THE EFFECT OF CONCEPTUAL CHANGE BASED INSTRUCTION ON TENTH GRADE STUDENTS' UNDERSTANDING OF PROBABILITY CONCEPTS, PROBABILITY ACHIEVEMENT AND ATTITUDES TOWARD PROBABILITY

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ABSTRACT

THE EFFECT OF CONCEPTUAL CHANGE BASED INSTRUCTION ON TENTH GRADE STUDENTS' UNDERSTANDING OF PROBABILITY CONCEPTS, PROBABILITY ACHIEVEMENT AND ATTITUDES TOWARD PROBABILITY

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The purpose of the current study is to investigate the effect of conceptual change based instruction on tenth grade students' understanding of probability concepts, probability achievement and attitudes toward probability. This study was conducted with 118 students from one Anatolian high school in Ankara during the spring semester of 2010-2011. The treatments were performed by two teachers who had randomly assigned one control and one experimental group. Conceptual change based instruction (CCBI) was used in the experimental groups, while traditional instruction (TI) was used in the control groups. Instructions lasted three weeks as 12 class hours. Before the treatment, the equivalence of the experimental and control groups was tested in terms of mean scores of mathematics achievement and pre-measures on Probability Concept Test (PCT), Probability Achievement Test (PAT), Pre-requisite Knowledge Test for Probability, Probability Attitude Scale (PAS), and Mathematics Attitude Scale. After the treatment, PCT, PAT and PAS were administered as post-tests in order to test the null hypotheses of the study with multivariate analysis of covariance.

The results revealed that there was a statistically significant mean difference between students in CCBI and those in TI with respect to understanding of probability concepts and probability achievement in favor of CCBI. However, it was found that there was no statistically significant mean difference between the groups with respect to attitudes toward probability. Results also indicated that after the treatment, the proportion of misconceptions held by students in CCBI was less than those in TI.

Keywords: Conceptual Change Based Instruction, Misconception, Probability Achievement, Attitude toward probability, Mathematics Education

ÖZ

KAVRAMSAL DEĞİŞİM TEMELLİ ÖĞRETİMİN ONUNCU SINIF ÖĞRENCİLERİNİN OLASILIK KAVRAMLARINI ANLAMALARI, OLASILIK BAŞARILARI VE OLASILIĞA YÖNELİK TUTUMLARI ÜZERİNE ETKİSİ

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Bu çalışmanın amacı kavramsal değişim temelli öğretimin onuncu sınıf öğrencilerinin olasılık kavramlarını anlamaları, olasılık başarıları ve olasılığa yönelik tutumları üzerine etkisini incelemektir. Bu çalışma 2010-2011 öğretim yılı ilkbahar döneminde Ankara'daki bir Anadolu lisesinden 118 öğrenci ile gerçekleştirilmiştir. Uygulama rastgele atanan bir deney ve bir kontrol grubuna sahip iki öğretmen tarafından yürütülmüştür. Uygulama süresince deneysel grupta kavramsal değişim temelli öğretim (CCBI) kullanılırken kontrol grubunda geleneksel öğretim kullanılmıştır. Uygulama üç hafta, 12 ders saati sürmüştür. Uygulama öncesi, deney ve kontrol grubunun denkliği, matematik başarı ortalamaları ve Olasılık Kavram Testi (PCT), Olasılık Başarı Testi (PAT), Olasılık için Ön Bilgi Testi, Olasılık Tutum Ölçeği (PAS) ve Matematik Tutum Ölçeği üzerindeki ön ölçüm ortalamaları açısından test edilmiştir. Çalışmanın sıfır hipotezlerini çok değişkenli kovaryans analizi ile test etmek için, öğretim süreci sonrası PAT, PCT ve PAS uygulanmıştır.

Çalışmanın sonuçları, olasılık kavramlarını anlama ve olasılık başarısı açısından, kavramsal değişim temelli öğretim grubundaki öğrencilerle geleneksel öğretim grubundaki öğrencilerin ortalamaları arasında istatistiksel olarak CCBI lehine anlamlı bir fark olduğunu göstermiştir. Bununla birlikte, gruplar arasında, öğrencilerin olasılığa yönelik tutumları açısından istatistiksel olarak anlamlı bir fark olmadığı bulunmuştur. Sonuçlar, ayrıca uygulama sonrasında CCBI grubundaki öğrencilerin sahip oldukları kavram yanılgıları oranının geleneksel öğretim öğrencilerinin kavram yanılgısı oranından daha az olduğunu göstermiştir.

Anahtar Kelimeler: Kavramsal Değişim Temelli Öğretim, Kavram Yanılgısı, Olasılık Başarısı, Olasılığa Yönelik Tutum, Matematik Eğitimi

To the memory of my father,

To my mother,

To my husband &

To my son

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TABLE OF CONTENTS

LIST OF TABLES

TABLES

LIST OF FIGURES

FIGURES

LIST OF ABBREVIATIONS

CCBI	: Conceptual Change based Instruction
CCM	: Conceptual Change Model
CG	: Control Group
EG	: Experimental Group
Mach	: Mathematics Achievement
MANCOVA	: Multivariate Analysis of Covariance
MAS	: Mathematics Attitude Scale
PAS	: Probability Attitude Scale
PAT	: Probability Achievement Test
PCT	: Probability Concept Test
PKT	: Prerequisite Knowledge Test for Probability
Post-PAS	: Students' Post-test Scores on the Probability Attitude Scale
Post-PAT	: Students' Post-test Scores on the Probability Achievement Test
Post-PCT	: Students' Post-test Scores on the Probability Concept Test
Pre-Mach	: Students' Previous Semester Mathematics Grades
Pre-MAS	: Students' Pre-test Scores on the Mathematics Attitude Scale
Pre-PCT	: Students' Pre-test Scores on the Probability Concept Test
Pre-PAS	: Students' Pre-test Scores on the Probability Attitude Scale
Pre-PAT	: Students' Pre-test Scores on the Probability Achievement Test
Pre-PKT	: Students' Pre-test Scores on the Prerequisite Knowledge Test for Probability
TI	: Traditional Instruction

CHAPTER 1

INTRODUCTION

Probability is an important concept in school mathematics not only because it is used in many other fields but also because it is inseparable part of our everyday life. People frequently encounter the information including probabilistic terms in their daily life. For example, they can hear some news related to lung cancer which states that smoking increases the risk of lung cancer or they can read an article informing about seat belt use and stating in case of an accident, seat belt use reduces the risk of fatal injury. Winning a lottery is another example in which people are exposed to probability. Moreover, many other fields and occupations like quantum physics and insurance is based on the probability theory (Lappan et al., 1987).

Mathematics Curriculum gives importance to probability subject. In Turkey, the probability concept firstly took place in high school mathematics curriculum in 1960's. However, it did not receive much attention (Bulut, 1994). During the current study, probability concept was a mandatory component of school curricula in grades 4-8 at elementary school level and also in grade ten at high school level (Ministry of National Education [MoNE], 2005a, 2005b, 2005c). In the high schools, the probability concept was taught only in grade ten. Then, since the mathematics curriculum was again revised, probability concept was taught in grade 11 at high school level (MoNE, 2011). The current mathematics curriculum was revised in 2013. So, the probability concepts are taught in grade eight and in grades 9-12 (MoNE, 2013a, 2013b). Similarly, National Council of Teachers of Mathematics (NCTM, 2000) emphasizes the importance of probability in school curricula. Also, probability is part of the mathematics curricula for primary and secondary schools in some other countries like Spain, Iceland and Ireland (Eurydice, 2011). Although the mathematics curriculum give importance to teaching probability concepts, many research studies have emphasized that there are still some problems and difficulties in teaching and learning probability concepts (e.g., Çelik & Güneş, 2007; Fischbein & Schnarch, 1997; Gürbüz, 2006a; Gürbüz, Çatlıoğlu, Birgin, & Erdem, 2010; Gürbüz, Erdem, & Fırat, 2012; Van Dooren, De Bock, Depaepe, Janssens & Verschaffel, 2003). Similarly, many studies state that probability is a difficult concept for teachers to teach and for students to learn (e.g., Batanero, Godino, & Roa, 2004; Durmuş, 2004; Kutluca & Baki, 2009; Tatar, Okur, & Tuna, 2008).

Some studies mentioned the reasons for the difficulties related to teaching and learning of probability (e.g., Carpenter, Corbitt, Kepner, Linquist, & Reys, 1981; Garfield & Ahlgren, 1988; Gürbüz et al., 2010; Toluk, 1994). These are lack of sufficient knowledge and skills of teachers (Toluk, 1994), difficulties experienced with prerequisite concepts (Carpenter et al., 1981; Green, 1983; Piaget & Inhelder, 1975), lack of effective teaching materials (Gürbüz, 2006a), misconceptions (Çelik & Güneş, 2007; Fast, 1997a; Garfield & Ahlgren, 1988; Konold, Pollatsek, Well, Lohmeier, & Lipson, 1993; Lecoutre, 1992; Van Dooren, et al., 2003;Watson & Moritz, 2002), difficulties in probabilistic reasoning (Fischbein & Schnarch, 1997), and attitudes toward probability (Bulut, 2001).

In this sense, one of the most important reasons for learning/teaching difficulties in probability concepts is that students have some misconceptions about the probability concept (Fast, 1997a; Garfield & Ahlgren, 1988). People tend to make explanations or inferences and also perceive patterns about events which they encounter in their environment (Galotti, 2013). This is one of the fundamental ability of our mind and helps to shape our understanding and perception of world around us. Thus, students come to a learning situation with primary intuitions related to probability concepts (Fischbein, 1987). However, due to the counter-intuitive nature of probability, this can lead to some misconceptions (Ben-Hur, 2006). For example, people tend to find patterns in the outcomes of random processes. Thus, they may think that heads is more likely at the fifth tosses after four consecutive tails are observed. Such judgemental heuristics in probability are prevalent and also robust to change even after instruction in probability. For this reason, misconceptions of probability or judgemental heuristics has been widely studied (e.g., Chiesi & Primi, 2009; Çelik & Güneş, 2007; Dereli, 2009; Doğucu, 2013; Fischbein & Schnarch, 1997; Hayat, 2009; Kahneman & Tversky, 1972, 1973; Mut, 2003; Piaget & Inhelder, 1975; Shaugnessy, 1992; Teglas, Girotto, Gonzales, & Bonatti, 2007; Yıldız & Bulut, 2002). Similarly, the related literature also provides many studies examining effects of some instructional methods on probability achievement and attitude (e.g., Austin, 1974; Biehler, 1991; Cankoy, 1989; Castro, 1998; Demir, 2005; Jiang & Potter, 1993; Şengül & Ekinözü, 2006). For example, there are many national studies conducted to investigate the effect of various instructional methods on teaching/learning probability. These instructional methods include mathematics laboratory instruction (Cankoy, 1989), computer assisted instruction (Bulut, 1994; Esen, 2009; Şen, 2010), cooperative learning method (Arısoy, 2011, Bulut, 1994; Efe, 2011; Ünlü, 2008), discovery learning (Yazıcı, 2002), problem posing instruction (Demir, 2005), instruction based on graph theory (Seyhanlı, 2007), dramatization method (Ekinözü & Şengül, 2007; Şengül & Ekinözü, 2006), active learning method (Memnun, 2008), multiple intelligence activities (Boztepe, 2010; Ercan, 2008), interdisciplinary teaching approach (Alp, 2010), game based teaching (Kavasoğlu, 2010), instruction with concrete materials (Yağcı, 2010), creative drama based instruction (Geçim, 2012), and instruction with worksheets (Özdemir, 2012). The current study examines the effect of conceptual change based instruction (CCBI) on students' understanding of probability concepts, probability achievement and attitudes toward probability. The current study differs from these studies in terms of purpose and teaching method. Also, literature review for the current study showed that there are only a few studies on teaching and learning strategies to overcome probabilistic misconceptions in Turkey (e.g., Avaroğlu, 2013). Similarly, it was found few studies about this issue in other countries (e.g., Fast, 1997a, 1997b; Fischbein & Gazit, 1984). Thus, there is a need for examining the effect of instruction on students' understanding of probability concepts in Turkey. When it is considered negative effect of misconceptions on students' understanding of probability concept and as well as probability achievement, it is crucial to conduct studies to overcome probability misconceptions. Thus, the current study explores the effect of instructional methods on Turkish 10th grade students' understanding of probability concepts and probability achievement.

On the other hand, many studies showed that traditional instruction is inadequate in enhancing understanding of scientific concepts or removing misconceptions (e.g., Cankoy, 1998; Chambers & Andre, 1997; Çelikten, ipekçioğlu, Ertepınar, & Geban, 2012). So, research is necessary on effective teaching ways of scientific concepts. In effective teaching of mathematics, it is mentioned two common recommendations, students' active involvement (Boaler, 2006; Middleton & Jansen, 2011; NCTM, 2000; Silberman, 1998; Turner & Patrick, 2004; Willis, 2010) and connection new knowledge to previous one (NCTM, 2000, Schoenfeld, 1988). According to constructivism knowledge is constructed by the learners. That is, they are not passively received knowledge but they actively construct their own knowledge on the basis of existing conceptions (Matthews, 1993). Students come to a learning situation with their prior knowledge. Due to their prior ideas, they may reject outright a scientific knowledge or resist accepting and believing it (Driver, 1989). Thus, teacher should give importance to students' prior conceptions to facilitate meaningful learning during their learning experiences. That is to say, during this process students should be encouraged to express their pre-conceptions. Consequently, effective instruction should include active involvement of the learner in learning process and help the learners to construct their knowledge on the basis of prior knowledge and experiences.

Many researchers have emphasized that constructivist approach is effective not only for conceptual understanding but also for increasing students' attitudes (Basili & Sanford, 199; Uzuntiryaki, 2003). Conceptual change is a model to the application of constructivist principles to instruction (Hewson & Thorley, 1989). Recent studies, especially in science education, have shown that instructional strategies based on conceptual change approach are effective in promoting students' understanding of scientific concepts. Instruction based on conceptual change is valuable to enhance students' understanding and to overcome students' misconceptions. In the literature there are many studies to showing effective results of conceptual change instruction to overcome students' misconceptions in science (e.g., Chambers & Andre, 1997; Çetingül and Geban, 2011). Recently, conceptual change instruction has become important in mathematics education (Vosniadou, 2008). However, it is found a few studies related to conceptual change instruction in mathematics education throughout the literature review process of this study (e.g., Cankoy, 1998; Castro, 1998; Toka, 2001). Moreover, these studies emphasize that conceptual change model (CCM) is promising method to improve mathematics learning. Therefore, research is needed on the effectiveness of CCBI on students' probability understanding and achievement. So, in the present research, lesson plans based on CCM were developed by the researcher.

It is also essential to find methods which encourage positive attitude toward the probability concepts since attitude toward a subject affect the learning outcomes. Many studies emphasized that there are positive correlation between mathematics achievement and attitudes toward mathematics (Ma, 1997; Reyes, 1984). MoNE (2005c) also gives importance to affective development of the students during the instruction. Thus, some studies investigated the effect of instructional methods on students' attitudes toward probability (e.g., Demir, 2005; Seyhanlı, 2007). Also, Aiken (1976) emphasizes that students' attitudes toward mathematics can be affected by the teaching methods. However, it is not met any national research study which investigates the effect of conceptual change based instruction (CCBI) on students' attitudes toward probability. Thus, another purpose of the current study is to explore the effect of CCBI on students' attitudes toward probability.

Shaughnessy (1992) was conducted a literature review related to probability and statistics for the "*Handbook of Research on Mathematics Teaching and Learning*". Here, Shaughnessy presented a research agenda in terms of probability and statistics for the next decade. In this research agenda, it was recommended to conduct studies on secondary school students' conceptions and misconceptions related to statistics and probability. According to Shaughnessy, most of the probability studies was conducted with elementary or college students. In the "*Second Handbook of Research on Mathematics Teaching and Learning*", Jones, Langrall, and Mooney (2007) presented a review about research in probability. They also presented a research agenda related to probability. According to them, "there is still a void in the kinds of classroom studies that Shaughnessy advocated, that is, studies that investigate the effect of instruction on secondary students' probability learning" (p. 944). Because of this, the current study was conducted with tenth grade students.

In conclusion, the topic of probability is important in daily life and in other disciplines and occupations as well as in mathematics. Similarly, mathematics curriculum also gives importance to probability learning. However, many studies show that students have misconceptions and learning difficulties in this important topic. In order to overcome learning difficulties, designing effective instruction by considering educational philosophies and learning theories is essential. Then, it is also essential to test the effectiveness of this instruction on students' understanding of probability, probability achievement and attitudes toward probability. Therefore, in the present study, instruction based on CCM was designed.

The current study presents various activities in probability instruction. So, the present study also aims to offer an insight into implementation of high school mathematics curriculum with the use of conceptual change model and to provide information to teachers and students on the teaching/learning probability with conceptual change based instruction. This study may contribute Turkish students in improving their understanding of probability and achievement in probability. The probability concept is one of the main subjects of mathematics which is important both in other scientific areas and in daily life. Therefore, improving students' understanding of probability may contribute their success in other fields and their daily life.

1.1 Research Problem

The main problem of the present study is:

What is the effect of conceptual change based instruction as compared to traditional instruction on tenth grade students' understanding of probability concepts, probability achievement and attitudes toward probability?

The sub-problems based on the main problem are stated as:

Sub-problem 1

What is the effect of conceptual change based instruction as compared to traditional instruction on tenth grade students' understanding of probability concepts?

Sub-problem 2

What is the effect of conceptual change based instruction as compared to traditional instruction on tenth grade students' probability achievement?

Sub-problem 3

What is the effect of conceptual change based instruction as compared to traditional instruction on tenth grade students' attitudes toward probability?

1.2 Hypotheses

The problem of the current study will be tested with four hypotheses in null form. Hypotheses of the study are stated as;

Null Hypothesis 1

There is no statistically significant overall effect of conceptual change based instruction and traditional instruction on the population means of the collective dependent variables of tenth grade students' post-test scores of the probability concept, probability achievement and attitudes toward probability when the effect of students' previous mathematics achievement scores and students' pre-test scores of probability concept, probability achievement, attitudes toward probability, attitudes toward mathematics, and prerequisite knowledge for probability are controlled.

Null Hypothesis 2

There is no statistically significant difference between the post-test mean scores of tenth grade students instructed with conceptual change model and those instructed with traditional instruction on the population means of the probability concept post-test scores when the effect of students' previous mathematics achievement scores and students' pre-test scores of probability concept, probability achievement, attitudes toward probability, attitudes toward mathematics, and prerequisite knowledge for probability are controlled.

Null Hypothesis 3

There is no statistically significant difference between the post-test mean scores of tenth grade students instructed with conceptual change model and those instructed with traditional instruction on the population means of probability achievement post-test scores when the effect of students' previous mathematics achievement scores and students' pre-test scores of probability concept, probability achievement, attitudes toward probability, attitudes toward mathematics, and prerequisite knowledge for probability are controlled.

Null Hypothesis 4

There is no statistically significant difference between the post-test mean scores of tenth grade students instructed with conceptual change model and those instructed with traditional instruction on the population means of the attitudes toward probability post-test scores when the effect of students' previous mathematics achievement scores and students' pre-test scores of probability concept, probability achievement, attitudes toward probability, attitudes toward mathematics, and prerequisite knowledge for probability are controlled.

1.3 Definitions of the Terms

The definitions of terms which were used in the current study are presented below.

Misconception: Alternative frameworks or conceptions which is different from scientific meaning of the concept (Nakhleh, 1992).

Conceptual change model (CCM): A learning process in which the person must replace or reorganize his/her central concepts to accommodate the new concepts (Posner, Strike, Hewson, & Gertzog, 1982).

Conceptual change based instruction (CCBI): An instruction designed by the help of CCM. In this instruction, the conditions of CCM were met by the help of activities, discussions, and simulations.

Traditional instruction (TI): An instruction in which students are mostly passive and are mainly taught in a teacher-centered way.

Concept: "Units of mental representation roughly equivalent to a single word, such as object, animal, alive, heat, weight, and matter" (Carey, 2000, p.14).

Understanding of probability: Students' score on the "Probability Concept Test" (PCT). PCT which was used to assess students' misconceptions in probability concepts consists of 14 well-known probability questions in the literature related to common misconception types; "representativeness", "positive and negative recency effects", "simple and compound events", "effect of sample size", "conjunction fallacy", "heuristic availability", "the time axis fallacy" and "equiprobability bias".

Probability achievement: Students' score on the "Probability Achievement Test" (PAT).

Attitude: "A learned predisposition or tendency on the part of an individual to respond positively or negatively to some object, situation, concept, or another person" (Aiken, 1970, p.551).

Attitude toward probability: Students' score on the "Probability Attitude Scale" (PAS).

Attitude toward mathematics: Students' score on the "Mathematics Attitude Scale" (MAS).

Prerequisite knowledge for probability: Students' score on the "Prerequisite Knowledge Test for the Probability" (PKT). It was used to test students' prerequisite knowledge in terms of concepts necessary for learning basic probability concepts.

Mathematics achievement (MAch): Students' mathematics course grade in the fall semester of 2010-2011 academic year.

Instructional methods: The method of instruction; either the traditional instruction (TI) or conceptual change based instruction (CCBI).

Control group (CG): The group who received traditional instruction.

Experimental group (EG): The group who received conceptual change based instruction.

Representativeness: Evaluating the probability of an uncertain event “by the degree of correspondence between the sample and the population, or between an occurrence and a model” (Kahneman & Tversky, 1972, p. 451).

