elementary school mathematics and reading*. St. Louis: CEMREL Inc.

Durmuş, S., & Karakırık, E. (2006). Virtual manipulatives in mathematics education: A theoretical framework. *The Turkish Online Journal of Educational Technology (TOJET)*, *5*(1), 12.

Enki, K. (2014). *Effects of using manipulatives on seventh grade students' achievement in transformation geometry and orthogonal views of geometric figures* (Unpublished master's thesis). Ankara: Middle East Technical University .

Fuson, K. C., & Briars, D. J. (1990). Using a base-ten blocks learning/teaching approach for first and second-grade place-value and multidigit addition and subtraction. *National Council of Teachers of Mathematics*, *21*(3), 180-206. http://dx.doi.org/10.2307/749373

Goracke, M. A. (2009). *The role of manipulatives in the eighth grade mathematics classroom*. Harvard, Nebraska: University of Nebraska.

Gökmen, A. (2012). *İlköğretim matematik ve sınıf öğretmenlerinin matematik eğitiminde materyal (manipülatif) kullanmaya yönelik inançları ile kullanım düzeyleri arasındaki ilişki* (Yayımlanmamış yüksek lisans tezi). Konya: Necmettin Erbakan Üniversitesi Eğitim Bilimleri Enstitüsü.

Gürbüz, R. (2007). Olasılık konusunda geliştirilen materyallere dayalı öğretime öğretime ilişkin öğretmen ve öğrenci görüşleri. *Kastamonu Eğitim Dergisi*, *15*(1), 259-270.

Hartshorn, R., & Boren, S. (1990). *Experiential learning of mathematics: Using manipulatives*. ERIC Publications, ERIC Digests.

Holmes, A. B. (2013). *Effects of manipulative use on PK-12 mathematics achievement: A meta-analysis*. Poster presented at the meeting of Society for Research in Educational Effectiveness, Washington, DC.

Hynes, M. C. (1986). Selection criteria. *Arithmetic Teacher*, *33*(6), 11-13.

İpek, A. S., & Baran, D. (2011). İlköğretim matematik öğretmen adaylarının teknoloji destekli temsillerle ilgili düşünceleri. In *5th International Computer & Instructional Technologies Symposium*. ELAZIĞ: Fırat University.

Kablan, Z., Baran, T., Işık, Ç., Kal, F. M., & Hazer, Ö. (2013). Powerpoint öğretim materyalleri ile somut öğretim materyallerin öğrenme etkililiği açısından karşılaştırılması. *Eğitim ve Bilim*, *38*(170), 206-222.

Kaptan, S. (1998). *Bilimsel araştırma ve istatistik teknikleri* (11 b.). Ankara: Bilim Yayınevi.

Kayma, A. Ö. (2010). *İlköğretim 5. sınıfa yönelik materyallerin geliştirilmesi ve uygulanması* (Yayımlanmamış yüksek lisans tezi). Van: Yüzüncü Yıl Üniversitesi Fen Bilimleri Enstitüsü.

Kelly, C. A. (2006). Using manipulatives in mathematical problem solving: A performance-based analysis. *The Mathematics Enthusiast*, *13*(2), 184.

Kennedy, L. M. (1986). A rationale. *Arithmetic Teacher*, *33*(6), 6-7.

Kocaman, N. B. (2015). *Manipülatifler kullanılarak yapılan öğretimin 11. sınıf öğrencilerinin matematik başarısına etkisi* (Yayımlanmamış yüksek lisans tezi). İstanbul: Yıldız Teknik Üniversitesi Fen Bilimleri Enstitüsü.

Laski, E., Jor'dan, J., Daou, C., & Murray, A. (2015). What makes mathematics manipulatives effective? Lessons from cognitive science and montessori education. *SAGE Open*, 1-8. http://dx.doi.org/10.1177/2158244015589588

Marshall, L., & Swan, P. (2005). Developing mathematical thinking with the assistance of manipulatives. *The Mathematics Education into the 21st Century Project*, 144-147.

McClung, L. W. (1998). *A study on the use of manipulatives and their effect on student achievement in a high school algebra class*. Salem-Teikyo University.

McNeil, N., & Jarvin, L. (2007). When theories don't add up: Disentangling he manipulatives debate. *Theory Into Practice*, *46*(4), 309-316. http://dx.doi.org/10.1080/00405840701593899

MEB. (2009). *İlköğretim matematik dersi 6-8. sınıflar öğretim programı ve kılavuzu*. Ankara: T.C. Milli Eğitim Bakanlığı Talim ve Terbiye Kurulu Başkanlığı.

Moyer, P. S. (2001). Are we having fun yet? How teachers use manipulatives to teach mathematics. *Educational Studies in mathematics*, *47*(2), 175-197. http://dx.doi.org/10.1023/A:1014596316942

NCSM. (2014). Improving student achievement in mathematics by using manipulatives with classroom ınstruction. *NCSM: Leadership in Mathematics Education*, *52*(3), 34.

Ojose, B., & Sexton, L. (2009). The effect of manipulative materials on mathematics achievement of first grade students. *The Mathematics Educator*, *12*(1), 3-14.