Negative recency effect: In probability estimations, expecting different results relying on obtaining successive same results (Cohen, 1957).

Positive recency effect: In probability estimations, expecting again same results relying on obtaining successive same results because of the assumption that the conditions are not fair (Fischbein, 1975).

Misconception on simple and compound events: Confusing simple and compound events especially in defining their sample space (Fischbein, Nello & Marino, 1991).

Effect of sample size: Neglecting the effect of sample size while comparing probabilities (Kahneman &Tversky, 1972)

Conjunction fallacy: Assigning higher probabilities to combined event than each event of combined event (Tversky & Kahneman, 1983).

Availability heuristic: Estimating frequency or probability of an event by its easiness of come to mind (Tversky & Kahneman, 1973).

Time-axis fallacy (the Falk phenomenon): Disregarding the effect of a later event on an outcome that has already happened (Falk, 1986).

Equiprobability bias: Evaluating all results of an experiment as equiprobable (Lecoutre, 1992).

CHAPTER 2

REVIEW OF THE RELATED LITERATURE

This chapter gives a review of the literature related to theoretical background of the study and probability concept. In this section, the literature is discussed in terms of constructivism, conceptual change approach, development of probability concept in children, difficulties on probability learning and teaching, probabilistic misconceptions, overcoming misconceptions, probability achievement and attitudes toward probability. Finally, a literature review summary is presented.

2.1 Theoretical Background of the Study

In the current study, conceptual change model was used. Conceptual change model is based on constructivism. For this reason, in the following two sections, constructivism and conceptual change model was discussed, respectively.

2.1.1 Constructivism

We have frequently encountered with the concept of constructivism in recent times. Constructivism which is a theory of knowing has become a powerful theory during the last two decades (Tobin, 1993). Constructivism seems a powerful alternative form of instruction to direct instruction (Von Glaserfeld, 1990). Actually, constructivism is not a new didactic paradigm different from present educational theories since it does not provide any homogeneous new theory (Terhart, 2003).

Constructivist perspective stems from cognitive psychology, especially the Dewey, Vygotsky and Piaget's works (Danielson, 1996). According to constructivist view, people are not passively received knowledge but they actively build up their own knowledge. Constructivism says that learning is a knowledge construction process and in this process individual constructs his/her new concept based on existing conceptions. There are several movements in constructivism such as cognitive, social, and radical. However, two, cognitive constructivism, or sometimes radical constructivism and social constructivism have gained prominent attention (Liu & Matthews, 2005).

According to the view of cognitive constructivism, knowledge is a product of individual's cognitive acts (Confrey, 1990). That is, individuals construct or interpret their own reality based upon experiences, mental structures, and beliefs (Jonnasen, 1991). Also, radical constructivism states that knowledge is a product of individual experience. Von Glasersfeld (1989) mentioned two basic principles of radical constructivism. First principle stated that knowledge is not passively received, but it is actively constructed by the cognizing subject. Second principle said that knowledge acquisition process is an adaptive process organizing the experiential world, not the discovery of ontological world. According to social constructivism, knowledge is constructed as a result of individuals' interaction with their environment (Liu & Matthews, 2005).

Although constructivism says that knowledge is constructed by the individual, in this construction process the teacher's role is also important. Brooks and Brooks (2001) listed some properties of constructivist teachers like supporting student autonomy and initiative, encouraging classroom discourse and student inquiry, and identifying students' understandings of concepts before sharing their own understandings. Because constructivists believe the significant role of misconceptions in conceptual development (Ben-Hur, 2006), identifying students' understandings of concepts is crucial. According to Ben-Hur, constructivism says that "students first understand mathematics from their misconceived perspective and as they progress they gradually refine and reorganize their knowledge" (p. 43). So, he states that constructivists refer to misconceptions in developmental terms like “preconception” or “naive intuitive ideas”.

As a result, there is a common idea that people construct their own knowledge. In this knowledge construction process, individual actively build up their own knowledge based on previous experiences, mental structures, and beliefs. In the current study, the idea of constructivism was used. Students in experimental group were guided to construct probability concept by using conceptual change model.

2.1.2 Conceptual Change

By the time children come to school they have developed their own explanations/ideas about objects and events around them (Baroody, 1987; Kamii, 1994). Source of this kind of knowledge can be experiences, their environment, people around them, events, and media. Learning is the process of knowledge construction under the effect of these prior experiences and existing concepts (Tsai, 2000). That is, according to Tsai, in the process of meaningful learning, individuals construct integrated knowledge structures that contain prior knowledge, experiences, new concepts and other relevant knowledge. If students’ existing knowledge is inconsistent with that of scientific community, students do not associate new conceptions with preconceptions. Therefore, identification and elimination of students’ misconceptions is very important to provide meaningful learning.

Researchers have emphasized that students often have naive ideas about objects and events around them (Posner et al., 1982; Strike & Posner, 1992). Students use their preexisting ideas to interpret concepts which are confronted newly and to comprehend their instructional experiences (Driver & Easley, 1978). However, preconceptions mainly contradict scientifically correct one and can hinder students’ learning (Driver & Easley, 1978; Helm & Novak, 1983). Also, they are robust to change and even after instruction some students can still have some misconceptions (Champagne, Gunstone & Klopfer, 1985; Driver & Easley, 1978).

Conceptual change is an instructional model that takes into consideration constructivism and students' conceptions in classroom context (Hewson & Thorley, 1989). That is to say, it is "an approach to application of constructivist ideas to science instruction" (p. 541). Weaver (1998) stated that while constructivism focuses on the general process of learning, focus of the conceptual change theory is on the specific conditions which are necessary for modification of existing structures by new conception.

Conceptual change approach (theory of accommodation) is one approach focused on fundamental changes in "people's central, organizing concepts from one set of concepts to another set, incompatible with the first" (Posner et al., 1982, p.211). This model proposed by Posner and his friends. Theoretical framework of this approach based on constructivist learning. Actually, its starting point is based on the idea of "learning is the result of the interaction between what the student is taught and his current ideas or concepts" (p. 211). However, they also stated that this is not a new idea of learning because it took source from early Gestalt psychologist and affected Piaget's studies. Conceptual change model (CCM) is based on the Piaget's assimilation, accommodation, and equilibration concepts. To fulfill assimilation, a person must use existing conceptions to interpret new experiences. However, if current conceptions are inadequate to overcome new phenomena, accommodation occurs. Equilibration which encompasses both assimilation and accommodation describes the balance between accommodation and assimilation (Driscoll, 1994).

Posner et al. (1982) was mentioned two phase of conceptual change namely, assimilation and accommodation. The first phase of conceptual change is "assimilation" and it only occurs students use current conceptions to overcome new experience. However, if students' existing conceptions are not enough to interpret new phenomena, "students must replace or reorganize his central concepts" (p.212). They defined this more radical form of conceptual change as "accommodation". Their focus was on kinds of radical conceptual changes, that is, accommodations.

Two major components of the CCM are conditions of conceptual change and conceptual ecology. Posner et al. (1982) elaborates on accommodation and proposed four conditions that are necessary to be fulfilled for accommodation. Thus, there are four conditions that must be met for conceptual change. These are "dissatisfaction", "intelligibility", "plausibility" and "fruitfulness". Before a person experience conceptual change, these conditions must be satisfied. They also mentioned the term "conceptual ecology". They used this term to refer learner's current conceptions. According to them, an individual's conceptual ecology has an effect while selecting of a new central concept.

Posner et al. (1982) stated that some important conditions must be provided before accommodation occurs. These are:

1) *Dissatisfaction with existing conceptions:* First condition is dissatisfaction. If the individual's current conception is insufficient to explain new experience, dissatisfaction occurs. Posner et al. (1982) emphasized that individuals can make changes in their concepts "if they lost faith in the capacity of their current concepts to solve unsolved puzzles or anomalies" (p.214). They also emphasized that without dissatisfaction with existing conception the individual must not seriously think a new concept.
2) *Intelligibility of a new conception:* Intelligibility is required for accommodation. However, only intelligibility is not enough for accommodation. An understanding of component terms and symbols used and the syntax of the mode of expression is necessary to be fulfilled intelligibility at a simple level. However, Bransford and Johnson (1973, as cited in Posner at al., 1982) stated that constructing coherent representation of a passage or theory is also necessary for intelligibility.
3) *Initial plausibility of a new conception:* "Initial plausibility can be thought of as the anticipated degree of fit of a new conception into an existing conceptual ecology" (Posner, et al., 1982, p. 218). To be fulfilled plausibility, the new conception should not only have the potential to solve the problems generated by existing concept but also consistent with other knowledge.

4) *Fruitfulness of a new conception:* The new concept should have the capacity in solving further problems.

Conditions of conceptual change are related to learners' existing conceptions or new conceptions to be experienced. The *status* of a person's conception is related to the extent to which the concept satisfies the three conditions of conceptual change; "intelligibility", "plausibility", and "fruitfulness". That is, changing the status of the concept is focus of the conceptual change model.

In the current study, Posner et al.'s (1982) conceptual change model was applied in the treatment of experimental group. The lesson plans for the experimental group were prepared in a way that satisfies conditions of conceptual change; "dissatisfaction", "intelligibility", "plausibility" and "fruitfulness".

2.2 Educational Studies on Conceptual Change

There are many studies about application of the conceptual change approach in science education. Research studies have shown that in dealing with students' misconceptions in science conceptual change is an effective method. According to Chi and Roscoe (2002), misconceptions are ontological miscategorizations of concepts. In their study, they especially focused on definition of misconception and argued why it is difficult to change them. They emphasized that conceptual change process is difficult if students do not know when they need a shift and which concept they should shift into. Teachers should provide various activities to make students aware of their misconceptions and feel a need to change them. Also, they should present an alternative conception to shift into.

Teaching for conceptual change does not imply a specific teaching model but group of teaching models. Actually conceptual change model provides a guideline for teaching. Students' prior concepts are very important in teaching for conceptual change. To promote conceptual change, teachers may use various teaching strategies. For example, Minstrell (1985) used some instructional strategies to improve students' understanding of physics concepts. He stated that using these strategies made him more effective in changing his students' initial ideas. In the study, he listed six instructional principles for facilitating conceptual change. These are: (1) engaging students' initial conceptions, (2) using several laboratory activities, demonstrations, or other experiences related to students' initial conceptions, (3) using discussions which encourage students to solve unclear points between their initial conceptions and their observations from experience (4) beginning instruction with concrete experiences and continue with more abstract thought (5) giving repeated opportunities to apply new ideas in new contexts (6) working within limits of students' differences in initial conceptions, logical reasoning and information processing. He also stated that awareness of students' existing conceptions, providing several experiences related to them and supporting students to resolve inconsistencies between their conceptions helped them change their initial concepts.

Champagne et al. (1985) also proposed another teaching strategy to promote conceptual change. In this strategy which was based on ideational confrontation, opportunities for discussing existing conceptions, awareness of them, scientific explanations and a discussion environment to compare students' existing conceptions and scientific conceptions were provided to students.

Some research studies used refutational or conceptual change text based instruction to enable conceptual change (e.g., Chambers & Andre, 1997; Çetin, Ertepınar, & Geban, 2004; Çetingül & Geban, 2005; Hynd, Alverman, & Qian, 1997; Markow & Lonnning, 1998; Pabuçcu & Geban, 2006). For example, Çetingül and Geban (2005) used conceptual change text based instruction in order to improve students' understanding of science concepts. They studied with tenth grade students. Results revealed that students' performance taking conceptual change instruction accompanied with analogies on acids and bases concepts was better than students' performance taking traditional instruction. Similarly, Çetin et al. (2004) designed an instruction including conceptual change texts to improve ninth grade students' understanding of ecology concepts. Results indicated that the experimental group students who received conceptual change instruction accompanied with small group work acquired scientific conceptions better than the control group students who received traditional instruction. Similar to results of these studies, Sungur, Tekkaya, and Geban (2001) found significant effect of conceptual change text on students' understanding of scientific concepts. They investigated the contribution of conceptual change texts to students' understanding of scientific concepts related to human circulatory system. They designed an instruction for tenth grade students. Their instruction included conceptual change texts accompanied by concept mapping. Their study results revealed that this instruction caused a better acquisition of scientific conceptions.

Concept map is another instructional tool which is used to promote conceptual change. "Concept map is a two dimensional, hierarchical, node-link representation that depicts the major concepts and relationships in the knowledge structure" (Martin, Mintzes & Clavijo, 2000, p.306). Concept map helps students organize concepts and construct relationship between them (Odom & Kelly, 2001). Some researchers showed that concept mapping is effective in facilitating meaningful learning. For example, Okebukola (1990) and Heinze-Fry and Novak (1990) found similar results which showed that concept mapping caused meaningful learning of concepts. Similarly, Uzuntiryaki and Geban (2005) investigated the effectiveness of conceptual change instruction accompanied with concept mapping (CCI) on students' understanding of solution concepts and their attitudes toward science. Study was conducted with 8th grade students. Results indicated that the CCI was superior in terms of acquisition scientific conceptions and improving positive attitudes toward science than traditional instruction.

Cooperative learning approach is an encountering strategy in some studies aiming to promote conceptual change (e.g., Basili & Sanford, 1991; Bilgin & Geban, 2006; Çelikten et al., 2012; Esiobu & Soyibo, 1995). During the cooperative learning process, students work together to achieve learning goals (Johnson & Johnson, 1999). Çelikten et al. (2012) studied the effect of conceptual change based instruction through cooperative learning (CCICL) on students' understanding and attitudes. They studied with 4^{th} grade students. Results of the study revealed that students who were instructed with CCICL had significantly better acquisition of scientific concepts than the students who were instructed with traditional instruction. However, results revealed that there was no significant difference between post-test mean scores of students who were instructed with CCICL and those who were instructed with traditional instruction with respect to their attitudes toward earth and sky concepts.

To facilitate conceptual change some studies use demonstrations. For example, Ceylan and Geban (2010) investigated the effect of the conceptual change oriented instruction through demonstration (CCID). They studied with tenth grade students on chemical reactions and energy concepts. Results indicated that CCID led to significantly better acquisition of scientific concepts than traditional instruction. Similarly, results showed that there was a significant difference between post-test mean scores of students who were instructed with CCID and those who were instructed with traditional instruction with respect to their attitudes toward chemistry in favor of CCID. Hewson and Hewson (1983) also examined the effect of instruction based on conceptual change strategy. Their experimental study was conducted with ninety students from 9th graders. Throughout the study, in the experimental group conceptual change based instruction including experiments, discussion, demonstrations, and worksheets (CCBI) was used while in the control group traditional instruction (TI) was used. Their study results showed that CCBI were more effective on understanding of mass, volume, density, and relative density concepts and eliminating alternative conceptions than TI.

Cognitive conflict is also common strategy using to promote conceptual change. For example, Nieswandt (2000) conducted a study based on cognitive conflict strategy for the purpose of improving students' learning of basic chemical concepts. The study was conducted 81 ninth graders at four different schools. For the study, the researcher prepared six teaching units based on cognitive conflict strategy. The main aim of the researcher was to provide students awareness of their everyday conceptions and planned cognitive conflict by confronting students a discrepant event. The teaching strategy applied in the sequence of discussing students' existing concepts about the topic, then to provide cognitive conflict confronting them with a phenomenon that cannot be explained with their previous concepts. To collect data an open-ended questionnaire was used. According the result of the study, while some students changed their everyday conceptions to scientific ones in some topics, the others' notions were consistent with a mixture of everyday descriptions and scientific explanations. The researcher also stated that these students were moving toward the scientific concept but they did not achieve this at the end of the study.

Scott, Asoko, and Driver (1991) presented a review of pedagogical strategies based on conceptual change. They focused on two groups of strategies to enable conceptual change. These strategies include strategies based on cognitive conflict and the resolution of conflict and strategies based on learners' current conceptions and extend them. They also stated that various approaches to teaching for conceptual change used cognitive conflict as a base. They also emphasized that such approaches require situations in which the student's previous conceptions are made explicit and are also challenged to create cognitive conflict. Then, these approaches require students to resolve this conflict. The other group of teaching strategies teaching and learning activities based on students' existing conceptions requires students to develop and to extend these previous ideas toward the scientific ones.

Some researchers described conceptual change learning as a process which includes discussions of students' conceptions (e.g., Dreyfus, Jungwirth, & Eliovitch, 1990; Nussbaum & Novick, 1982). Niaz, Aguilera, Maza and Liendo (2002) used a strategy based on classroom discussions. They conducted a study with 160 freshman students in order to support students' understanding of atomic structure. The topics covered in the study were firstly explained to experimental and control groups. Their instructional model based on classroom discussions was used only in experimental group after the traditional instruction of both control and experimental groups. Experimental groups participated in discussions about the six items with alternative responses during three weeks. In this process, students were responsible for selecting a response, participating in classroom discussions leading to arguments in favor or against their selected response and then selecting a new response. Results showed that experimental students which had opportunities to discuss their opinions experienced conceptual change. Similar strategy was applied by Roth, Anderson, and Smith (1987). They also suggested a teaching strategy based on classroom talk. To promote conceptual change they recommended eliciting and responding to students' misconceptions, concentrating students' explanations, probing after students' responses, organizing discussions, and allowing students to practice. Similarly, Vosniadou, Ionnides, Dimitrakopoulou, and Papademetriou (2001) conducted a study in which a learning environment was designed by using research based conceptual change principles for teaching mechanics to students from fifth and sixth graders. In this learning environment, they had chance to control actively their own learning. They also studied in small groups and discussed their work with all classrooms. In order to promote metaconceptual awareness, students were encouraged to express their opinions, to test and compare them with other students' ideas and to give scientific explanations. Results showed that experimental learning environment contributed students' understanding of the topics covered in the study.

Instructional technologies are also important tools to facilitate conceptual change (Snir, Smith, & Raz, 2003). For example, dynamic representations ensure visual explanations for scientific phenomena which are not directly observable (Gobert, 2000). Hameed, Hackling, and Garnett (1993) investigated the effectiveness of a computer-assisted instructional (CAI) package based on CCM on dealing with students' misconceptions. The CAI package was designed based on the conditions of CCM. Simulations were used in creating cognitive conflict and facilitating accommodation. Results indicated that it caused significant conceptual change in students. Zacharia and Anderson (2003) also used to computer simulations to improve students' conceptual understanding of physics. They studied with 13 in-service and pre-service science teachers. According to results, the use of simulations improved participants' conceptual understanding of physics concepts and led to a significant conceptual change.

Besides the studies investigating the effect of instructional strategies on understanding of scientific concepts, there are also some studies which examine the effect of conceptual change instruction on students' science achievement and attitudes toward science. However, while some studies indicated that conceptual change instruction improved students' attitudes, the others showed that conceptual change instruction did not have a significant effect on students' attitudes. For example, many studies showed that conceptual change instruction was more effective in improving students' achievement and attitude toward science than traditional instruction (e.g., Basili & Sanford, 1991; Ceylan & Geban, 2010; Çaycı, 2007; Esiobu & Soyibo, 1995; Gürses, Doğar, Yalçın, & Canpolat, 2002). However, some studies indicated that traditional instruction and conceptual change instruction developed the similar attitude toward science (e.g., Başer & Çataloğlu, 2005; Başer & Geban, 2007; Çelikten et al., 2012; Pınarbaşı, Canpolat, Bayrakçeken, & Geban, 2006).

As a result, there are many studies to investigate the effect of conceptual change instruction on students' understanding, achievement and attitudes in science education. The strategies based on conceptual change require active involvement of students to instruction. During the instruction, students should be supported to express their ideas. Discussions is important tools to promote conceptual change. Students who participate in discussions during the teaching and learning process can easily realize own and others' ideas.

The implementation studies of the conceptual change approach in mathematics learning and teaching is relatively new since the adoption of conceptual change approach which was developed mainly in the context of physical sciences has been a reluctant process for the mathematics education community (Vosniadou, 2008). According to Vosniadou, because of the similarities in learning science and mathematics, conceptual change approach can be also applied in mathematics learning. However, it is found few studies related to conceptual change instruction in mathematics education throughout the literature review process of this study (e.g., Cankoy, 1998; Castro, 1998; Toka, 2001).

Castro (1998) investigated the effect of conceptual change instruction (CCI) on students' performance in probability calculations and in probability reasoning, attitude toward mathematics and level of conceptual change. Castro conducted the study with 136 students in the first year of secondary school. While in the experimental group CCI was applied, in the control group traditional instruction (TI) was applied. Results showed that CCI improved students' skills in probability calculations and in intuitive probability reasoning while it did not affect students' attitudes toward mathematics. Also, conceptual change instruction led to a higher level of conceptual change.

In Turkey, Toka (2001) investigated the effectiveness of cognitive conflict instruction (CCI) and conceptual change text instruction (CCTI) on students' achievement in "first degree equations with one unknown". The participants of the study were174 seventh grade students. Their study was an experimental study. During the instruction, one experimental group was instructed with CCI and the other experimental group was instructed with CCTI, while the control group received traditional instruction. The results revealed that students at cognitive conflict instruction got significantly higher scores on achievement test comparing to CCTI. However, there was no significant difference between mean scores of CCI and TDI and also between mean scores of CCTI and TDI.

Another study in mathematics education was conducted by Cankoy (1998). He examined the effect of conceptual change instruction (CCI) on interpreting and applying decimals. He conducted the study with preservice elementary teachers. Firstly, he determined the preservice teachers' misconceptions related to topic. Then, the experimental group received CCI while the control group received traditional instruction (TI). His study results indicated that CCI is effective to overcome students' misconceptions in applying and interpreting decimals. Similarly, CCI caused better conceptual understanding of the concepts than TI.

As a result, in order to facilitate students' understanding and eliminate their misconceptions, many instructional strategies based on conceptual change model have been proposed. These approaches include conceptual change text, concept map, cognitive conflict, analogy, demonstration, cooperative learning, computer simulations, and discussions. Since using activities, discussions and simulations are effective strategies in mathematics learning as well as science learning, in this study conceptual change based instruction accompanied by discussions, activities and computer simulations was used.

2.3 Development of the Probability Concept in Children

Research studies show that the concept of probability develops over time (Davies, 1965; Fischbein, 1975; Fischbein & Gazit, 1984; Piaget & Inhelder, 1975). That is, “the acquisition of the concept of probability is developmental in nature” (Davies, 1965, p. 787). Piaget and Inhelder (1975) explained the development of notions of chance and probability in children in three successive stages. In stage 1 which is the sensory motor stage lasted up to age 7, the child does not understand random phenomena. In stage 2 which is the concrete-operational stage lasted age between 7 and 10, notion of probability starts to develop. In the stage 3 that is the formal operational stage beginning at approximately age 11, the child develops a full understanding of notion of probability. However, the concept may not be acquired completely because of the individuals’ incompletely progress in the stages (Davies, 1965).

Fischbein and Gazit (1984) supported the findings of Piaget and Inhelder (1975). They analyzed the effectiveness of a teaching program in probability on grades 5, 6, and 7. Their study showed that most of the notions were too difficult for fifth graders. The study also showed that most of the concepts in probability were understood and used by about 60-70% of the sixth graders and about 80-90% of the seventh graders. Similarly, at the end of a study in which 13- and 17-year-olds were examined in terms of intuitive notions of probability, Carpenter et al. (1981) concluded that intuitive notions of probability develops with age and also stressed that they do not require to be absolutely correct.

Davies (1965) was also interested in the development of the probability concept in children. She conducted a study with total 112 children at age from 3 through 9 years for the purpose of obtaining additional information related to Piaget’s theory of the development of the probability concept. However, while her some findings supported the Piaget and Inhelder findings, some of them did not. Davies stated, like Piaget and Inhelder, the concept of probability is developmental. She found that the non-verbal behavior of preoperational children (approximately age 3 through 6 years) may be related to event probabilities. She also stated that Piaget’s generalization that probability notion first develops in concrete-operational stage only measures the ability to verbalize the probability concept. In this aspect, she also examined the mean age of acquisition of the verbal ability. Her conclusion was that this ability was acquired approximately age between 7 years, 4 months and 9 years.

There are also some additional studies supported controversy ideas with interpretation of Piaget and Inhelder in literature (e.g., Fischbein, 1975; Goldberg, 1966; Yost, Siegel, & Andrews, 1962). For example, some studies claimed that even preschool children may have elementary probabilistic estimations (Goldberg, 1966; Yost et al., 1962) or correct probabilistic intuitions (Fischbein, 1975). According to study of Carpenter et al. (1981) which was conducted with twenty-two hundred and twenty-four hundred students at 13- and 17-years old, respectively, although many students know some general notions of probability, they do not know how to report probabilities by using conventional methods.

As a result, research studies show that the concept of probability or intuitive notions of probability develops over time. However, it is emphasized that these intuitive notions of probability may not be correct. In the current study, students' intuitive notions of probability were also taken into consideration while planning lessons in the experimental group.

2.4 Difficulties on Probability Learning and Teaching

The probability concept is one of the concepts in which both students and teachers have difficulty. For example, in Turkey, Tatar et al. (2008) conducted a study to investigate preservice mathematics, science and elementary teachers' opinions about difficulties of high school mathematics subjects. For this reason, a difficulty index questionnaire with 29 items was applied to 506 preservice teachers. Results of the study showed that preservice elementary teachers thought that the probability concept was the one of the difficult concepts to learn, whose difficulty index was found above 50% in this study. According to preservice mathematics and science teachers, the difficulty indices of probability concept were 33% and 39%, respectively. At the total the difficulty index of probability subject was found as 43%. As a result, probability concept was thought as one of the difficult concepts to learn for preservice teachers. Similarly, Boyacıoğlu, Erduran and Alkan (1996) investigated the subjects in which students and teachers were confronted difficulties while learning and teaching them. Permutation, combination and probability were found as difficult subjects for 84% of the teachers and for 91% of the 45 students.

Similarly, Durmuş (2004) conducted a study to determine subjects perceived difficult by preservice teachers and reasons behind these perceived difficulties. The study was conducted with 481 preservice elementary science, mathematics and classroom teachers. The subjects perceived as difficult by the prospective teachers was determined through a questionnaire. And the reasons behind these perceived difficulties were investigated through interviews conducted with the 20 participants selected randomly from 481 preservice teachers. The results of the study revealed that the probability subject was perceived as a difficult subject. Interview results also showed that there were two important reasons behind perceived difficulties of prospective teachers namely, “deficiency of motivation” and “abstractness of concepts”.

Memnun, Altun, and Yılmaz (2010) investigated 90 eighth grade students’ understanding level of basic probability concepts and abilities to practice them. The data was collected by using a probability achievement test with five open-ended questions. The results showed that students maturity and developmental level had a key role in learning and perception of probability concepts. Also, it was seen that students had difficulties in probabilistic reasoning and in interpreting of the concept of sample space , exclusive events and independent events.

In the literature, there are several reasons for learning difficulties in probability concepts. For example, the lack of sufficient knowledge and skills of teachers to teach probability concept effectively (Toluk, 1994), difficulties experienced with prerequisite concepts like “fractions” (Carpenter et al., 1981), and “ratio” (Green,1983; Piaget & Inhelder, 1975), students difficulties in interpreting the problems (Carpenter et al.,1981), students’ distaste for probability (Garfield & Ahlgren, 1988) and misconceptions (Lecoutre, 1992;

Shaughnessy, 1992; Watson & Moritz, 2002) can be listed as reasons for difficulties.

Difficulties experienced with prerequisite concepts like “fractions”, “decimals”, “percents”, “operations on set” can lead difficulties in learning probability concepts. Carpenter et al. (1981) stated that difficulties on fractions limit the students’ ability on some probability concepts. Similarly, the rational number concept relates with integrated subconstructs and processes related to probability (Behr, Lesh, Post, & Silver, 1983). So, students’ difficulties with rational numbers and proportional reasoning can lead difficulties in probability.

Students difficulties in interpreting the problems can also cause the difficulties in learning probability concepts. Carpenter et al. (1981) found that many students tend to use numbers in the problem in their response to a probability problem. The other reason can be students’ distaste for probability developed because of the teaching probability in a manner abstract and formal way (Garfield & Ahlgren, 1988).

Memnun (2008) investigated difficulties encountered during learning probability and reasons of these difficulties by reviewing some literature on probability concept. She determined six reasons for probability learning difficulties namely, age, insufficiency of prerequisite knowledge, inadequacy of reasoning skill, teacher, students’ negative attitudes, and misconceptions. Similarly, Garfield and Ahlgren (1988) emphasized the importance of teacher in learning probability. They stated that “despite the enthusiastic development of new instructional materials, little seems to be known about how to teach probability and statistics effectively” (p.45). Teachers’ competencies on probability affect their instruction. Reasons underlying perceived difficulties of students on probability may take roots from teachers’ competencies on probability. Thus, Bulut (2001) investigated the probability performance of prospective mathematics teachers. She conducted her study with 125 prospective mathematics teachers. She obtained data by using a probability achievement test. According to results of the study, prospective teachers did not have enough competencies on probability subject. Also, these prospective teachers did not have some basic probability concepts like probability of occurring events, sample point and sample space. In other similar study, Bulut and Şahin (2003) investigated students' and preservice mathematics teachers' competencies on probability concept. They conducted their study 97 ninth grade and 95 eleventh grade students, and 125 prospective mathematics teachers. They found that not only 9th and 11th grade students but also prospective mathematics teachers had low probability achievement mean scores, 8.5, 16.8, and 15.7 out of 26, respectively. These results reflected that both students and prospective mathematics teachers did not have enough competencies about probability concept. A similar result was supported by Bulut, Kazak, and Yetkin (2000). They studied on prospective teachers' proficiencies on probability concepts. In order to collect data, probability achievement test was used. According to results, pre-service teachers did not have most of the basic probability concepts.

On the other hand, probabilistic misconceptions are among the most important reasons of difficulties on probability teaching and learning. Students' wrong intuitions, biases, and misconceptions make difficult to learn probability (Konold, 1989; Shaughnessy, 1992). Several studies reported that developing an intuition about the general ideas of probability was difficult for many students even after instruction (Shaughnessy, 1981). A significant amount of research has been conducted to investigate the use of heuristics in subjective probability judgements (e.g., Fischbein & Schnarch, 1997; Kahneman & Tversky, 1972, 1973; Piaget & Inhelder, 1975; Shaugnessy, 1992). Most of them focused the relationship between individuals' natural, intuitive approaches and the formal, mathematically based solutions (Fischbein et al., 1991). Intuition which consists of most of our mental activity is not a conscious and analytical thinking process (Bunge, 1962). The probability concept is the main area of mathematics to see counterintuive concepts (Ben-Hur, 2006). Thus, this naive intuition leads to various probabilistic misconceptions.

To sum up, literature on probability shows that students experience difficulties in learning probability concepts. Probabilistic misconceptions are among the most important reasons of difficulties on probability learning. The present study took into consideration of students' misconceptions on probability. Lessons in the experimental group were designed to address students' intuitively based probabilistic misconceptions. In following sections probabilistic misconceptions will be mentioned in detail.

2.5 Probabilistic Misconceptions

Carey (2000) defined the concept as “units of mental representation roughly equivalent to a single word, such as object, animal, alive, heat, weight, and matter” (p. 14). Also, Carey states that according to many cognitive scientists concepts are complex representational structures. Review of the research literature showed that, since the early 1970s, there has been an increasing interest in research on the children’s concepts, beliefs, ideas and theories bring to class constructed in an attempt to make sense of their world. To represent these ideas or concepts which differ from the scientifically correct ones several terms have been used such as “naive beliefs” (Caramaza, McCloskey, & Green, 1981), “intuitive conceptions” (Lee & Law, 2001), “pre-conceptions” (Novak, 1977), “misconceptions” (Helm, 1980), “alternative conceptions” (Driver & Easley, 1978; Gilbert & Watts, 1983), and “children’s science” (Gilbert, Osborne & Fensham, 1983) . In this study, the term “misconception” was used. Misconceptions are alternative frameworks or conceptions which is different from scientific meaning of the concept (Nakhleh, 1992). These conceptions may be obtained from daily life or previous learning experiences. If we want to provide meaningful learning, students’ prior knowledge should be taken into account during the instructional process. Because of this, several studies about the students’ pre-instructional conceptions and how to overcome them have been conducted.

Many studies show that children develop basic probability concept intuitively unless any instructional practice (Fischbein & Schnarch, 1997; Shaugnessy, 1992). Students come into learning environment with these “pre-conceptions”. These intuitively probabilistic concepts are mostly wrong and lead some misconceptions. According to Shaugnessy (1977), reasons of students’ misconceptions about probability may be related to combinatorial growth and decay and also inexperience with the mathematical laws of probability. Literature also shows that the evolution with age of probabilistic misconceptions is different. The impact of some improves with age, others decreases with age, and some is stable across ages (Fischbein & Schnarch, 1996).

Probabilistic misconceptions have taken interest from not only mathematics education researchers (e.g., Fischbein, 1975; Shaughnessy, 1992) but also psychologist (e.g., Kahneman & Tversky, 1972, 1973; Piaget & Inhelder, 1975). Tversky and Kahneman was published some of the earliest works related to probabilistic misconceptions (Kahneman & Tversky, 1972, 1973, 1982).

Probabilistic misconceptions are very important because students' misconceptions in probability affect their understanding of basic probability concepts (Fischbein & Schnarch, 1997). In the literature, there are some studies to determine students' misconceptions in probability. In Turkey, for example, Dereli (2009) investigated the eighth grade students' mistakes and misconceptions in probability. The study was conducted with 349 students. According to results, students had misconceptions in probability. Most of the misconceptions were related to empirical and theoretical probability, and dependent and independent events. Similar to research of Dereli, Hayat (2009) conducted a study to determine 8th grade students' conceptual and procedural knowledge and misconceptions in probability. The participants were composed of 130 students. According to the findings, he stated that students' conceptual and procedural knowledge level was low, and they had misconceptions related to basic probability concepts. There are also some studies investigating probabilistic misconceptions of inservice teachers and preservice teachers. For example, Yıldız and Bulut (2002) found that prospective teachers had probabilistic misconceptions. Doğucu (2013) also studied with mathematics teachers to investigate the relationship between mathematics teachers' probability approaches (theoretical, experimental and subjective) and misconceptions. This study was conducted with 72 participants. Participants were composed of preservice mathematics teachers, teachers who had less than ten years of teaching experience and teachers who had ten or more years of teaching experience. According to results of the study, it can be said that there was not enough evidence to say that experience level of the teachers help them to overcome probability misconceptions.

The well-known probability misconceptions are “representativeness”, “negative and positive recency effects”, “simple and compound events”, “the conjunction fallacy”, “the effect of sample size”, “availability”, “the time-axis fallacy” and “equiprobability bias”. Mut (2003) investigated these types of misconceptions related to probability concepts in terms of grade level, and previous instruction on probability and gender. He conducted the study with 885 students from 5th, 6th, 7th, 9th and 10th graders. Probabilistic Misconception Test was used to collect data. Results of the study showed that frequencies of misconception types differed in terms of grade levels. Higher percentages in the probabilistic misconceptions on “effect of sample size” and “time axis fallacy” were observed among students received previous instruction on probability than those not received previous instruction. However, the percentages of the other type of misconceptions were higher among students not received previous instruction than those received previous instruction. In other similar study, Çelik and Güneş (2007) examined the students’ understanding and misconceptions about probabiliy based on their intuitions and experiences. They conducted a cross sectional research with 218 students from different grade levels, 7th, 8th, and 9th grades. The data was collected through a multiple choice test. The results showed that “representativeness” and “negative and positive recency effect” misconceptions decreased with the grade level while “simple and compound events”, “conjuction fallacy” and “effect of sample size” were observed stable across grade levels.

As a result, research studies show that individuals develop basic probability concept intuitively unless any instructional practice. They also come into learning environment with these “pre-conceptions” which are mostly wrong and lead some misconceptions. Probabilistic misconceptions are very important because students’ misconceptions in probability affect not only their achievement but also their understanding of basic probability concepts. The literature also presents the well-known probability misconceptions as “representativeness”, “negative and positive recency effects”, “simple and compound events”, “the conjunction fallacy", "the effect of sample size", "availability", "the time-axis fallacy" and "equiprobability bias". The current study took into consideration of these eight misconception types. The lessons in experimental group were designed to address these types of misconceptions.

2.5.1 Representativeness

The misconception of representativeness was first mentioned by Kahneman and Tversky (1972). They stated that because of the "representativeness heuristic" a person makes an uncertainty judgement based on "the degree to which it is: (i) similar in essential properties to its parent population; and (ii) reflects the salient features of the process by which it is generated" (Kahneman & Tversky, 1972, p. 431).

If an event A appears more representative than an event B, A is judged to be more likely than B as a result of "representativeness heuristic" (Kahneman & Tversky, 1972). However, to be representative, similarity of an uncertain event to parent population is not enough; it also reflects the properties of the uncertain process by which it is generated. Kahneman and Tversky examined this type of heuristic by applying a questionnaire to about 1500 students from grade 10, 11 and 12. Consider the following question from Kahneman and Tversky (1972):

> All families of six children in a city were surveyed. In 72 families the exact order of births of boys and girls was GBGBBG. What is your estimate of the number of families surveyed in which the exact order of births was BGBBBB? (p. 432)

Actually, both sequences have equal chances to occurrence ($1/2^6$). However, students who had representativeness heuristic, judged the order of births GBGBBG more likely than the order of births BGBBBB, since the sequence with three boys and three girls reflect the proportion of boys and girls in the population (Kahneman & Tversky, 1972). Then, in the same problem context, students were interviewed to evaluate the number of families surveyed in which the exact order of births was BBBGGG. Students judged the order of births BBBGGG less likely than the order of births GBGBBG. In this situation, students may judge BBBGGG less random from GBGBBG because of the regularity of the order of the births (Kahneman & Tversky, 1972). For example, since a sequence of coin tosses such as HTHTHTHT or TTHHTTHH does not reflect the randomness of the process, people may assign lower probabilities to such sequences. That is, the expectation is irregularity.

In Turkey, Çelik and Güneş (2007) examined the students' understanding and misconceptions about probabiliy based on their intuitions and experiences. They found that about a third of the seventh grade students had representativeness heuristic, while this rate was gradually decreasing at grade eight and nine. Fischbein and Schnarch (1997) also studied this type of misconception with students from 5th, 7th, 9th, and 11th graders and with prospective teachers. They found that this heuristic decreased with age. Similar result was supported by Mut (2003). Mut also stated that this type of misconception was seen less in students who took previous probability instruction.

2.5.2 Negative and Positive Recency Effects

In probability estimations some people expect different results relying on obtaining successive same results (Cohen, 1957). Negative recency effect which is also known "gambler fallacy" (Fischbein & Schnarch, 1997) and "law of averages" (Garfield & delMas, 1990) can also be explained representativeness heuristics. Carpenter et al. (1981) stated that if an event has obtained a number of times successively, it is supposed that because of "the law of averages", obtaining the event on the next trial is unlikely. They also stated that this misunderstanding was often based on the failure to recognize the independence of certain events. Consider an example of tossing a coin; if a person tosses a coin four times, and at each time s/he gets tails, s/he may think that he will get more likely heads at the fifth tosses. This type misconception is called as "the negative recency effect" or "the gambler's fallacy" (Fischbein & Schnarch, 1997). Gambler's Fallacy emerges because people think even small number of experiments (samples) to reflect the fairness of the laws of chance (Shaughnessy, 1977). On the contrary, the person may think that s/he will get more likely tails at the fifth tosses because of the assumption that the conditions were not fair. This misconception type is called “the positive recency effect” (Fischbein, 1975). Consider the following question from Fischbein and Schnarch (1997).

> When tossing a coin, there are two possible outcomes: either heads or tails. Ronni flipped a coin three times and in all cases heads came up. Ronni intends to flip the coin again. What is the chance of getting heads the fourth time?
> Smaller than the chance of getting tails (main misconception; negative recency effect)
> Equal to the chance of getting tails (correct)
> Greater than the chance of getting tails (positive recency effect) (p. 98)

The person who gets three heads may then think that the fourth toss is more likely to be tails (negative recency effect). Or one may think that the conditions are not fair and then the fourth toss is more likely to be heads (positive recency effect).

Fischbein and Schnarch (1997) found that negative recency effect decreased with age, while positive recency strategy was almost absent. However, in Turkey, Mut (2003) did not find any effect of age on these misconception types but positive effect of instruction. In other words, his study results indicated that instruction on probability decreased these types of misconceptions. Çelik and Güneş (2007) also found 7th, 8th and 9th graders had positive and negative recency effect. However, this type of misconception decreased with the grade level.

2.5.3 Simple and Compound Events

Probabilistic reasoning about compound events is one of the difficulties of students (Shaugnessy, 1992). Lecoutre and Durant (1988, as cited in Fischbein & Schnarch, 1997) studied on this type of misconception. In their study, they found that students interpret in rolling of two dice obtaining 5-6 and 6-6 as equiprobable. Similarly, Fischbein et al. (1991) asked students to compare the probabilities in rolling of two dice, obtaining 5 and 6 with two 6. They also asked students to compare the probabilities, in tossing two coins, getting one head and one tail with two heads. They found that most of the students at all age level considered the outcomes (6-6 and 5-6 or TH and HH) as equivalent. Fischbein and Gazit (1984) also found that in their study, most students computed the size of the sample space as 12 while computing probabilities of different sums of two dice.

This type of misconception seems related to defining the sample space. While defining sample space, students did not count the possible orders of results separately (e.g., HT and TH or 5-6 and 6-5) (Fischbein et al., 1991). Fischbein and Schnarch (1997) found simple and compound events misconception as frequent and stable across age. In Turkey, similar result was supported by Mut (2003). Çelik and Güneş (2007) also found that most of the students from 7th, 8th and 9th grade had simple and compound event heuristic and it was seen mostly in grade nine.

2.5.4 Effect of Sample Size

Tversky and Kahneman (1982) stated that people are prone to neglect the effect of sample size while comparing probabilities. Fischbein and Schnarch (1997) asked the following problem to students to reveal the effect of sample size on probabilistic judgements.

> The likelihood of getting heads at least twice when tossing three coins is:
> Smaller than/equal to/greater than
> The likelihood of getting heads at least 200 times out of 300 times. (p.99)

They found that substantial number of students from each grade level 5, 7, 9 and 11 judged these probabilities as equal although the former, in fact, is more likely. They also stated that “students are apparently misled by their beliefs that one must use ratios to solve this problem” (p.103). However, a person has to think “the law of large numbers”; as the number of experiments or the sample size increases, empirical probability converge the theoretical probabilities (Fischbein & Schnarch, 1997).

Fischbein and Schnarch (1997) and Mut (2003) found that this type of strategy developed with age. Mut also found that this misconception was seen more among the students in Anatolian High School and Private High Schools.
Also, he stated that this type of misconception was more frequent among the students who took instruction on probability. In Turkey, Çelik and Güneş (2007) also found that most of the students from 7th, 8th and 9th grade had the effect of sample size heuristic.