O'shea, T. (1993). The role of manipulatives in mathematics education. *Contemporary Education*, *65*(1), 6-9.

Özkul Kayma, A. Ö. (2010). *İlköğretim 5. sınıfa yönelik materyallerin geliştirilmesi ve uygulanması*. (Yayımlanmamış yüksek lisans tezi). Van: Yüzüncü Yıl Üniversitesi Fen Bilimleri Enstitüsü.

Parham. J. L. (1983). *A meta-analysis of the use of manipulative materials and student achievement in elementary school mathematics*. Dissertation Abstracts International.

Perry, B., & Howard, P. (1997). Manipulatives in primary mathematics: Implications for teaching and learning. *Australian Primary Mathematics Classroom*, *2*(2), 25-30.

Piaget, J. (1965). *The child's conception of number*. New York: W. W. Norton & Company.

Raphael, D., & Wahlstrom, M. (1989). The influence of instructional aids on mathematics achievement. *Journal for Research in Mathematics Education*, *20*(2), 173-190. http://dx.doi.org/10.2307/749281

Ross, C. J. (2004). *The effect of mathematical manipulative materials on third grade students' participation, engagement, and academic performance*. Orlando, Florida: B.S. University of Central Florida.

Ross, R., & Kurtz, R. (1993). Making manipulatives work: A strategy for success. *Arithmetic Teacher*, *40*(5), 254.

Sowell, E. J. (1989). Effects of manipulative materials in mathematics instruction. *Journal for Research in Mathematics Education*, *20*(5), 498-505. http://dx.doi.org/10.2307/749423

Strom, J. (2009). *Manipulatives in mathematics instruction*. Bemidji, Minnesota, USA: Bemidji State University.

Suydam, M. N. (1986). Manipulative materials and achievement. *Arithmetic Teacher*, *33*(6), 10-32.

Şahin, T. (2013). *Somut ve sanal manipülatif destekli geometri öğretiminin 5. Sınıf öğrencilerinin geometrik yapıları inşa etme ve çizmedeki başarılarına etkisi* (Yayımlanmamış yüksek lisans tezi). Bolu: Abant İzzet Baysal Üniversitesi, Eğitim Bilimleri Enstitüsü.

Thompson, P. W. (1992). Notations, conventions, and constraints: Contributions to effective uses of concrete materials in elementary mathematics. *Journal for Research in Mathematics Education*, *23*(2), 123-147. http://dx.doi.org/10.2307/749497

Thompson, P., & Thompson, A. (1990). Salient aspects of experience with concrete manipulatives. In *Proceedings of the 14th Annual Meeting of the International Group for the Psychology of Mathematics* (pp. 46-52). Mexico City: Illinois State University.

Tuncer, D. (2008). *Materyal destekli matematik öğretiminin ilköğretim 8. sınıf öğrencilerinin akademik başarısına ve başarının kalıcılık düzeyine etkisi*. Ankara: Gazi Üniversitesi Eğitim Bilimleri Enstitüsü.

Tunç, M. P., Durmuş, S., & Akkaya, R. (2014). İlköğretim matematik öğretmen adaylarının matematik öğretiminde somut materyalleri ve sanal öğrenme nesnelerini kullanma yeterlikleri. *Matematik Eğitimi Dergisi*, *1*(1), 13-20.

Tutak, T., Kılıçarslan, S., Akgül, A., Güder, Y., & İç, Ü. (2012). İlköğretim matematik öğretmen adaylarinin somut öğretim nesnelerinin kullanimina yönelik bilgi düzeylerinin belirlenmesi. *X. Ulusal Fen Bilimleri ve Matematik Eğitimi Kongresi*. Niğde: PEGEM Akademi.

Wearne, D., & Hiebert, J. (1988). A cognitive approach to meaningful mathematics ınstruction: Testing a local theory using decimal numbers. *National Council of Teachers of Mathematics*, *19*(5), 371-384. http://dx.doi.org/10.2307/749172

White, K. M. (2012). *The effect of an instructional model utilizing hands-on learning and manipulatives on math achievement of middle school students in georgia*. Lynchburg, Virginia: Liberty University, Lynchburg, VA.

Winograd, T., & Flores, F. (1986). *Understanding computers and cognition: A new foundation for design* (5 b.). Norwood, New Jersey, United States of America: Ablex Publishing Corporation.

Yağcı, F. (2010). *The effect of instruction with concrete models on eighth grade students' probability achievement and attitudes toward probability*. Ankara: Middle East Technical University.

Yeniçeri, Ü. (2013). *İlköğretim 6. sınıf matematik öğretim programında yer alan kesirler alt öğrenme alanı kazanımlarının öğretimde sanal manipülatif kullanımının öğrencilerin başarılarına etkisi*. Ankara: Gazi Üniversitesi Eğitim Bilimleri Enstitüsü.

Yıldız, B., & Tüzün, H. (2011). Üç boyutlu sanal ortam ve somut materyal kullanımının uzamsal yeteneğe etkileri. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi (H.U. Journal of Education)*, *41*, 498-508.