2.5.5 Conjunction Fallacy

Tversky and Kahneman (1983) mentioned the conjunction rule as “the simplest and the most basic qualitative law of probability” (p.293). They explained that, if sets A and B are given, the conjunction set (A and B) is a subset of A and of B, thus P (A and B) cannot exceed both P (A) and P (B). However, people often disregard this rule and assign higher probabilities to combined events, which is called “conjunction fallacy” (Tversky & Kahneman, 1983).

Tversky and Kahneman (1983) asked following question to 142 undergraduates to examine conjunction fallacy.

> Linda is 31 years old, single, outspoken and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in antinuclear demonstrations.Which of two alternatives is more probable?
> (a) Linda is a bank teller (T)
> (b) Linda is a bank teller and is active in the feminist movement (T&F). (p.299)

Their study result showed that 85% of respondents had conjunction fallacy. In other words, respondents thought that conjunction (T&F) was more probable than one of its constituents (T). However, the probability of a conjunction cannot exceed the probability of any of its constituents but some people can commit conjunction fallacy because of the representativeness and availability heuristics (Tversky & Kahneman, 1983).

Fischbein and Schnarch (1997) stated that this fallacy was observed as very strong in grade 5, 7 and 9 but less in high school and college students. However, in Turkey, Mut (2003) found that conjunction fallacy varied across grade levels. Also, he emphasized that instruction on probability decreased this type of misconception. Çelik and Güneş (2007) also found that 7th, 8th and 9th graders had conjuction fallacy at about same rate.

2.5.6 Availability Heuristic

Tversky and Kahneman (1982) mentioned “representativeness” and “availability” not only as classifications of various heuristics but also as general characteristics underlying intuitive judgements. People who have availability heuristic tend to evaluate frequency or probability “by the ease with which instances or associations could be brought to mind” (Tversky & Kahneman, 1973, p. 164). For example, one judge the heart attack rate in a community by recalling heart attacks among one’s own environment because of “availability”.

According to availability heuristic people compare (relative) frequency of two categories by assessing their easiness of come to mind (Tversky & Kahneman, 1973). For example, one can estimate the number of possible committees of two members that can be formed from a set of ten people more than the number of committees of eight members. The person judge the former pattern is more available because of their distinctiveness and easiness to visualize (Tversky & Kahneman, 1973). Tversky and Kahneman also emphasized that in real life, preoccupation with an event may increase its “availability” and its perceived likelihood. For example, seeing a car accident may increase a person’s subjective probability of an accident. As a result, they concluded that because of “availability” a person may perceive events of extreme utility (or disutility) more likely than they actually are.

Fischbein and Schnarch (1997) found that frequency of availability heuristic developed with age. However, in Turkey, Mut (2003) did not find a clear effect of age on availability heuristic but he found that instruction on probability had an effect on decreasing this type of misconception.

2.5.7 Time-Axis Fallacy (The Falk Phenomenon)

"The time-axis fallacy" is regarding conditional probability. This type of misconception is seen when the individuals experience difficulties in perceiving that an outcome that has already happened can be affected by later event or outcome (Fischbein & Schnarch, 1997). Consider the following example (Fischbein & Schnarch, 1997):

> Yoav and Galit each receive a box containing two white marbles and two black marbles.
> (A) Yoav extracts a marble from his box and finds out that it is a white one. Without replacing the first marble, he extracts a second marble. Is the likelihood that this second marble is also white smaller than, equal to, or greater than the likelihood that it is a black marble?
> (B) Galit extracts a marble from her box and puts it aside without looking at it. She then extracts a second marble and sees that it is white. Is the likelihood that the first marble she extracted is white smaller than, equal to, or greater than the likelihood that it is black? (p. 99)

Generally, students answer first part of the question correctly (1/3). However, majority of students answer second part differently (1/2). In this situation, generally students' justification is "the first ball does not care whether the second is white or black" (Falk, 1986, p. 292). Students actually disregard the information about the later outcome. In other words, most students easily understand that outcome of an event can affect the outcome of a later event but they do not easily perceive it can affect another outcome that has already happened.

Fischbein and Schnarch (1997) found that the frequency of time-axis fallacy increased with age of the student. However, Mut (2003) stated that time axis fallacy decreased from grade 5 to 7 but increased at grade level 8. He also found that this misconception increased with instruction.

2.5.8 Equiprobability Bias

Lecoutre (1992) mentioned "equiprobability bias". According to "equiprobability bias", all results of an experiment are equiprobable. The logic under this heuristic is related to chance factor; as a result of this logic people think random events are equiprobable "by nature" (Lecoutre, 1992).

Lecoutre (1992) stated that people tend to see all random events as equiprobable. Consider the example of rolling two dice. People with this heuristic think that being 9 and 11 the sum of two dice is equal. Actually being 9 the sum of two dice is more probable than being 11. Similarly, because of the "equiprobability bias", beginning probability students often think that when tossing three coins, the probability of obtaining 3 heads is 1/4 (Shaugnessy, 1977). That is, they judge that outcomes are equally probable; 3H, 2H and 1T, 1H and 2T, and 3T.

In Turkey, Mut (2003) found that this type of misconception varied across grade levels. He also stated that this bias was common in all grade levels. Another finding showed that this misconception was less frequent among students who took probability instruction.

2.6 Overcoming Misconceptions

Students' alternative conceptions are a serious problem which affects negatively their learning of new conceptions. Many researchers developed alternative learning models such as, conceptual change model (Posner, et al., 1982) and Learning cycle (Champagne, 1988) to solve this problem. However, educational community gave particular attention to "Conceptual Change Model" (Özdemir, 2004). Research studies also emphasize that informed teachers can change their students' alternative conceptions by redesigning the instructional sequence where necessary and by providing various experiences about applications of the concept (Derry, Osana, Levin, & Jones, 1998; Nisbett, Fong, Lehman, & Chang, 1987).

Developing strategies to overcome students' probability misconceptions is as important as determining them. Determining misconceptions should be the first step. However, the teaching and learning strategies to overcome these misconceptions should also be investigated. In Turkey, there are some studies which propose different teaching methods to teach probability concepts. For example, Gürbüz (2007) designed a probability instruction based on materials. He developed concrete teaching materials, two worksheets and a concept map. This instruction was applied 44 eighth graders. To collect data, two teachers and 16 students were interviewed about the instruction. Results said that both teachers and the students had positive opinions related to probability instruction based on materials. Similarly, Gürbüz (2006a) investigated the effect of concrete instructional materials, worksheets and a concept map on eighth grade students' conceptual development of probability concepts. Twenty students participated in the study. A conceptual development test was applied both before and after the intervention. According to results, these instructional materials were found to be effective in developing of probability concepts.

However, literature review for the current study showed that there are only few studies on teaching and learning strategies to overcome probabilistic misconceptions in Turkey (e.g. Avaroğlu, 2013). Similarly, it was found limited number of studies about this issue in other countries (Castro, 1998; Fast, 1997a; Fischbein & Gazit, 1984). For example, in Turkey, Avaroğlu (2013) used an instructional software in order to improve sixth grade students' achievement, intuitive reasoning and learning experience. He found that the instructional software was more effective in improving students' achievement and intuitive reasoning. Similarly, Castro (1998) designed an instruction based on conceptual change in order to promote students' performance in probability calculations and in probability reasoning, attitude toward mathematics and level of conceptual change. Result showed that conceptual change instruction improved students' skills in probability calculations and in intuitive probability reasoning while it did not affect students' attitudes toward mathematics. Similarly, Fast (1997a) showed analogies to be effective overcoming student teachers' probability misconceptions. Fischbein and Gazit (1984) also found that their teaching program in probability was effective on some intuitively based misconceptions of students in grades 5, 6, and 7.

To sum up, students' alternative conceptions affects negatively their learning of the new conceptions. Many researchers developed alternative learning models to solve this problem. However, "Conceptual Change Model" gave special attention. However, literature review for the current study showed that there was not enough study on teaching and learning strategies to overcome probabilistic misconceptions in Turkey. Similarly, it was found limited number of studies about this issue in other countries. This inadequacy in studies searching instructional strategies to overcome students' probabilistic misconceptions does not mean this issue is not important. On the contrary, this issue is an important issue to investigate because of the importance of probability concepts. The present study gives importance to overcome students' misconceptions in probability and aims to investigate the effect of conceptual change based instruction on students' understanding of probability concepts.

2.7 Research on Probability Achievement and Attitudes toward Probability

In the literature, there are many studies related to students' probability achievement and attitudes toward probability. However, in Turkey, it was not met any research study inspecting the impacts of CCBI on students' probability achievement and attitudes toward probability, while there are some studies examining the effectiveness of different teaching methods on students' probability achievement and attitudes toward probability. These studies are explained below.

Some of these studies investigated the effect of various teaching methods on probability achievement and attitudes toward probability (e.g., Avaroğlu, 2013; Bulut, 1994; Demir, 2005; Efe, 2011; Geçim, 2012; Özdemir, 2012; Tuncer, 2011; Yağcı, 2010). For example, Demir (2005) conducted a study with 82 tenth grade students in order to explore the effectiveness of problem posing instruction on students' probability achievement and attitudes. Twenty-seven of the students were instructed with problem posing while 55 of them were instructed with traditional method. According to result of the study, problem posing instruction was more effective than traditional instruction method in terms of improving students’ achievement and attitudes. Similarly, Seyhanlı (2007) revealed that the instruction based on graph theory was more effective than traditional instruction in terms of improving students’ probability achievement and attitudes toward probability.

Ünlü (2008) compared the effect of cooperative learning method to traditional instruction on eighth grade students’ achievement and recall levels of permutation and probability subjects. Achievement test was used as pre-, post-, and post-delayed test. Results indicated that there was a significant difference between cooperative learning method and traditional learning method in terms of students’ achievement and recall levels in favor of cooperative learning method. Similar to results of Ünlü, Cankoy (1989) found significant effect of mathematics laboratory instruction on eighth grade students’ probability achievement. Ercan (2008) also used multiple intelligence activities to teach permutation and probability unit at eight grades. While the experimental group was instructed with multiple intelligence method, the control group was instructed with traditional method. Results revealed that multiple intelligence method was more effective than traditional method in improving students’ achievement.

Esen (2009) searched the effect of computer based instruction on students’ probability achievement. The study was conducted with 316 sixth grade students. While the control group students were taught with traditional instruction, experimental group students were taught with computer based instruction. According to findings, computer assisted instruction was more useful in improving students probability achievement than traditional instruction. Similarly, Memnun (2008) examined the effectiveness of active learning method on students’ permutation and probability achievement. The study was conducted with 197 eighth grade students. While experimental group was taught with active learning method, control group was taught traditional techniques. Results of the study indicated that students in experimental group outperformed students in control group on permutation and probability achievement test .

In another study conducted by Özdemir (2012), it was investigated the effect of worksheets on students' probability achievement. Thirty nine students participated in the study. While students of experimental group were instructed by using woksheets, students of control group were instructed with traditional instruction. According to results of the study, it was found that probability achievement scores of students instructed with worksheets was higher than those of students in traditional instruction group.

Contrary to results of studies explained above, some studies showed that students' attitudes toward probability/mathematics did not change or treatment did not have significant effect on students' probability achievement. For example, Bulut (1994) conducted a study to examine the effects of computer assisted instruction, cooperative learning method and traditional lecture method on students' probability achievement and attitudes toward probability. One hundred one 8th grade students participated in the study. The findings showed that there was a significant difference between cooperative learning group and traditional instruction group in terms of probability achievement mean scores. However, there was no significant mean difference among any other pairs of groups. Also, there was no significant mean difference on probability attitude scores among all groups. Yağcı (2010) also found similar result regarding attitude toward probability. She revealed that the instruction with concrete materials did not have significant effect on students' probability attitude. However, instruction with concrete materials had significant effect on students' probability achievement. Contrary to result of Yağcı regarding probability achievement, Ekinözü and Şengül (2007) found that there was no significant difference between traditional instruction and dramatization method on students' achievement on permutation and probability. But there was a significant difference between two groups interms of recall level. In a different study, Şengül and Ekinözü (2006) used dramatization method in teaching permutation and probability unit in 8th grade mathematics. Findings of them revealed that there was no significant difference between traditional instruction and dramatization instruction with respect to students' attitudes toward mathematics mean scores. A similar result was supported by Geçim (2012). Geçim investigated the effect of creative-drama-based instruction on student' probability achievement and attitudes toward mathematics. Fourty three 7th grade students participated in the study. Experimental group was instructed with creative drama based instruction while control group was instructed with traditional instruction. According to results, it can be stated that creative drama based instruction was useful in promoting achievement in probability but it did not affect students' attitudes toward mathematics.

Some studies related to probability achievement and attitudes were conducted with preservice teachers or inservice teachers. For example, Özaytabak (2004) investigated the factors which affect preservice mathematics teachers' decisions on probability teaching. She conducted the study with 248 preservice mathematics teachers. Results showed that attitude toward probability, probability achievement and misconceptions affect preservice teachers' decisions on probability teaching. However, gender did not affect their decisions on probability teaching. Bulut, Yetkin, and Kazak (2002) investigated the preservice mathematics teachers' achievement in probability, attitudes toward mathematics and probability in terms of gender. Results indicated that there were significant differences between males and females probability achievement mean scores and also attitudes toward mathematics mean scores in favor of males, and females respectively. In terms of attitude toward probability there was not any difference between the groups. Bulut et al. (2000) also studied on prospective teachers' proficiencies on probability concepts. To collect data probability achievement test was used. According to results, pre-service teachers did not have most of the basic probability concepts.

Another type of studies on probability achievement and attitude is comparison study the private schools with public schools with respect to probability achievement and attitudes toward probability. For example, Tunç (2006) compared the eighth grade students of private schools to those of public schools with repect to probability achievement, attitudes toward probability and mathematics. Two hundred seven 8th graders participated in the study. The data was collected through probability achievement test, attitude scale toward probability and attitude scale toward mathematics. Results revealed that there were significant differences between private school and public school with respect to probability achievement mean scores and attitudes toward probability and attitudes toward mathematic mean scores in favor of private schools.

On the other hand, some studies present teaching/learning materials in order to improve probability achievement. Okur (2007) designed a web based teaching material to teach statistics and probability unit in sixth graders. The designed material was introduced to mathematics teachers. And then, the teachers were asked to evaluate the material by the help of a questionnaire. Analyzing the questionnaire results showed that the teachers think that using this material can be appropriate both in class and out of class. Similarly, they think that this material can increase students' motivation to learning. Similar study was conducted by Öztürk (2005). Öztürk designed a computer assisted instruction to teach permutation and probability unit at eighth grade students. In order to control appropriateness of instruction to classroom environment, the software was used in teaching permutation and probability unit at a group of 8th grade students. After the implementation, difficulties related to software were observed and tried to eliminate them. The study also presents suggestions related to computer assisted instruction. Gürbüz (2008) also presented a computer-aided material to teach probability concepts at the primary school level. This materials consisted of animations and simulations. In another study, Gürbüz (2006b) designed a concept map to teach probability concept. In the study, he presented a sample of concept map. Similarly, Bulut, Ekici, and İşeri (1999) presented a sample of activity sheet on teaching of probability.

In this section, some research studies which investigated the effects of different instructional methods on students' attitudes toward probability or students' probability achievement were examined. In some studies, students' positive attitudes toward probability and/or achievement in probability improved after the instruction, whereas in some studies students' attitudes toward probability and/or achievement in probability did not differ. The present study also gives importance to students' attitudes and achievement and aims to investigate the effect of CCBI on students' probability achievement and attitudes toward probability.

2.8 Summary of the Related Literature

The understandings of probability concepts are essential in teaching mathematics (Batanero, Henry, & Parzysz, 2005, MoNE, 2005c; NCTM, 2000). Thus, several research studies on the probability concept have been conducted by mathematics educators and psychologist to investigate students' difficulties with this concept and how the concept of probability can be taught (e.g., Kahneman & Tversky, 1972, 1973; Memnun, 2008; Piaget & Inhelder, 1975; Shaughnessy, 1992).

Research studies show that the concept of probability or intuitive notions of probability develops over time (Piaget & Inhelder, 1975). However, it is emphasized that these intuitive notions of probability may not be correct (Carpenter et al. (1981). Individuals develop basic probability concepts intuitively unless any instructional practice (Fischbein & Schnarch, 1997). They also come into learning environment with these "pre-conceptions" which are mostly wrong and lead some misconceptions.

The literature review reveals that students experience difficulties in learning probability concepts. Probabilistic misconceptions are among one of the most important reasons of difficulties on probability learning (Çelik & Güneş, 2007; Fast, 1997a; Fischbein & Schnarch, 1997; Van Dooren et al., 2003; Watson & Moritz, 2002). Probabilistic misconceptions are very important because students' misconceptions in probability affect not only their achievement but also their understanding of basic probability concepts. The literature also presents the well-known probability misconceptions as "representativeness", "negative and positive recency effects", "simple and compound events", "conjunction fallacy", "effect of sample size", "availability", "time-axis fallacy" and "equiprobability bias" (Cohen, 195; Fischbein et al., 1991; Fischbein & Schnarch, 1997; Kahneman & Tversky, 1972; Lecoutre, 1992; Shaughnessy, 1977; Tversky & Kahneman, 1982,1983).

However, literature review for the current study showed that there are only a few studies on teaching and learning strategies to overcome probabilistic misconceptions in Turkey (e.g., Avaroğlu, 2013). Similarly, it was also found few studies about this issue in other countries (e.g., Castro, 1998; Fast, 1997a). This inadequacy in studies searching instructional strategies to overcome students' probabilistic misconceptions does not mean this issue is not important. On the contrary, this issue is an important issue to investigate because of the importance of probability concepts.

There is a common idea that people construct their own knowledge. In this knowledge construction process, individual actively build up their own knowledge based on previous experiences, mental structures, and beliefs (Jonnasen, 1991).

Researchers argue that conceptual change is one of the most effective strategy to adress misconceptions (Castro, 1998; Konold et al., 1993; Stohl, 2005). Students' alternative conceptions affect negatively their learning of the new conceptions. Many researchers developed alternative learning models to solve this problem. However, "Conceptual Change Model" gave special attention. "Conceptual Change Model" focused on fundamental changes in "people's central, organizing concepts from one set of concepts to another set, incompatible with the first" (Posner et al., 1982, p.211). CCM says that students should use their prior knowledge during the learning process and they should actively participate in learning process (Posner et al., 1982). CCM also facilitates understanding of scientific knowledge.

In order to facilitate students' understanding and eliminate their misconceptions many instructional strategies based on conceptual change model have been proposed. These approaches include conceptual change text, concept map, cognitive conflict, analogy, demonstration, discussion, cooperative learning, computer simulations and so on. Using discussions and simulations are effective strategies to promote conceptual change (Champagne et al., 1985; Niaz et al., 2002; Zacharia & Anderson, 2003).

There are some research studies which examine the effects of different instructional methods on students' attitudes toward probability or students' probability achievement(e.g., Avaroğlu, 2013; Demir, 2005; Efe, 2011; Geçim, 2012; Özdemir, 2012; Tuncer, 2011; Yağcı, 2010). In some studies, students' positive attitudes toward probability and/or achievement in probability improved after the instruction, whereas in some studies students' attitudes toward probability and/or achievement in probability did not differ. Also, Aiken (1976) emphasizes that students' attitudes toward mathematics can be affected by the teaching methods.

In the light of summary of the related literature, it can be said that conceptal change based instruction leads to better acquisition of scientific concepts, achievement and attitudes. The literature review showed that students have difficulties and misconceptions in learning probability concepts. Morever, it is emphasized that probability misconceptions affect students' attitudes and achievement. For this reason, in the current study the effect of conceptual change based instruction on students' probability undestanding, achievement and attitudes toward probability was investigated.

CHAPTER 3

METHOD

The purpose of this chapter is to describe the methodology and procedures used in this study. It includes design of the study, brief description of the population and sample, variables of the study, instruments, description of the procedure, development of teaching/learning materials, treatments in the experimental and control groups, treatment verification, data analysis procedure, unit of analysis, and threats to internal validity.

3.1 Design of the Study

As the current study did not include the use of random assignment (Fraenkel & Wallen, 2003), the research design of this study was non-equivalent control group design which is a type of the quasi-experimental design. That is, in this study, previously formed classes were used. It was not possible to random assignment of the students to the experimental and control groups because of the administrative rules of the school. However, random assignment of the classes to the experimental and control groups was applied. Table 3.1 presents the research design of the study.

Table 3.1Research design of the study

Groups	Pre-test	Treatment	Post-test
EG	MAch, PKT, MAS, **PCT, PAT, PAS**	CCBI	**PCT, PAT, PAS,** Interview
CG	MAch, PKT, MAS, **PCT, PAT, PAS**	TI	**PCT, PAT, PAS,** Interview

In table 3.1, EG represents the experimental group instructed with conceptual change based instruction (CCBI) while CG represents control group instructed with traditional instruction (TI). MAch refers to "students' previous semester mathematics achievement scores", and other abbreviations are PKT for "prerequisite knowledge test for probability", MAS for "mathematics attitude scale", PCT for "probability concept test", PAT for "probability achievement test", and PAS for "probability attitude scale".

3.2 Population and Sample

The target population of the study is all tenth grade students from public high school students in Ankara. Accessible population is all tenth grade students in Çankaya district of Ankara. The sample of the current study was selected from accessible population through convenience sampling approach, one of nonrandom sampling methods.

For the study, ten high schools were selected to get permission. From these schools, for the pilot study, one public Anatolian high school and one public high school were selected for administration of tests and scales. Instruments were administered to total 220 tenth grade high school students at these schools in spring semester of 2009-2010 academic year. Also, pilot study for the treatment process was conducted in this public Anatolian high school.

One public Anatolian high school was chosen from the schools in Çankaya district of Ankara for the main study. This school was also one of the schools in which pilot study was conducted. Four tenth grade classrooms were selected randomly from the six possible classes in this school. Students were not assigned randomly experimental and control groups because school administration were formed the classes at the beginning of the semester. School administration also stated that all classes were formed randomly in a way that includes equal numbers of male and female students regardless of students' academic success. One hundred eighteen (118) tenth grade students participated in this study (53 males and 65 females). There were 59 students (28 male and 31 female) in the experimental group and also 59 students (25 male and 34 female) in the control group in spring semester of 2010-2011 academic year. Students' ages ranged from 16 to 17 years.

Interviews were conducted with eight volunteer students, four of them in experimental group (Int1E, Int2E, Int3E, and Int4E) and four of them in control group (Int1C, Int2C, Int3C, and Int4C). The following symbolism was used for indicating the groups to which the interviewee belongs. E represent experimental group; C represents control group. For example, IntE1 refers first interviewee from experimental group. Two female and two male students from each group participated in interviews. Int1E, Int4E, Int1C and Int4C were female while the other interviwees are male. Their previous semester mathematics grades ranged from 3 to 5. Int 1E and Int2C had grades “5”, Int 3C had grades “3”. The other interviewees had grade “4”.

3.3 Variables

In this study, there were three dependent variables and seven independent variables.

3.3.1 Dependent Variables

The dependent variables of the current study are students' understandings of probability concepts measured by “Probability Concept Test” (PCT), students' probability achievements measured by ” Probability Achievement Test” (PAT) and students' attitudes toward probability measured by "Probability Attitude Scale" (PAS). All these dependent variables are continuous. Table 3.2 presents some characteristics of the dependent variables.

Table 3.2 Variables in the Study

Name of Variable	Type of Variable	Type of Data	Scale
Post-PCT Post-PAT Post-PAS	Dependent	Continuous	Interval
Pre-MAch Pre-PKT Pre-MAS Pre-PAS Pre-PAT Pre-PCT	Independent	Continuous	Interval
IM	Independent	Categorical	Nominal

3.3.2 Independent Variables

The independent variables of this study are students' previous semester mathematic achievement scores (pre-MAch), students' pre-test scores on "Prerequisite Knowledge Test for Probability" (pre-PKT), students' pre-test scores on "Mathematics Attitude Scale" (pre-MAS), students' pre-test scores on "Probability Attitude Scale" (pre-PAS), students' pre-test scores on "Probability Achievement Test" (pre-PAT), students' pre-test scores on "Probability Concept Test" (pre-PCT) and instructional method or treatment (IM) which is varied in two ways, conceptual change based instruction (CCBI) and traditional instruction (TI). Pre-MAch, pre-PKT, pre-MAS, pre-PAS, pre-PAT, pre-PCT are the potential covariates. Pre-MAch was obtained by collecting data related to students' previous semester mathematics achievement scores. Table 3.2 presents some characteristics of the independent variables.

3.4 Measuring Instruments

"Probability Concept Test" (PCT), "Probability Attitude Scale" (PAS), "Prerequisite Knowledge Test for Probability" (PKT), "Probability Achievement Test" (PAT), "Mathematics Attitude Scale" (MAS), classroom observation checklist and interviews were used as data collection tools.

3.4.1 Probability Concept Test

This test which consists of 14 well-known probability questions was used to assess students' misconceptions in probability concepts. A probability test developed by Mut (2003) was used as "Probability Concept Test" (PCT) for this study (see Appendix C for PCT). This test was also used to assess students' understanding of probability concepts because misconceptions are important indicators of students' understanding (Osborne, 1996). The test consists of 14 well-known probability questions related to common misconception types; "representativeness", "positive and negative recency effects", "simple and compound events", "effect of sample size", "conjunction fallacy", "heuristic availability", "time axis fallacy" and "equiprobability bias". Table 3.3 presents common misconceptions probed by PCT (Mut, 2003, p. 25-29).

Table 3.3 Common misconceptions probed by Probability Concept Test

Item	Common Misconception	Sources
1 and 2	Representativeness	(Kahneman & Tversky, 1972; Shaughnessy,1992; Tversky&Kahneman ,1982)
3 and 4	Positive and Negative Recency Effects	(Cohen, 1957; Fischbein, 1975; Fischbein et al., 1991).
5	Simple and Compound Events	(Lecoutre & Durant, 1988)
6	Simple and Compound Events	(Mut, 2003)
7 and 8	Effect of Sample Size	(Tversky & Kahneman, 1982).
9	Conjuction Fallacy	(Shaughnessy, 1992; Tversky & Kahneman, 1983).
10	Heuristic Availability	(Tversky & Kahneman, 1973)
11 and 12 together	Time Axis Fallacy	(Falk, 1979; Fischbein, 1997; Shaughnessy, 1992).
13 and 14	Equiprobability Bias	(Green, 1983)

Mut (2003) provided the content validity of the test by revising the questions by three instructors from mathematics department in terms of mathematical structure. While preparing the test, he also took into consideration recommendations of one expert in measurement and evaluation in terms of appropriateness of the test with the curriculum followed in schools and also a Turkish teacher in terms of grammar of the test.

PCT with 14 items is in multiple-choice item format. As different from Mut's (2003) test, this test also included "why" question for each item. In this part, students were expected to explain their justifications of the answers. The data obtained by "why" question was used to analyze students' misconceptions in section 4.3. The questions in PCT were scored 1 if it is true. Maximum score which students can get from PCT was 14 while minimum score was 0. However, in order to analyze frequencies of students' misconceptions, each question was also coded according to its alternatives.

3.4.2 Probability Attitude Scale

"Probability Attitude Scale" (PAS) was used to assess the students' attitudes toward probability as a school subject. PAS was developed by Bulut (1994). PAS was administered to students both before the treatment and after the treatment.

Bulut (1994) scaled the 28-item PAS on a six-point Likert type scale: strongly agree, agree, tend to agree, tend to disagree, disagree, and strongly disagree. However, for the current study the 28-item PAS was scaled on a five-point Likert type scale: strongly agree, agree, undecided, disagree, and strongly disagree (see Appendix D for PAS). PAS included 15 positive and 13 negative items. While positive items scores ranged from 1 for strongly disagree to 5 for strongly agree, negative items scores ranged from 1 for strongly agree to 5 for strongly disagree. Total score for PAS ranged from 28 to 140.

Bulut (1994) conducted a factor analysis and results supported that PAS was unidimensional. She administered PAS to 191 eight grade students and calculated alpha reliability coefficient of the PAS as 0.95.

To calculate the alpha reliability of the PAS, the researcher also conducted pilot study. During the pilot study, PAS was administered to 220 tenth grade students from one public high school and one public Anatolian high school. After the pilot study, the Cronbach's alpha reliability coefficient of the PAS was calculated as 0.94. The PAS was also administered to 118 tenth grade students for the current study. For the main study, the Cronbach's alpha reliability coefficient was found as 0.95.

3.4.3 Prerequisite Knowledge Test for Probability

"Prerequisite Knowledge Test for Probability" (PKT) was administered to test students' prerequisite knowledge in terms of concepts necessary for learning basic probability concepts. PKT with fifteen items was formed by adding five questions to PKT with ten items developed by Bulut (1994). In this study, PKT was used only as a pre-test.

PKT developing by the Bulut (1994) included ten items to test prerequisite knowledge about sets, fractions and decimals. For the current study, the researcher added items about factorials, permutation and combination to PKT since permutation and combination serve as a basis for developing probability concepts (Piaget & Inhelder, 1975). Firstly, seven items was added to PKT. In the light of recommendations of one mathematics teacher and one expert in mathematics education, final form of PCT was formed. Table of specification of PKT was presented in Appendix E. The content validity was controlled by a high school mathematics teacher and one expert in mathematics education and by reviewing the table of specification.

The content of PKT included decimals, sets, fractions, factorials, permutations and combinations. Knowledge of fractions is necessary while computing probabilities. In computing probabilities of independent events, for example, multiplication of fractions is a necessary prerequisite knowledge. Similarly, knowledge of sets is required for learning basic probability concepts, like sample space. Decimals are used to represent probabilities and do operations with probability. Factorials, permutations and combinations are necessary for determining sample space.

The final form of PKT consisted of 15 essay type questions (see Appendix F). While the eighth and ninth questions had two items, the 6^{th}, 10^{th} and 12^{th} questions had three items. There were 5 questions related to sets, 8 questions related to fractions, 3 questions related to decimals, and 7 questions related to factorials, permutations and combinations. The researcher was developed a scoring rubric to score items in PKT. Scoring rubric was revised by one high school mathematics teacher and one expert in mathematics education. In the light of their recommendations, final form of the scoring rubric for PKT was developed (see Appendix G). Scores of items in PKT ranged from zero (0) to two (2). If item was totally correct, it was scored as two (2). If item was partially correct, it was scored as one (1). Similarly, if it is totally incorrect or was left blank, it was scored as zero (0). The maximum score which a student can gain from PKT was 30 while the minimum was zero.

In order to calculate the alpha reliability of the PKT, the researcher conducted a pilot study. For the pilot study, PAS administered to 114 tenth grade students from one public high school and one public Anatolian high school in Çankaya district of Ankara. After the pilot study, the alpha reliability coefficient of the PKT was calculated as 0.71. According to Nunnally (1978) and Pallant (2011), this value is acceptable value for reliability.

3.4.4 Probability Achievement Test

“Probability Achievement Test” (PAT) was used to determine the students’ probability achievement before and after the treatment. PAT was formed by adding one item to the PAT developed by Bulut (1994). She developed PAT which consisted of 26 essay type questions. For the current study, the researcher added one questions about conditional probability to PAT since tenth grade mathematics curriculum includes this topic (MoNE, 2005c). Final form of PAT consisted of 27 essay type questions.

The researcher was prepared a table of specification of PAT (see Appendix H). There were 27 questions in PAT. The PAT included ten questions related to basic probability concepts, five questions related to type of events, and 12 questions related to applying rules to compute probabilities. The content validity was controlled by a high school mathematics teacher and one expert in mathematics education and by reviewing the table of specification (see Appendix I for PAT).

The researcher was also developed a scoring rubric to score items in the PAT. Scoring rubric was revised one high school mathematics teacher and one expert in mathematics education. In the light of their recommendations, final form of the scoring rubric for PAT was developed (see Appendix J). Scores of items in PKT ranged from zero (0) to two (2). If the item was totally correct, it was scored as two (2). If the item was partially correct, it was scored as one (1). If it is totally incorrect or was left blank, it was scored as zero (0). The maximum score which a student can gain from PAT was 54 while the minimum was zero.

The PAT with 27 essay type questions was administered to 102 tenth grade students from one public high school and one public Anatolian high school in Çankaya district of Ankara. The alpha reliability coefficient of the PAT was calculated as 0.76. According to Nunnally (1978) and Pallant (2011), this value is acceptable value for reliability.

3.4.5 Mathematics Attitude Scale

"Mathematics Attitude Scale" (MAS) was developed by Aşkar (1986). It consists of 20 items in five-point Likert-type scale: strongly agree, agree, undecided, disagree, strongly disagree (see Appendix K). She calculated alpha reliability coefficient of the scale as 0.96. MAS had 10 positive and 10 negative items. Total score for MAS ranged from 20 to 100.

To calculate the alpha reliability of the MAS, the researcher also conducted a pilot study. During the pilot study, PAS administered to 220 tenth grade students from one public high school and one public Anatolian high school. The alpha reliability coefficient of the MAS was calculated as 0.96.

3.4.6 Interviews

To examine students' conceptual understandings of probability concepts, interviews were conducted. Interviews were conducted with eight volunteer students, four of them in experimental group and four of them in control group. Interviews were conducted by the help of "Probability Concept Test"(PCT). During the interview process, students were asked to give details on their answers to PCT. During this process, interviewees explained their ideas and thinking process on each question in PCT. Sample interview questions were as follows:

What is your answer for first question in PCT?

Why? Explain your justification of answer?

Have you experienced any difficulty while answering this question?

Following episode from an interview shows how the questions were used in order to deepen the responses and to increase the richness of data:

Researcher: What do you think about 14th question?

Interviewee: I think possibility of being catched by all traps is equally likely.

Researcher: What makes you think so?

Interviewee: If the robot can select trap1, it can also select the other traps.

Researcher: Why?

Interviewee: Because there are eight traps and robot can be catched by any.

The purpose of this process was to elicit students' conceptions in probability and support the data obtained from post-PCT. Interviews were conducted at the end of the study. All students gave permission for tape recorder. So, all interviews were audiotaped. Each interview lasted about 15 minutes.

3.4.7 Classroom Observation Checklist

The researcher observed all experimental and control lessons. To facilitate classroom observation procedure, an observation checklist was prepared (see Appendix M). The purpose of the observations was to check whether the conceptual change based instruction and traditional instruction was applied properly in the groups. While preparing the observation checklist, properties of CCBI (Posner et al., 1982) and characteristics of TI were taken into consideration. The observation checklist consisted of 20 items scaled on a three-point Likert type scale: yes, partially and no. Two experts and two mathematics teachers examined the checklist. The checklist was used by the researcher during the observations. During the observations, the researcher also took field notes.

3.5 Procedure

In order to investigate the effect of conceptual change based instruction on students' understanding of probability concepts, probability achievement and attitudes toward probability, the current study was designed. The design of the study was a quasi-experimental design. For the study, a detailed literature review was conducted. Thus, the key words were firstly determined. The keywords of this study were probability, misconception, conceptual change approach, conceptual change models, constructivism, probabilistic reasoning, and traditional instruction.

Educational Resources Information Center (ERIC), Social Science Citation Index (SSCI), International Dissertation Abstracts, Ebscohost, Science Direct, JSTOR, Taylor & Francis, Wiley Inter Science, ProQuest Dissertations & Theses and Internet (Google scholar) were searched. METU Library Theses and Dissertations, Turkish Higher Education Council National Dissertation Center, and TÜBİTAK Ulakbim databases were also used to conduct literature review. Throughout this review process, related thesis, articles and also books were obtained. Obtained materials from this process were reviewed in detail.

Measuring instruments were obtained, reviewed and final versions of them were prepared by making necessary arrangements. And then, necessary permission was gotten for both pilot study and main study (see Appendix A). Instructional materials were prepared. During the spring semester of 2009-2010, in order to administer tests and scales, the pilot study was conducted with two high schools in Çankaya district of Ankara. One public Anatolian high school and one public high school were selected for administration of tests and scales. The pilot study of the treatment was also conducted with one of them.Instruments were administered to total 220 tenth grade high school students at these schools (84 of them from Anatolian high school and 136 of them from public high school) in spring semester of 2009-2010. After the pilot study, final forms of measuring instruments and instructional materials were formed.

Current study was conducted in 2010-2011 spring semester. In this study, firstly, one high school in Ankara was selected. Then four classes of two different teachers were selected randomly from six tenth grade classes at this school. One of the two classes of each teacher was randomly assigned as experimental group and the other as control group. So, each different teacher had one experimental and one control group. In order to test the equivalence of the groups in terms of probability achievement, understanding of probability concepts, prerequisite knowledge for probability, attitudes toward probability and attitudes toward mathematics, PAT, PCT, PKT, PAS and MAS was administered, respectively. Morever, students' mathematics grades in the previous semester was obtained. After pre-measurements, treatment procedure began. Specified time for the probability unit by the tenth grade mathematics curriculum was eight lesson hours (two week). However, during the treatment experimental group was instructed with conceptual change based instruction CCBI), while the control group was instructed with traditional instruction (TI) during three weeks, 12 lesson hours each lasted 45 minutes. Before the treatment, the teachers of experimental groups were informed about CCBI. The lesson plans based on conceptual change model were prepared for probability concepts by the researcher. Before the treatment, all lesson plans were given to the teachers and explained by the researcher. The teachers were also informed about what they should do in both groups and what the students' possible misconceptions in probability concept are. The researcher conducted observations during the all experimental lessons. According to observation results, there was no difference between the teachers in terms of applying conceptual change based instruction.

During the treatment, the same subject matters were covered both in the experimental and control groups. Content outline of the treatment was given in Appendix B. Probability concept was covered as a part of regular tenth grade mathematics curriculum. The same mathematics textbook was used in both experimental and control groups. Homework and quantitative questions solved in lessons were the same in both groups.

3.6 Pilot study of the Treatment

The pilot study was conducted during the spring semester of 2009-2010. The purpose of the pilot study was to provide an insight about main study process, to determine shortcomings and deficiencies of treatment process previously and to test whether the lesson plans work properly in classroom settings. For this reason, one public Anatolian high school was chosen from the schools in Çankaya district of Ankara for the pilot study. Three tenth grade classrooms were selected randomly from the five possible classes in this school. It is important to emphasize that the mathematics teachers of these five possible classes were different. Thus, teachers of the experimental and control groups were different during the pilot study. Seventy five (75) tenth grade students participated to this study (33 males and 42 females). There were 25 students (10 male and 15 female) in the experimental group and 50 students (23 male and 27 female) in the control group in spring semester of 2009-2010 academic year.

One class was determined as experimental group and two classes were determined as control groups. Mathematics teachers of all classes were different. The pilot study of the treatment included all of the phases of the main study. In other words, before the treatment, the equivalence of the experimental and control groups was tested in terms of mathematics achievement, probability achievement, understanding of probability concepts, prerequisite knowledge for probability, attitudes toward probability and attitudes toward mathematics. After pre-measurements, treatment procedure was started. While during the treatment experimental group was instructed with conceptual change based instruction (CCBI), the control group was instructed with traditional instruction (TI) during three weeks, 12 lesson hours each lasted 45 minutes. Before the treatment the teachers of experimental groups were informed about CCBI. The lesson plans based on CCBI were prepared by the researcher. Before the treatment all lesson plans were given to the teacher and explained by the researcher. The researcher conducted observations during the all experimental and control lessons. After the pilot study of the treatment process, instructions and lesson plans were revised by considering experiences related to implementation process and teachers views about instruction.

3.7 Development of the Teaching/Learning Materials

Prior to the study, the researcher developed lesson plans for the conceptual change based instruction (CCBI). The lesson plans were designed based on conditions of Posner et al.'s (1982) conceptual change model. In order to facilitate conceptual change, several instructional principles are proposed such as engaging students' initial conceptions, using several activities or other experiences related to students' initial conceptions, using discussions which encourage students to solve unclear points between their initial conceptions and their observations from experience, and giving repeated opportunities to apply new ideas in new contexts (Minstrell, 1985). In promoting conceptual change, it is essential to provide opportunities to students for discussing their existing conceptions and awareness of them, to present scientific explanations and to create a discussion environment to compare students' existing conceptions and scientific conceptions (Champagne et al., 1985). Similarly, some studies emphasize that computer simulations have more effective to promote conceptual change than direct experience (Winn, Stahr, Sarason, Fruland, Oppenheimer, & Lee, 2006). Thus, the lesson plans were prepared based on activities, simulations and discussions in order to facilitate conceptual change. Each lesson plans include subtitles to refer conditions of CCM namely, dissatisfaction, intelligibility, plausibility and fruitfulness (see Appendix L for sample lesson plan). Activities, simulations and discussion were used to meet conditions of CCM.

Many studies indicated that simulation usage is an effective way to improve students' learning and skills (Akban & Andre, 1999; Trundle & Bell, 2010). Also, computer simulations are more effective tools in promoting conceptual change than direct experience (Winn et al., 2006). For this reason, the CCBI included six simulations. The simulations were related to equiprobable events, simple and compound events, the relation between theoretical and experimental probability, and probability of dependent and independent events. Simulations were used to help students experience conceptual change. In a lesson plan, they were used either in intelligibility or in plausibility phase of CCM or in both of them. An example of computer simulation usage was seen in Appendix L.

The activity sheets were generally designed to address most common misconceptions related to probability concepts. In designing these activities, most of the problems including common misconceptions were taken from literature. Activities were used to help students experience dissatisfaction, intelligibility and plausibility phases of CCM. The CCBI was included eight activity sheets (see Appendix L for sample activity sheets).

The first activity was related to concept of sample space. This activity was used to provide dissatisfaction with existing conceptions and intelligibility of a new conception. The researcher was prepared this activity by adapting the "badminton or basketball lesson plan" (Center for Technology and Teacher Education [CTTE], 2008). Firstly, the teacher explained to class to do an activity and divided the class into groups. He said that "your gym teacher, Mrs. Semra, does not decide which would be more efficient: Having the class with six students play table tennis or having them play two on two basketball. Every time she has to take time to stop and start a new game, class time is wasted. Each game will be played as much as the number of rotations of players. Help the teacher to decide the play". Each student wrote down their own responses. And then, teacher said that they could discuss their responses with deskmates. During the discussion, the teacher walked around the discussion groups and listen their discussion but he did not do any intervention. After the small group discussion, the teacher asked the responses to whole class. The teacher gave opportunity to the students which had opposite ideas to explain their responses. The class was divided into two parts in terms of the response, basketball and table tennis. The students which had each different response explained their reasons of this response. Some students stated that "playing basketball is more appropriate since the number of different groups with four students is less than those with two students". Wrong responses were challenged by the other students or the teacher. The discussion process lasted until students realized that their knowledge failed to explain the situation. Then, students became dissatisfied with them. The purpose of this process was to provide awareness of misconceptions and also dissatisfaction with them. Then, the teacher gave a handout to each group. Half of the groups got table tennis handout while the other half of the groups got basketball handout. Teacher circulated while students complete the handout. In these handouts, it were given list of students in Mrs. Semra's gym class and asked to students create as many groups of four students (basketball handout) and as many pairs of students (table tennis handout) as possible. And then, they should determine the number of unique groups of four students (basketball handout) and two students (table tennis handout). After completing the handouts, a student from each group wrote their list on the board. And students discussed the groups until they realized relationship between table tennis and basketball group. In this process, students realized the relationship between the number of k-combinations formed from an n-set and those (n-k)-combinations of an n- set. Since, throughout this process, students had an opportunity to experience sample events about the concept, the concepts were aimed to be more intelligible.

The second activity was again related to concept of sample space because understanding the concept of sample space is essential for understanding probability. This activity was used to provide initial plausibility of a new conception. In this activity students were confronted with a new situation. The situation was presented in a daily life example. In this example, students were expected to interpret the situation which required using new knowledge about sample space. Firstly, the teacher gave a handout to each student. Each student wrote down their own responses. Then, a discussion process was implemented. The discussion process lasted until students gave plausible explanations about the situation. In such a situation, the teacher provided the students an opportunity to test the plausibility of the new concept.

The third and fourth activities were related to "equiprobability bias" and "representativeness", respectively. These activities were used to provide dissatisfaction with existing conceptions. The name of the activities was "true or false". The format of the "true or false" activities was prepared by inspiring Cankoy's (1998) "true or false activities" related to decimals. Problems in these activity sheets were adapted from Kahneman and Tversky's (1972) and Lecoutre's (1992) studies. Firstly, the teacher gave a handout to each student. Then, a discussion environment was provided. In these activity sheets, students were asked to evaluate a response which was given by a student as true or false and to explain the reason of their answers. These activity sheets included problems to address misconceptions on "representativeness" and "equiprobability bias". Justifications of students who had these types of misconceptions were consistent with these heuristics. The students which had each different response explained their reasons of this response. For example, in some problems, some students stated that an event A is more likely than B because A appears more representative than B. The discussion process lasted until students realized that their knowledge failed to explain the situation. The purpose of this process was to provide awareness of misconceptions and also dissatisfaction with them. After that, the teacher presented the concept of the lesson. The teacher presented mathematical explanation of the concept for the purpose of making concept more intelligible. Then, the lesson continued with solving the problems in the activity sheets by the help of new concept.

The fifth activity was related to equiprobable sample space. In this activity, Galton board (or bean machine) was introduced (MoNE, 2005c). This activity was used to provide initial plausibility of a new conception. Firstly, the teacher gave a handout including knowledge about Galton board to each student. And then students were asked to interpret the probability of balls falling each box. A discussing environment was also provided during this activity. The discussion process lasted until students gave plausible explanations about the situation. In such a situation, the teacher provided the students an opportunity to test the plausibility of the new concept. And then, the teacher started the simulation about the Galton board.

The sixth and seventh activities were related to "conjunction fallacy" and "effect of sample size", respectively. These activities were used to provide dissatisfaction with existing conceptions. The activities were again "true or false activity". The problems in the activity were adapted from studies on "conjunction fallacy" (Watson & Moritz, 2002) and "effect of sample size" (Kahnman &

Tversky, 1972). Firstly, the teacher gave a handout to each student. Each student wrote down their own responses. Then, a discussion environment was provided. In these activities, students were asked to evaluate a response which was given by a student as true or false and to explain the reason of their answers. These activity sheets included problems to address misconceptions on "conjunction fallacy" and "effect of sample size". Justifications of students who had these types of misconceptions were consistent with these heuristics. For example, some students assigned higher probabilities to combined events. The discussion process lasted until students realized that their knowledge failed to explain the situation. After that, the teacher presented the concept of the day's lesson. The teacher presented the mathematical explanation of the concept for the purpose of making concept more intelligible. Then, the lesson continued with solving the problems in the activity sheet by the help of new concept.

The eighth activity was related to dependent and independent events. In this activity, the teacher gave a handout to each student. In this handout, students were asked to interpret their following answers based on previous answers in a True/False test. For example, in the activity sheet, students were said that "you think that you have correctly answered first 20 questions, but you have no idea about the 21th question. Based on your previous 20 answers, what would you guess the answer of 21th question? "True" or "false"? Why?" In this situation, like to be in the other activities, the teacher directed the students to discuss their ideas. In this discussion process, students expressed their ideas related to activity. This activity was designed to help students express their misconceptions on "negative and positive recency effects". The activity revealed that while some students had negative recency effect, some had positive recency effects. That is, some students think that based on their previous answers, following answer must be selected (true or false) based on the law of average. Some of them thought that based on their previous answers, following answer must be selected based on the most selecting answer. Discussion process lasted until the students realized that their conceptions were not enough to explain the phenomena. Then, the teacher explained the dependent and independent events and their probabilities. After that, simulation related to the activity was presented to students. In this process, also, a discussion environment was provided by the teacher. So, the students were given a chance to learn the concept deeply and to test the intelligibility of the concept.

3.8 Treatment

The two groups received different treatments. Each group had two classes. The classes in both groups were instructed by their regular mathematics class teachers. Each teacher had one class from experimental group and one class from control group. Treatments in both experimental and control groups covered the same content. While experimental group was instructed with conceptual change based instruction, control group was instructed with traditional instruction.

3.8.1 Treatment in the Experimental Group

In the experimental group, conceptual change based instruction accompanied with computer simulations, activities and discussions (CCBI) were applied. The classes in the experimental group were instructed by their regular mathematics class teachers during three weeks, 12 lesson hours each lasted 45 minutes. Content outline of the treatment was given in Appendix B. Probability concept was covered as a part of regular tenth grade mathematics curriculum (MoNE, 2005c).

In this process, the conceptual change model developed by Posner et al. (1982) was followed by considering four conditions of conceptual change, "dissatisfaction", "intelligibility", "plausibility", and "fruitfulness". The instructions in the experimental group were prepared for the purpose of addressing students' probability misconceptions and eliminate them.

During the experimental lessons, teachers followed lessons plans prepared based on conceptual change strategy. During the experimental lessons, firstly, students were confronted with an activity sheet or a problem. In the first part of the lesson, the purpose of the problem or the activity was to provide dissatisfaction with existing conceptions. Each activity sheet or problem included relatively difficult problems containing a conceptual obstacle. Each student wrote down their own responses on activity sheets or notebook. And then, teacher said that they could discuss their responses with deskmates. During the treatment, both small group and whole class discussions were executed. During the discussion, the teacher walked around the discussion groups and listen their discussion but he did not do any intervention. After the small group discussion, the teacher asked the responses to whole class. The teacher gave opportunity to the students which had opposite ideas to explain their responses. The students which have each different response explained their reasons of the response. Wrong responses were challenged by the other students or the teacher. The discussion process lasted until students realized that their knowledge failed to explain the situation. Then, students became dissatisfied them. For instance, while the equiprobable sample space was taught, the teacher asked the students “what is the relationship between the probability of getting a sum of 9 and the probability of getting a sum of 11 when rolling two dice?” Different answers were given to this question. Some of their answers were “these probabilities are equal” “both probabilities are equal because both are 1/36”. Then, more questions addressing the relationship between the two probabilities were asked for the purpose of providing ways for students to become dissatisfied with their own concepts. In other words, the purpose of these kinds of questions was to help students develop awareness with their misconceptions and dissatisfaction with their current concepts (dissatisfaction). Students should realize their misconceptions during discussion. In this process the teacher did not provide any positive or negative feedback. The teacher’s role, in this process, was facilitator. However, when necessary, provocation or conflicting ideas also were provided by the teacher to ensure the exposure of all misconceptions. Students discussed underlying beliefs which caused errors. Then teacher summarized the ideas. The purpose of this process was to provide awareness of misconceptions and also dissatisfaction with them.

In the second part of the lesson, the purpose was to provide intelligibility of a new conception. In this part, after the discussion process was completed, the concept was explained. The teacher presented mathematical explanation of the concept for the purpose of making concept more intelligible. After that, the lesson was continued with computer simulation or solving the problems in the activity sheet. For example, to explain the equiprobable sample space and probabilities in equiprobable sample space, the teacher used computer simulation related to rolling one die and two dice. In this simulation, experiments with one die and two dice were performed. For each simulation, a discussion part was implemented. The purpose of the discussion part was to help students to explore a link between new concepts and their observations on the simulation. Since, throughout this process, students had an opportunity observing sample events about the concept, the concepts were aimed to be more intelligible (intelligibility).

Then, new examples about the concept were presented to the students to improve their understanding of concept. For instance, after explaining equiprobable sample space and computing probabilities in it, the teacher mentioned the Galton board and asked the probabilities of the balls falling in the each peg and reason of it. Since the teacher provided opportunities for students to use new concepts in solving problems, the purpose was to make the concepts more plausible to the students (initial plausibility of a new conception). Using students' new mathematical knowledge in solving problems was encouraged in order to provide plausibility. In the process of intelligibility or in the process of plausibility, activities or computer simulations were used in order to make concepts more intelligible or more plausible for the students.

Lastly, teacher encouraged students to use the new concept in explaining a new situation. To provide this, the teacher present some problems related to new concepts or gave homework to them. So, new conception explains new phenomena and provide new insights, it appears more fruitful to the students (fruitfulness of a new conception).

3.8.2 Treatment in the Control Group

In the control group, traditional instruction was used during instruction of probability concepts. The classes in control group were instructed by their regular mathematics class teachers during three weeks, 12 lesson hours each lasted 45 minutes. Content outline of the treatment was given in Appendix B. Probability concepts were covered as a part of regular tenth grade mathematics curriculum (MoNE, 2005c).

In the traditional instruction, students were mostly passive and were mainly taught in a teacher-centered way. During the treatment the teachers explained topics, made students to write some explanations and formulas related to topic on their notebooks. While explaining the concepts, the teachers did not take into consideration of their students' misconceptions. Discussion was rarely used during the explanations of concepts or problem solving sessions. Also, students solved quantitative problems. Homework and quantitative questions solved in lessons were the same in both groups. Also, it is important to emphasize that the problems presented in the activity sheets to experimental group were also solved in the control group. However, they were covered as a part of regular problem solving session but not as an activity format. At the end of the lesson, the teacher summarized the topic and gave some homework related to it.

3.9 Treatment Verification

The researcher observed all experimental and control lessons. To facilitate classroom observation procedure, an observation checklist was prepared (see Appendix M). The purpose of the observations was to check whether the conceptual change based instruction and traditional instruction was applied properly in the groups. While preparing the observation checklist, properties of CCBI (Posner et al., 1982) and characteristics of TI were taken into consideration. The observation checklist consisted of 20 items scaled on a three-point Likert type scale: yes, partially and no. Two experts and two mathematics teachers examined the checklist. The checklist was used by the researcher during the observations. Also, the researcher took notes during the observations.

During the observations, the researcher gave importance to observe implementation of treatment, students' reaction to the instruction, and their interactions among themselves and with their teachers. The treatment was conducted over three weeks in four classrooms at a public Anatolian high school in Ankara. During the treatment, the researcher participated in all lessons as a non-participant observer. During the observations, the researcher sat on the back side of the classrooms and took field notes related to instructional processes.

The experimental group was instructed with conceptual change based instruction. Conceptual change conditions, dissatisfaction, intelligibility, plausibility and fruitfulness, were applied to lessons by the teachers of experimental groups. Simulations and discussions especially attract students' attention. In the instructional process, doing activities and watching and discussing simulations motivated to students to participate in lessons. Presenting daily life examples related to probability concept by the teacher also provided encouragement to students. This facilitated giving and discussing daily life examples by the students.

In the control groups, the teacher used traditional instruction. Students were mostly passive and were mainly taught in a teacher-centered way. In this process, the teachers mostly solved the questions about the probability concepts. Discussion was rarely used during the explanations of concepts or problem solving sessions. Nevertheless, there was no any emphasis on students' misconceptions throughout the instruction of control groups.

Consequently, the researcher concluded that the teachers of the both experimental and control groups applied the treatment as planned before the instruction. Also, it can be concluded that CCBI was more effective than traditional instruction in terms of attracting students' interest and motivating them to actively participate in lessons.

3.10 Data Analysis

The data was analyzed by using Statistical Package for the Social Sciences (SPSS). After the students' responses to all pre- and post-tests were entered in SPSS files, firstly, descriptive statistic analysis was performed. Mean, standard deviation, maximum, minimum, kurtosis and skewness values were computed for each variable. In order to test equality of groups, independent samples t-test was used. Independent t-test was preformed for the variable Pre-

MAch, Pre-PKT, Pre-MAS, Pre-PAS, Pre-PCT, and Pre-PAT. Multivariate analysis of covariance (MANCOVA) was used to analyze the effect of treatment (CCBI versus TI) on students' understanding of probability concepts, probability achievement and attitudes toward probability. The purpose of the using MANCOVA was to equate groups on the independent variables. Assumptions of MANCOVA which are normality, homogeneity of regression, equality of variances, multicollinearity and independency of observations were checked. Also, follow-up ANCOVAs were used to analyze the effect of the treatment on each dependent variable separately. The null hypotheses of the study were tested at 0.05 level of significance.

3.11 Unit of Analysis

Unit of analysis for this study is each student. Experimental unit of analysis for this study, however, is each class. According to Glass and Hopkins (as cited in Stevens, 2002, p. 258), "whenever the treatment is individually administered, observations are independent. But where treatments involve interactions among persons, such as discussion method or group counseling, the observations may influence each other". Therefore, independent observations of the treatment could not be achieved. However, it can be said that independence of observations was achieved during the data collection procedure by preventing interactions between students.

3.12 Threats to Internal Validity

Internal validity of a study is defined by Fraenkel and Wallen (2003) as "internal validity means that observed differences on the dependent variable are directly related to the independent variable and not due to some other unintended variable" (p.178). These unintended (extraneous) variables are subject characteristics, loss of subjects (mortality), location, instrumentation, testing, history, maturation, attitude of subjects, regression, and implementation. Here are discussed possible threats to internal validity and how these threats are controlled by the researcher.

Subject characteristics threat which is known also selection bias occurs when the individuals (or groups) differ on such variables as age, gender, attitude, socioeconomic background, previous knowledge and the like (Fraenkel & Wallen, 2003). Random assignment is a powerful method to limit these differences. However, due to school administrative rules and ethical issues, random assignment was not applied in this study but random assignment of four intact classes to control and experimental groups were applied randomly. To handle this threat, the students' previous achievement scores, conceptual understanding scores, and attitude scores were obtained before the treatment. Analysis of these scores showed that there was no significant mean differences between experimental and control groups. This threat was also controlled by equating groups statistically with using MANCOVA.

For some reasons, for example illness or requirements of other activities, some students may be lost as the study progresses (Fraenkel & Wallen, 2003). This is referred to as a mortality threat. To handle this threat, missing data analysis can be done. In this study there was no any missing data. For this reason, it can be said that mortality threat was under control.

When particular locations are used while collecting the data or carrying out an intervention, location threat may occur (Fraenkel & Wallen, 2003). In this study, location threat was under control since both instruction and data collection processes were applied in regular class hours at school.

Instrumentation threat may be handled in terms of instrument decay, data collector characteristics and data collector bias. Instrument decay threat may occur "if the nature of the instrument (including the scoring procedure) is changed in some way or another" (Fraenkel & Wallen, 2003, p.181). In this study, PCT contained multiple-choice items and PAS and MAS contained Likert-type items. For this reason, for these tests, instrumentation decay was less likely a threat. However, PKT and PAT contained essay type items. For these instruments to minimize instrument decay threat, the researcher formed and used the scoring rubrics in Appendix G and in Appendix J, respectively. Thus, scoring process of PKT and PAT was easier and also more reliable. Data collector characteristics threat was controlled by attending data collection process. Thus, the data collector characteristics were same throughout the study. The teacher of each classroom also attended the data collection sessions. This also helped to control data collector bias.

When pre-testing is used in any intervention study, testing threat may occur. In this study, the time interval between pre- and post-testing procedure was established as six weeks to minimize testing threats.

When unplanned events occur during the course of the study, students responses can be affected (Fraenkel & Wallen, 2003). This event is referred to a history threat. Since throughout the study the researcher observed all courses of the study and data collection procedure, she observed that no unplanned event occurred during the courses of the study.

Improvement during a treatment may arise from passing of time rather than treatment (Fraenkel & Wallen, 2003). This refers to a maturation threat. In this study, maturation threat was controlled because time of the study was not long. Similarly most of the students' ages were the same. Thus, any improvement due to age is expected to be equal for all students.

Views of participants regarding the study can be a serious threat to internal validity (Fraenkel & Wallen, 2003). This threat is known as attitude of subjects threat. Hawthorne effect is the well-known attitude of subjects threat. This threat states that better performance of experimental participants may be due to novelty of treatment rather than the nature of the treatment. It was difficult to control Hawthorne effect for this study. In order to minimize this threat, the teachers of the study emphasized that this instruction was not a new and special method just a regular part of instruction. Teachers also emphasized that the same instruction could be given the other classrooms in the future too. Thus, demoralization of students in the control groups was reduced.

Regression threat may occur in the studies conducted with only one group. In order to overcome regression threat an equivalent control or comparison group can be used (Fraenkel & Wallen, 2003). This threat was not a problem for the current study because there were both experimental and control groups and also the selection of the participants was not based on their low or high performance in pre-tests.

In order to control implementation treat, both experimental and control groups was instructed by their teachers and teachers were informed about implementing the both methods used in groups (Fraenkel & Wallen, 2003). Also observations by the researcher were conducted throughout the current study. Thus, treatment verification was obtained.

3.13 Assumptions, Limitations and Delimitations

Assumptions of this study were as followings:

- All students were answered all pre-and post-tests accurately and sincerely.
- Both mathematics teachers had similar abilities to teach mathematics.
- Both mathematics teachers were not biased for experimental or control groups.

Limitations of this study which were barriers beyond the control of the researcher were as followings:

- Because of the previously formed classes, random sampling was not applied.
- Only some students gave explanations about their answers on post-PCT.
- Interviewees did not give explanations about their response to PCT at desired level.

Delimitations of this study which were factors formed by the researcher were as followings:

- This study only covered the probability unit in tenth grade mathematics lesson.
- The scope of this study was limited to tenth grade students in four classes from only one high school in Ankara.
- The duration of the treatment was limited.
- Observations of the lessons were only conducted by the researcher.

CHAPTER 4

RESULTS

This chapter presents results of descriptive statistics and inferential statistics related to pre- and post- PCT, PAT, and PAS, pre-MAch, pre-MAS and pre-PKT. Furthermore, analysis of students' misconceptions is also presented.

4.1 Descriptive Statistics

In this study only PAS, PAT and PCT were used as both pre-test and post-test. In Table 4.1, descriptive statistics are presented in terms of students' probability concept pre- and post-test scores (pre- and post-PCT), probability achievement pre- and post-test scores (pre- and post-PAT), and attitude toward probability pre- and post-test scores (pre- and post- PAS).

Table 4.1 Descriptive statistics related to pre-and post-scores on Probability Concept Test (PCT), Probability Achievement Test (PAT), and Probability Attitude Scale (PAS)

Group	Test	Min	Max	Mean	SD
	Pre-PCT	1	9	6.57	1.89
	Post-PCT	7	13	10.01	1.40
EG	Pre-PAT	2	44	21.25	12.22
	Post-PAT	19	52	36.77	7.48
	Pre-PAS	28	140	87.64	25.80
	Post-PAS	34	140	91.00	27.77

Table 4.1(continued)

Group	Test	Min	Max	Mean	SD
CG	Pre-PCT	3	9	6.84	1.37
	Post-PCT	3	11	7.81	1.65
	Pre-PAT	2	41	25.49	11.58
	Post-PAT	11	50	34.13	9.00
	Pre-PAS	28	136	87.96	23.66
	Post-PAS	30	140	89.81	22.32

Note: N= 59, Maximum score for PCT = 14, Maximum score for PAT = 54, and Maximum score of PAS= 140.

According to Table 4.1, the experimental group students' probability concept pre-test scores ranged from 1 to 9 with a mean value of 6.57 (SD= 1.89) while the control group students' probability concept pre-test scores ranged from 3 to 9 with a mean value of 6.84 (SD=1.37). Because the mean scores of two groups were very close to each other, it can be said that students' understanding levels were similar and low when compared to maximum score for PCT before the instructions. However, probability concept post-test scores of the experimental group ranged from 7 to 13 with a mean value of 10.01 (SD=1.40) while those of control group ranged from 3 to 11 with a mean value of 7.81 (SD=1.65). The mean of post-PCT scores in experimental group was higher than that in control group while the pre-PCT mean scores of both groups were very close to each other.

As seen in Table 4.1, the EG students' probability achievement pre-test scores ranged from 2 to 44 with a mean value of 21.25 (SD= 12.22) while the CG students' probability achievement pre-test scores range from 2 to 41 with a mean value of 25.49 (SD=11.58). The mean of pre-PAT scores in control group was higher than that in experimental group. However, pre-PAT mean scores were low in both groups when compared to maximum score for PAT. On the other hand, probability achievement post-test scores of the EG ranged from 19 to 52 with a mean value of 36.77 (SD=7.48) while those of the CG ranged from 11 to 50 with a mean value of 34.13 (SD=9). In other words, the mean of post-PAT scores in experimental group was higher than that in control group while the mean of pre-PAT scores in control group was higher than that in experimental group.

Table 4.1 also indicates that the EG students' attitudes toward probability pre-test scores ranged from 28 to 140 with a mean value of 87.64 (SD=25.80) while the CG students' attitudes toward probability pre-test scores ranged from 28 to 136 with a mean value of 87.96 (SD= 23.66). Because the mean scores of two groups were very close to each other, it can be said that before the instructions, attitudes toward probability were similar in both groups. On the other hand, attitude toward probability post-test scores of the EG ranged from 34 to 140 with a mean value of 91.00 (SD= 27.77) while those of the CG ranged from 30 to 140 with a mean value of 89.81 (SD=22.32). That is, the mean of post-PAS scores in experimental group was slightly higher than that in control group while pre-PAS mean scores of both groups were very close to each other.

Table 4.2 presents descriptive statistics related to pre-MAch, pre-PKT and pre-MAS. Pre-MAch was obtained by collecting data related to students' previous semester mathematics achievement scores. PKT and MAS was only used as pre-test.

Table 4.2 Descriptive statistics related to Pre-MAch, Pre-PKT and Pre-MAS

Group	Test	Min	Max	Mean	SD
EG	Pre-MAch	1	5	3.54	1.11
	Pre-PKT	12	30	25.38	4.36
	Pre-MAS	22	100	75.38	19.63
CG	Pre-MAch	1	5	3.63	1.03
	Pre-PKT	16	30	25.69	3.38
	Pre-MAS	29	100	75.93	14.98

Note: N= 59, Maximum score for MAch = 5, Maximum score for PKT = 30, and Maximum score of MAS= 100.

Table 4.2 shows that the experimental group students' previous mathematics achievement scores ranged from 1 to 5 with a mean of 3.54 (SD= 1.11) while the control group students' previous mathematics achievement scores ranged from 1 to 5 with a mean of 3.63 (SD= 1.03). Because the mean scores of two groups were very close to each other, it can be said that before the instructions, previous mathematics achievement of both groups were similar.

Similarly, the experimental group students' prerequisite knowledge for probability pre-test scores ranged from 12 to 30 with a mean of 25.38 (SD= 4.36) while the control group students' prerequisite knowledge for probability scores ranged from 16 to 30 with a mean of 25.69 (SD= 3.38). Because the mean scores of two groups were high and also very close to each other, it can be said that before the instructions, the students had necessary prerequisite knowledge in terms of concepts necessary for learning basic probability concepts.

Experimental group students' attitudes toward mathematics pre-test scores ranged from 22 to 100 with a mean value of 75.38 (SD= 19.63) while the control group students' attitudes toward mathematics pre-test scores ranged from 29 to 100 with a mean value of 75.93 (SD=14.98). Because the mean scores of two groups were very close to each other, it can be said that students' attitudes toward mathematics were similar before the instructions.

4.2 Inferential Statistics

Determination of covariates, assumptions of MANCOVA, results of MANCOVA, and results of follow-up analysis are presented in this section.

4.2.1 Determination of Covariates

Firstly, in order to check whether experimental and control group was significantly different in terms of pre-MAch, pre-PKT, pre-MAS, pre-PAS, pre-PCT, and pre-PAT, independent sample t-test analyses were performed.

Table 4.3Results of independent sample t-test for Pre-MAch, Pre-PKT, Pre-MAS, Pre-PAS, Pre-PCT, and Pre-PAT

		Levene's test		t-test	
	Equal variances	F	Sig.	df	Sig
Pre-MAch	Assumed	.203	.653	116	.670
Pre-PKT	Assumed	1.616	.206	116	.672
Pre-MAS	Assumed	2.560	.112	116	.866
Pre-PAS	Assumed	1.464	.229	116	.944
Pre- PCT	Not assumed	4.480	.036	105.794	.376
Pre- PAT	Assumed	.577	.449	116	.056

As seen in Table 4.3, there was no statistically significant mean difference between the groups in terms of students' mathematics achievement ($t\ (116) = -0.43$, $p>0.05$), prerequisite knowledge($t\ (116) = -0.42$, $p>0.05$), attitudes toward mathematics ($t\ (116) = -0.17$, $p>0.05$) and probability ($t\ (116) = -0.07$, $p>0.05$), understanding of the probability concepts ($t\ (105.794) = -0.89$, $p>0.05$) and probability achievement ($t\ (116) = -1.93$, $p>0.05$).

According to independent t-test results there was no need to use none of the independent variables as a covariate to control pre-existing differences. However, "the ideal is to choose as covariates variables that of course are significantly correlated with the dependent variable and that have low correlations (e.g., smaller than 0.80) among themselves" (Stevens, 2002, p.345). Table 4.4 presents the correlations among independent and dependent variables.

Table 4.4 Correlations among independent and dependent variables

Variables	Pre-MAch	Pre-PKT	Pre-MAS	Pre-PAS	Pre-PCT	Pre-PAT	Post-PAS	Post-PCT
Pre-PKT	.302							
Pre-MAS	.459	.295						
Pre-PAS	-.057	.003	.014					
Pre-PCT	.120	.031	-.001	.083				
Pre-PAT	.190*	.426	.122	.002	.175			
Post-PAS	-.044	.017	.115	.770	.185*	-.034		
Post-PCT	.109	-.009	.020	.073	.299	.021	.081	
Post-PAT	.236*	.366	.143	.011	.167	.596	-.031	.319

* Correlation is significant at the 0.05 level (2-tailed).

Table 4.4 shows that pre-MAch and pre-PCT have a significant correlation with at least one of the dependent variables. Also, correlations among these independent variables are less than 0.80 (Stevens, 2002). Because of this, pre-MAch and pre-PCT were determined to use as covariates.

4.2.2 Assumptions of MANCOVA

There are five assumptions of MANCOVA. These are independence of observations, normality, multicollinearity, equality of variances, and homogeneity of regression.

If treatment involves interactions among persons, the observations are not independent (Stevens, 2002). Thus, independent observations of the treatment could not be achieved. However, during the data collection procedure, the researcher was present in both control and experimental groups. During pre- and post-testing procedure, there was no interaction among students. So, it can be said that independence of observations was met during the data collection.

Table 4.5 Skewness and Kurtosis values for the variables

Test	EG		CG	
	Skewness	Kurtosis	Skewness	Kurtosis
Pre-PCT	-.932	1.017	-.540	.690
Post-PCT	.007	-.560	-.400	.331
Pre-PAT	.133	-1.362	-.445	-1.085
Post-PAT	-.412	-.299	-.626	-.359
Pre-PAS	.066	-.694	-.374	.310
Post-PAS	-.114	-.798	-.122	.736
Pre-MAch	-.759	.227	-,549	-.081
Pre-PKT	-1.416	1.374	-.854	.065
Pre-MAS	-1.031	.956	-.522	.594

Table 4.5 indicates that skewness and kurtosis values of the test scores were between -2 and +2. According to George and Mallery (2003), these values are acceptable for normality. So, it can be said that all variables were normally distributed both in the control group and in the experimental group. So, normality assumption was satisfied. Box's Test was checked to test the multivariate normality assumption. Multivariate normality assumption was satisfied since the significance value (0.198) was larger than 0.05.

"The problems that result from high correlations between some of the independent variables are known as multicollinearity" (Cohen, Cohen, West, & Aiken, 2003, p.419). Thus, correlations among the independent variables are necessary to check multicollinearity assumption. According to Table 4.4, all correlations did not exceed 0.90 (Pallant, 2011). So, it can be said that the multicollinearity assumption was satisfied.

İn order to check equality of variances assumption, Levene's test of equality of error variances was checked. Table 4.6 shows the result of the Levene's test of equality of error variances.

Table 4.6 Levene's test of equality of error variances

Variables	F	df1	df2	Sig.
Post-PAS	5.374	1	116	.022
Post-PCT	1.487	1	116	.225
Post-PAT	2.769	1	116	.099

Table 4.6 indicates that this test is not significant for the Post-PCT and Post-PAT. However, Levene’s test is significant for the Post-PAS since p value (0.022) is smaller than 0.05. Thus, equality of variances assumption was verified for the Post-PCT and Post-PAT but not for the Post-PAS.

In order to test the homogeneity of regression assumption, Multivariate Regression Correlation (MRC) analysis was performed. This analysis was performed for all dependent variables, post-PAS, post-PCT and post-PAT. Set A included covariates, pre-MAch and pre-PCT. Set B constituted group membership variable (treatment). Set C was formed by all interaction terms of Set A and Set B which were formed by multiplying Set A with Set B. MRC analysis result was presented in Table 4.7 for dependent variable post-PAS.

Table 4.7 First multivariate regression correlation analysis for the Post-PAS

Change Statistics for the Post-PAS					
Model	R^2 Change	F Change	df1	df2	Sig.F Change
Set A	.039	2.304	2	115	.104
Set B	.001	.164	1	114	.687
Set C (Set A*SetB)	.016	.937	2	112	.395

According to Table 4.7, there was not a significant interaction between Set A and Set B for the post-PAS (R^2 = 0.016, F Change= 0.937, df_1=2, df_2=112, p= 0.395). Thus, homogeneity of regression assumption was satisfied for the dependent variable post-PAS. MRC analysis result was presented in Table 4.8for the dependent variable post-PCT.

Table 4. 8 First multivariate regression correlation analysis for the Post-PCT

Change Statistics for the Post-PCT					
Model	R^2 Change	F Change	df1	df2	Sig. F Change
Set A	.095	6.007	2	115	.003
Set B	.378	81.834	1	114	.000
Set C (Set A*SetB)	.111	14.929	2	112	.000

As seen in Table 4.8, there was a significant interaction between Set A and Set B for the post-PCT (R^2 = 0.111, F Change= 14.929, df_1=2, df_2=112, p= 0.000). As a result, homogeneity of regression assumption was not satisfied for the dependent variable post-PCT. MRC analysis result was presented in Table 4.9 for the dependent variable post-PAT.

Table 4.9 First multivariate regression correlation analysis for the Post-PAT

Change Statistics for the Post-PAT					
Model	R2 Change	F Change	df1	df2	Sig. F Change
Set A	.075	4.686	2	115	.011
Set B	.032	4.139	1	114	.044
Set C (Set A*SetB)	.056	3.733	2	112	.027

As seen in Table 4.9, there was a significant interaction between Set A and Set B for the the post-PAT (R^2 change= 0.056, F Change= 3.733, df_1=2, df_2=112, p= 0.027). Thus, homogeneity of regression assumption was not satisfied for the dependent variable post-PAT.

As a result, homogeneity of regression assumption was not met for the dependent variables post-PCT and post-PAT. For this reason, MANCOVA could not be performed. To satisfy the homogeneity of regression assumption, additional MRC analysis should be performed. In this MRC analysis, significant covariate and its interaction term were included in the Set B.

Second MRC was conducted for all dependent variables, post-PAS, post-PCT and post-PAT. Set A included covariate, Pre-MAch. Set B constituted group membership variable (treatment), pre-PCT and treatment* pre-PCT. Set C was formed by all interaction terms of Set A and Set B which were formed by multiplying Set A with Set B. Second MRC analysis result was presented in Table 4.10 for dependent variable post-PAS.

Table 4.10 Second multivariate regression correlation analysis for the Post-PAS

Change Statistics for the Post-PAS					
Model	R^2 Change	F Change	df1	df2	Sig.F Change
Set A	.002	.220	1	116	.640
Set B	.039	1.512	3	113	.215
Set C(Set A*SetB)	.021	.802	3	110	.495

According to Table 4.10, there was not a significant interaction between Set A and Set B for the post-PAS (R^2 = 0.021, F Change= 0.802, df_1=3, df_2=110, p= 0.495). So, homogeneity of regression assumption was satisfied for the dependent variable post-PAS. Second MRC analysis result was presented in Table 4.11 for the dependent variable post-PCT.

Table 4. 11 Second multivariate regression correlation analysis for the Post-PCT

Change Statistics for the Post-PCT					
Model	R^2 Change	F Change	df1	df2	Sig.F Change
Set A	.012	1.396	1	116	.240
Set B	.572	51.712	3	113	.000
Set C (Set A*SetB)	.005	.476	3	110	.699

As seen in Table 4.11, there was not a significant interaction between Set A and Set B for the post-PCT (R^2 change= 0.005, F Change= 0.476, df_1=3, df_2=110, p= 0.699). So, homogeneity of the regression assumption was satisfied for the dependent variable post-PCT. Second MRC analysis result was presented in Table 4.12 for the dependent variable post-PAT.

Table 4.12 Second multivariate regression correlation analysis for the Post-PAT

Change Statistics for the Post-PAT					
Model	R2 Change	F Change	df1	df2	Sig.F Change
Set A	.056	6.845	1	116	.010
Set B	.088	3.869	3	113	.011
Set C (Set A*SetB)	.049	2.241	3	110	.088

As seen from Table 4.12, there was not a significant interaction Set A and Set B for the the Post-PAT (R^2 change= 0.049, F Change= 2.241, df_1=3, df_2=110, p= 0.088). So, homogeneity of the regression assumption was satisfied for the dependent variable post-PAT. As a result, homogeneity of regression assumption was met for all dependent variables; MANCOVA could be performed.

4.2.3 MANCOVA Model

After regression, in order to conduct MANCOVA, pre-MAch was used as covariate; group, pre-PCT, and group* pre-PCT were used as fixed factors and post-PAS, post-PCT and post-PAT were used as dependent variables.

However, in MANCOVA, in order to include pre-PCT in fixed factors it should be changed as a categorical variable. For this reason, students' pre-PCT scores were recoded so pre-PCT scores were categorical. Levels of students' pre-probability concept test (pre-PCT) scores were determined as low, medium, and high. The students who had a score a half-standard deviation around the mean (M- $\frac{1}{2}$SD, M+$\frac{1}{2}$SD) were included in medium level, the students who had a score a half-standard deviation below the mean (M- $\frac{1}{2}$SD, and below) were included in low level, and the students who had a score a half-standard deviation above the mean (M+ $\frac{1}{2}$SD, and above) were included in high level (Akkus, Gunel, & Hand, 2007). After that, they were recoded as 1 for low achievers, as 2 for medium achievers and as 3 for high achievers in pre-PCT. Now, pre-PCT was a categorical variable with three levels. Then, MANCOVA could be performed.

However, firstly, the hypotheses should be revised according to current MANCOVA model. In this MANCOVA model, following revised hypotheses will be tested.

Null Hypothesis 1

There is no statistically significant overall effect of conceptual change based instruction and traditional instruction on the population means of the collective dependent variables of tenth grade students' post-test scores of the probability concept, probability achievement and attitudes toward probability when previous mathematics achievement scores are controlled.

Null Hypothesis 2

There is no statistically significant difference among low-, medium-, and high-achieving students in pre-PCT with respect to the population means of the collective dependent variables of tenth grade students' post-test scores of the probability concept, probability achievement and attitudes toward probability when previous mathematics achievement scores are controlled.

Null Hypothesis 3

There is no statistically significant interaction effect between treatment and students' probability concept pre-test scores with respect to the population means of the collective dependent variables of tenth grade students' post-test scores of the probability concept, probability achievement and attitudes toward probability when previous mathematics achievement scores are controlled.

Null Hypothesis 4

There is no statistically significant difference between the post-test mean scores of tenth grade students instructed with conceptual change model and those instructed with traditional instruction on the population means of the probability concept post-test scores when previous mathematics achievement scores are controlled.

Null Hypothesis 5

There is no statistically significant difference among low-, medium-, and high-achieving students in pre-PCT with respect to tenth grade students' population means of the probability concept post-test scores when previous mathematics achievement scores are controlled.

Null Hypothesis 6

There is no statistically significant interaction effect between treatment and students' probability concept pre-test scores with respect to tenth grade students' population means of the probability concept post-test scores when previous mathematics achievement scores are controlled.

Null Hypothesis 7

There is no statistically significant difference between the post-test mean scores of tenth grade students instructed with conceptual change model and those instructed with traditional instruction on the population means of the attitudes toward probability post-test scores when previous mathematics achievement scores are controlled.

Null Hypothesis 8

There is no statistically significant difference among low-, medium-, and high-achieving students in pre-PCT with respect to tenth grade students' population means of the attitudes toward probability post-test scores when previous mathematics achievement scores are controlled.

Null Hypothesis 9

There is no statistically significant interaction effect between treatment and students' probability concept pre-test scores with respect to tenth grade students' population means of the attitudes toward probability post-test scores when previous mathematics achievement scores are controlled.

Null Hypothesis 10

There is no statistically significant difference between the post-test mean scores of tenth grade students instructed with conceptual change model and those instructed with traditional instruction on the population means of probability achievement post-test scores when previous mathematics achievement scores are controlled.

Null Hypothesis 11

There is no statistically significant difference among low-, medium-, and high-achieving students in pre-PCT with respect to tenth grade students' population means of probability achievement post-test scores when previous mathematics achievement scores are controlled.

Null Hypothesis 12

There is no statistically significant interaction effect between treatment and students' probability concept pre-test scores with respect to tenth grade students' population means of probability achievement post-test scores when previous mathematics achievement scores are controlled.

After regression, Box's Test was also checked to test the multivariate normality assumption. Multivariate normality assumption was still satisfied since Box's Test was not significant (p=0.211).

Table 4.13 presents results of Levene's test of equality of error variances after regression. Levene's test was not significant for the dependent variables post-PAS, post-PCT and post-PAT. So, equality of variances assumption was met for post-PAS, post-PCT and post-PAT.

Table 4.13 Levene's test of equality of error variances after regression

Variables	F	df1	df2	Sig.
Post-PAS	1.341	5	112	.250
Post-PCT	1.468	14	103	.128
Post-PAT	1.250	14	103	.068

Assumptions of MANCOVA were met; the results of the MANCOVA model are presented in following sections.

4.2.3.1 Results on Main Effects

The first null hypothesis was "there is no statistically significant overall effect of conceptual change based instruction and traditional instruction on the population means of the collective dependent variables of tenth grade students' post-test scores of the probability concept, probability achievement and attitudes toward probability when previous mathematics achievement scores are controlled". This null hypothesis was tested by the help of the MANCOVA. The results of the MANCOVA model are presented in Table 4.14.

Table 4.14 MANCOVA results for main effect

Effect	Wilks' Lambda	F	Hyp. df	Error df	Sig.	Eta Squared	Observed Power
Treatment	.565	28.020	3	109	.000	.435	1.000
Pre-PCT	.752	5.569	6	218	.000	.133	.997

As seen from Table 4.14, MANCOVA results indicated that there was a statistically significant mean difference between groups on the collective dependent variables of the post-PCT, post-PAT, and post-PAS when the pre-MAch scores were controlled. Thus, first null hypothesis was rejected. The observed power in terms of treatment was 1. The power of this study showed that the difference between experimental and control group arised from the treatment. Effect size of treatment is 0.435 which is a large effect size (Cohen, 1988). So, it can be stated that 43.5 % of multivariate variance on the dependent variables was associated with the treatment. As a result, difference between experimental and control group had a practical value.

The second null hypothesis was "there is no statistically significant difference among low-, medium-, and high-achieving students in pre-PCT with respect to the population means of the collective dependent variables of tenth grade students' post-test scores of the probability concept, probability achievement and attitudes toward probability when previous mathematics achievement scores are controlled". Results of MANCOVA indicated that there was a statistically significant mean difference across students' levels in pre-PCT on the collective dependent variables of the post-PCT, post-PAT, and post-PAS when the pre-MAch scores were controlled. Thus, second null hypothesis was also rejected.

In order to see the effect of treatment and pre-PCT on each dependent variable, ANCOVAs, as a follow up analysis, were performed. Table 4.15 shows the results of ANCOVA for post-PCT.

Table 4.15 Results of ANCOVA for Post-PCT

Dependent Variable	Source	df	F	Sig.	Eta Squared	Observed Power
	Corrected Model	6	20.899	0.000	0.530	1.000
	Intercept	1	335.645	0.000	0.751	1.000
Post-PCT	Treatment	1	83.604	0.000	0.430	1.000
	Pre-PCT	2	22.402	0.000	0.186	0.996
	Treatment* Pre-PCT	2	10.055	0.000	0.153	0.983

The null hypothesis 4 was "there is no statistically significant difference between the post-test mean scores of tenth grade students instructed with conceptual change model and those instructed with traditional instruction on the population means of the probability concept post-test scores when previous mathematics achievement scores are controlled". As seen from the Table 4.15, according to results of ANCOVA, there was a statistically significant difference between the post-test mean scores of experimental group and those of control group on the population means of the probability concept post-test scores in favor of the experimental group when the students' previous semester mathematics achievement scores were controlled. Thus, the fourth null hypothesis was rejected. The observed power in terms of treatment is 1. Effect size for post-PCT is 0.43 which is a large effect size (Cohen, 1988). As a result, difference between experimental and control group in terms of post-PCT had a practical value. Post-PCT mean score of students in experimental group was 10.01 (SD=1.40) while that in control group was 7.81 (SD=1.65). This difference was found to be both practically and statistically significant. However, with the effect of covariate, the estimated mean scores differed. While the pure mean difference between groups was 2.20, the estimated mean difference was 2.69 due to mean adjustment with the covariate effect.

The fifth null hypothesis was "there is no statistically significant difference among low-, medium-, and high-achieving students in pre-PCT with respect to tenth grade students' population means of the probability concept post-test scores when previous mathematics achievement scores are controlled". Results also showed that there was a significant difference among the levels of pre-PCT with respect to post-PCT. So, fifth null hypothesis was rejected. In order to examine the differences among the levels of pre-PCT, Post Hoc test result were presented in Table 4.16.

Table 4.16 Follow-up pairwise comparisons for Post-PCT

Dependent Variable	Level	Level	Mean Difference	Std. Error	Significance
Post-PCT	Low	Medium	-.939	.365	.011
		High	-1.895	.390	.000
	Medium	Low	.939	.365	.011
		High	-.956	.283	.001
	High	Low	1.895	.390	.000
		Medium	.956	.283	.001

As seen from Table 4.16, there were statistically significant differences between the low-achievers and medium-achievers, low-achievers and high-achievers, medium-achievers and high-achievers on post-PCT scores. Table 4.17 presents ANCOVA results in terms of post-PAS.

Table 4.17 Results of ANCOVA for Post-PAS

Dependent Variable	Source	df	F	Sig.	Eta Squared	Observed Power
	Corrected Model	6	1.223	0.300	0.062	0.464
	Intercept	1	126.475	0.000	0.533	1.000
Post-PAS	Treatment	1	0.768	0.383	0.007	0.140
	Pre-PCT	2	2.830	0.063	0.049	0.546
	Treatment* Pre-PCT	2	0.723	0.488	0.013	0.170

The null hypothesis 7 was "there is no statistically significant difference between the post-test mean scores of tenth grade students instructed with conceptual change model and those instructed with traditional instruction on the population means of the attitudes toward probability post-test scores when previous mathematics achievement scores are controlled". As seen from the Table 4.17, the seventh null hypothesis was failed to be rejected. Treatment did not have a statistically significant effect on the dependent variable post-PAS. In other words, there was no significant difference between the post-test mean scores of tenth grade students instructed with conceptual change model and those instructed with traditional instruction on the population means of the attitudes toward probability post-test scores when the students' previous semester mathematics achievement scores were controlled. Post-PAS mean score of students in experimental group was calculated as 91.00 (SD= 27.77) while that in control group was calculated as 89.81 (SD=22.32). However, with the effect of covariate, the estimated mean scores were adjusted. The estimated mean score of experimental group was 88.921 while that of control group was 80.285. However, this difference was not found statistically significant.

Similarly, eighth null hypothesis was also failed to be rejected. The eighth null hypothesis was “there is no statistically significant difference among low-, medium-, and high-achieving students in pre-PCT with respect to tenth grade students’ population means of the attitudes toward probability post-test scores when previous mathematics achievement scores are controlled”. So, it can be stated that there was no significant difference among low-, medium-, and high-achieving students in pre-PCT with respect to students’ population means of the attitudes toward probability post-test scores when previous mathematics achievement scores were controlled. Table 4.18 presents ANCOVA results for post-PAT.

Table 4.18 Results of ANCOVA for Post-PAT

Dependent Variable	Source	df	F	Sig.	Eta Squared	Observed Power
Post-PAT	Corrected Model	6	3.437	0.004	0.157	0.934
	Intercept	1	11.909	0.000	0.502	1.000
	Treatment	1	7.483	0.007	0.063	0.774
	Pre-PCT	2	4.049	0.020	0.068	0.711
	Treatment* Pre-PCT	2	2.002	0.140	0.035	0.406

Null hypothesis 10 was “there is no statistically significant difference between the post-test mean scores of tenth grade students instructed with conceptual change model and those instructed with traditional instruction on the population means of probability achievement post-test scores when previous mathematics achievement scores are controlled”. According to results of ANCOVA, Table 4.18 shows that there was a statistically significant difference between the post-test mean scores of tenth grade students instructed with conceptual change model and those instructed with traditional instruction on the population means of the probability achievement post-test scores. Thus, the tenth null hypothesis was rejected. Also, this difference was in favor of the experimental group. As seen from Table 4.18, effect size for post-PAT is 0.063 which is a moderate effect size (Cohen, 1988). Post-PAT mean score of students in experimental group was 36.77 (SD=7.48) while that in control group was 34.13 (SD=9). However, with the effect of covariate, the estimated mean scores were adjusted. The estimated mean score of experimental group was calculated as 37.185 while that of control group was calculated as 31.05 with the effect of covariate. This difference was found to be statistically significant.

The 11th null hypothesis was "there is no statistically significant difference among low-, medium-, and high-achieving students in pre-PCT with respect to tenth grade students' population means of probability achievement post-test scores when previous mathematics achievement scores are controlled". Table 4.18 also showed that there was a statistically significant difference among the levels in pre-PCT with respect to post-PAT. So, 11th null hypothesis was rejected. In order to examine the differences among the levels in pre-PCT, Post Hoc test result was presented in Table 4.19.

Table 4.19 Follow-up Pairwise Comparisons for Post-PAT

Dependent Variable	Level	Level	Mean Difference	Std. Error	Significance
Post-PAT	Low	Medium	-5.526	2.161	.012
		High	-6.263	2.312	.008
	Medium	Low	5.526	2.161	.012
		High	-.737	1.677	.661
	High	Low	6.263	2.312	.008
		Medium	.737	1.677	.661

As seen from Table 4.19, there were significant differences between the low-achievers and medium-achievers, low-achievers and high-achievers on post-PAT scores.

4.2.3.2 Results on Interaction Effects

The third hypothesis was “there is no statistically significant interaction effect between treatment and students’ probability concept pre-test scores with respect to the population means of the collective dependent variables of tenth grade students’ post-test scores of the probability concept, probability achievement and attitudes toward probability when previous mathematics achievement scores are controlled”. Table 4.20 presents MANCOVA results for interaction effect.

Table 4.20 MANCOVA results for interaction effect

Effect	Wilks’ Lambda	F	Hyp. df	Error df	Sig.	Eta Squared	Observed Power
Treatment* Pre-PCT	.822	3.735	6	218	.001	.093	.959

According to Table 4.20, there was a statistically significant interaction effect between treatment and students’ probability concept pre-test scores on the collective dependent variables of the post-PCT, post-PAT, and post-PAS when the Pre-MAch scores were controlled. So, third null hypothesis was rejected. In order to see whether this interaction effect differs with respect to each dependent variable, ANCOVAs, as a follow up analysis, were performed. Results of the ANCOVAs for interaction effects are presented in Table 4.21.

Table 4.21 Results of ANCOVAs for interactions for each dependent variable, Post-PAS, Post-PCT and Post-PAT

Dependent Variable	Source	df	F	Sig.	Eta Squared	Observed Power
Post-PAS	Treatment* Pre-PCT	2	0.723	0.488	0.013	0.170
Post-PCT	Treatment* Pre-PCT	2	10.055	0.000	0.153	0.983
Post-PAT	Treatment* Pre-PCT	2	2.002	0.140	0.035	0.406

The 12th null hypothesis was "there is no statistically significant interaction effect between treatment and students' probability concept pre-test scores with respect to tenth grade students' population means of probability achievement post-test scores when previous mathematics achievement scores are controlled". According to ANCOVA results, as seen in Table 4.21, there was no a significant interaction effect between treatment and students' probability concept pre-test scores with respect to post-PAT scores. So, 12th null hypothesis was failed to be rejected.

Null hypothesis nine states that "there is no statistically significant interaction effect between treatment and students' probability concept pre-test scores with respect to tenth grade students' population means of the attitudes toward probability post-test scores when previous mathematics achievement scores are controlled". According to ANCOVA results, there was no a significant interaction effect between treatment and students' probability concept pre-test scores with respect to post-PAS scores. So, 9th null hypothesis was failed to be rejected.

The sixth null hypothesis was "there is no statistically significant interaction effect between treatment and students' probability concept pre-test scores with respect to tenth grade students' population means of the probability concept post-test scores when previous mathematics achievement scores are controlled”. According to ANCOVA results, there was a statistically significant interaction effect between treatment and students’ probability concept pre-test scores with respect to post-PCT scores. Figure 4.1 shows this interaction.

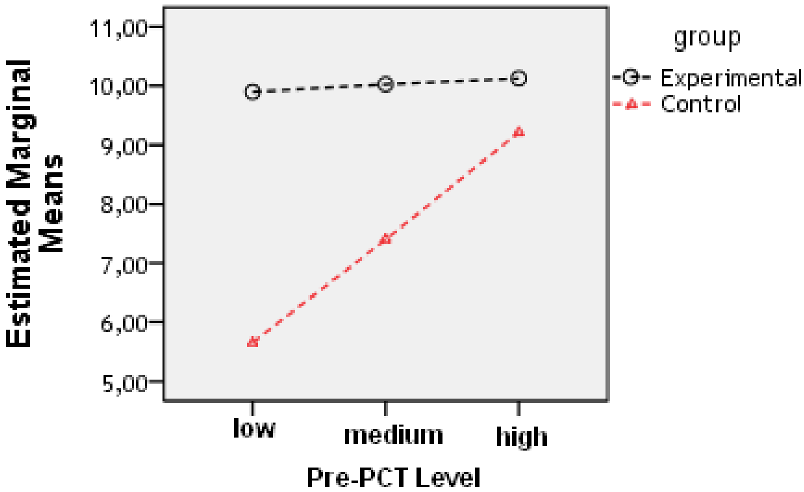

Figure 4.1 Interaction between treatment and Pre-PCT with respect to Post-PCT

Figure 4.1 shows that in the experimental group, the mean scores of students in each pre-PCT level were very close to each other on post-PCT. However, in the control group, there were observed differences among levels in pre-PCT. In the control group, low-achieving students had lower scores than medium-achieving students, and medium-achieving students had lower scores than high-achieving students. Figure 4.2 and Figure 4.3 compare students’ mean scores in each level on pre-PCT and post-PCT.

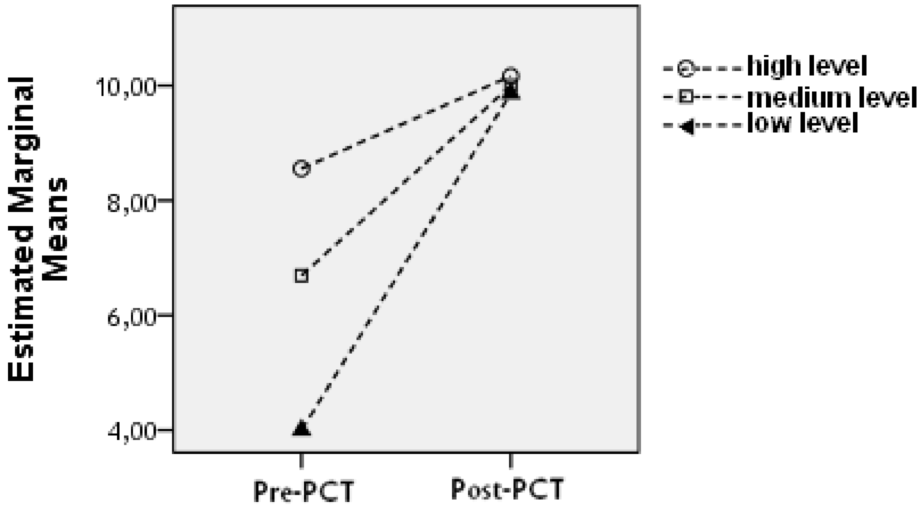

Figure 4.2 Comparison of mean scores of Pre-PCT levels in experimental group on Pre-PCT and Post-PCT

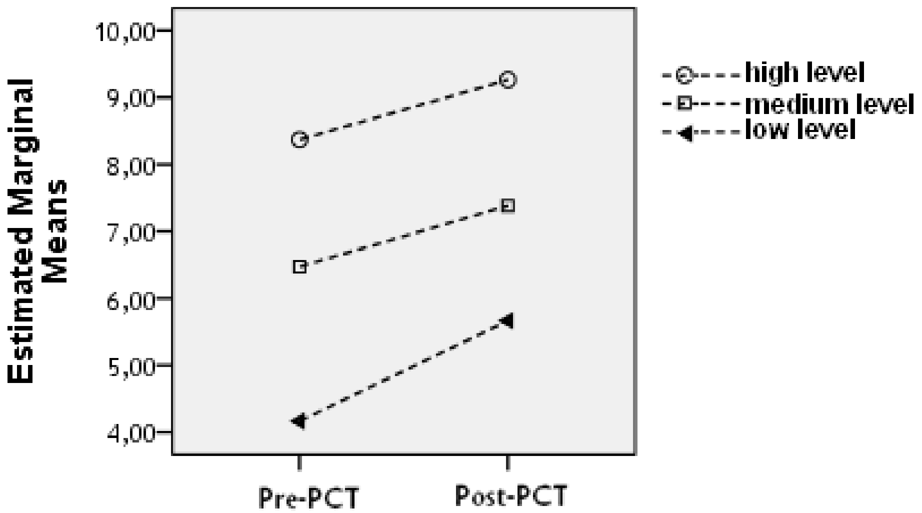

Figure 4.3 Comparison of mean scores of Pre-PCT levels in control group on Pre-PCT and Post-PCT

According to Figure 4.2 and Figure 4.3, it is seen that there were observed differences among pre-PCT mean scores of the levels in both groups. However, in the experimental group, the mean differences among the levels almost disappeared after the treatment.

4.3 Analysis of Students' Misconceptions

Main focus of the current study was to eliminate students' misconceptions in probability. Probabilistic misconceptions in this study were mainly determined among the misconceptions mentioned in the studies of Fischbein and Schnarch (1997), Fischbein et al. (1991), Kahneman and Tversky (1972), Tversky and Kahneman (1982, 1983) and Lecoutre (1992).

The PCT with 14 items was used to assess students' misconceptions in probability concepts.This test also included "why" question for each item. In this part, students are expected to explain their justifications of their answers. However, during the post-testing procedure, only some students from experimental and control groups wrote their justifications of their answers on PCT. In addition, four interviewees from experimental group (Int1E, Int2E, Int3E, and Int4E) and four interviewees from control group (Int1C, Int2C, Int3C, and Int4C) explained their response during the interview process. In this part, findings will be supported with justifications both in post-PCT and in interviews.

4.3.1 Misconception on Representativeness

One of the misconceptions observed in the study was representativeness. The first and second questions of PCT were related to the misconception of representativeness. Table 4.22 shows the percentages related to question 1.The question 1 was:

> You flip a quarter 5 times in succession, if H represents heads and T represents tails, which of the following sequences are you most likely to observe?
> a) TTTHH b) THHTH c) HTHHH d) THTHT
> e) Among (a)-(d) one is likely as the other.

Table 4.22 Percentages of students' responses in terms of Representativeness (1)

Response	Experimental Group (n=59)				Control Group (n=59)			
	Pre-PCT		Post-PCT		Pre-PCT		Post-PCT	
	n	%	n	%	n	%	n	%
Correct (e)	45	76.3	52	88.1	45	76.3	53	89.8
Misconception(d)	10	16.9	1	1.7	9	15.3	3	5.1
Incorrect (a)	3	5.1	1	1.7	4	6.8	1	1.7
Incorrect (b)	0	0	3	5.1	1	1.7	2	3.4
Incorrect (c)	1	1.7	2	3.4	0	0	0	0
TOTAL	59	100	59	100	59	100	59	100

According to Table 4.22, before the treatment, some students from both experimental group (16.9%) and control group (15.3%) had this type of misconception. However, after the treatment, the percentage of the students in the control group with this misconception (5.1) was higher than the percentage of the students in the experimental group (1.7).

The question 2 from PCT was also used to test for representativeness heuristic. Table 4.23 shows the percentages related to question 2. The question 2 was:

> In a lotto game, one has to choose 6 numbers from a total of 40. Ahmet has chosen 1, 2, 3, 4, 5 and 6, and Nuray has chosen 39, 1, 17, 33, 8 and 27. Who has a greater chance of winning?
> a) Ahmet
> b) Nuray
> c) Ahmet and Nuray have the same chance of winning

Table 4.23 Percentages of students' responses in terms of Representativeness (2)

Response	Experimental Group (n=59)				Control Group (n=59)			
	Pre-PCT		Post-PCT		Pre-PCT		Post-PCT	
	n	%	n	%	n	%	n	%
Correct (c)	47	79.7	49	83.1	47	79.7	50	84.7
Misconception(b)	11	18.6	5	8.5	9	15.3	8	13.6
Incorrect (a)	1	1.7	5	8.5	3	5.1	1	1.7
TOTAL	59	100	59	100	59	100	59	100

In the question 2, before the treatment, like in question 1, some students from both experimental group (18.6 %) and control group (15.3 %) had this type of misconception. However, after the treatment, the percentage of the students in the control group with this main misconception (13.6) was higher than those in the experimental group (8.5).

According to pre-PCT results, the percentage of the students which selected correct option for the first question was close to that for the second question in both experimental and control groups. However, post-PCT results showed that although the second question tested the same misconception type with the first question, the misconception of representativeness was observed as stronger in the second question. This result is consistent with the finding of some other studies (e.g., Mut, 2003). The reason can be definite variations in the alternatives of the question 2 (Mut, 2003).

In the first question of PCT, alternative "d" (THTHT) reflects the proportion of heads and tails in the population and also appears more random. This alternative reflects the main misconception ("representativeness") for the first question. Similarly, in the second question, alternative "b" (39, 1, 17, 33, 8 and 27) seems more random than alternative "a" (1, 2, 3, 4, 5, 6). According to representativeness heuristic, people judge the probability of an event by considering how well it represents some characteristics of its parent population (Kahneman & Tversky, 1972). The justifications given by students seem to confirm these explanations. For example, in the written justifications in post-

PCT, one student from control group who chose THTHT stated that “this sequence is more close to 50:50 expected ratio of heads and tails”. Similarly, one student from control group expressed the same idea, but differently, as the following: “There are two possibilities in flipping a coin, heads and tails. The probability of obtaining heads and tails is equal. So, THTHT seems more probable”. Similarly, justifications of the students who selected correct option reflects correct reasoning about the questions. For example, one student from experimental group stated that “the sample space equiprobable”. Similarly, some students from both experimental and control groups stated that “ the probability of obtaining heads or tails is $\frac{1}{2}$ in each trial”. Some students from experimental groups explained their answers to second question as the following: “In the game, each number appears only one time. So, the probabilityof winning is equal for both number sequences.”

As a result, in question 1 and 2, some alternatives appears more representative to some students, although in both questions, all alternatives are equally likely to occur. Justifications of the students also supported this conclusion. According to post-test results, it can be stated that the proportion of students with “representativeness” misconception in experimental group was less than that of in control group after the treatment.

4.3.2 Misconception on Positive and Negative Recency Effects

Positive and negative recency effect was one type of the misconception observed in the study. The third and fourth questions of PCT tested for the misconception of positive and negative recency effect. The results of the frequency analysis are presented in Table 4.24 for the question 3. The question 3 was:

> Özge flipped a fair coin three times and in all cases tails came up. Özge intends to flip the coin again. What is the chance of getting tails at the fourth time?
> a) Equal to the chance of getting heads
> b) Smaller than the chance of getting heads
> c) Greater than the chance of getting heads

Table 4.24 Percentages of students' responses in terms of Negative and Positive recency effects (1)

Response	Experimental Group (n=59)				Control Group (n=59)			
	Pre-PCT		Post-PCT		Pre-PCT		Post-PCT	
	n	%	n	%	n	%	n	%
Correct (a)	48	81.4	58	98.3	51	86.4	54	91.5
Misconception(b)	9	15.3	0	0	4	6.8	3	5.1
Incorrect (c)	2	3.4	1	1.7	4	6.8	2	3.4
TOTAL	59	100	59	100	59	100	59	100

For the third question, 15.3% of the students in the experimental group and 6.8 % of the students in the control group selected the alternative including main misconception (negative recency effect) before the treatment. After the treatment, this misconception was not observed in the experimental group while the percentage of the students in the control group with this misconception was 5.1. The results of the frequency analysis were presented in Table 4.25 for the question 4. Question 4 was:

> A father plays the following game with his son: The father hides a coin in one of his hands behind his back, and if his son knows in which hand he hides the coin, he wins the coin. The past 14 days, the son won 5 times and lost 9 times. Which of the following options would you expect to happen the next 14 days?
> a) The son wins more than he looses
> b) The son looses more than he wins
> c) The number of the games he loses is equal to the number of the games he wins.

Table 4.25 Percentages of students' responses in terms of Negative and Positive recency effects (2)

Response	Experimental Group (n=59)				Control Group (n=59)			
	Pre-PCT		Post-PCT		Pre-PCT		Post-PCT	
	n	%	n	%	n	%	n	%
Correct (c)	34	57.6	46	78	42	71.2	46	78
Misconception(a)	12	20.3	3	5.1	6	10.2	5	8.5
Incorrect (b)	13	22.0	10	16.9	11	18.6	8	13.6
TOTAL	59	100	59	100	59	100	59	100

In the 4th question, while 57.6% of the students in the experimental group and 71.2% of the students in the control group selected correct alternative before the treatment, after the treatment, the percentage of students who correctly answered the question was 78% for both groups. After the treatment, the percentages of the students in experimental and control groups who had still this main misconception (negative recency effect) were 5.1% and 8.5%, respectively. Similarly, in question 3 and question 4, the proportions of students having "the positive receny effect" decreased after the treatments in both groups.

According to "negative and positive recency effect", while estimating the probability of an event, one expects different results relying on obtaining successive same results (Cohen, 1957) or expects the same results because of the assumption that the conditions were not fair (Fischbein, 1975). In the third question, the alternative "b" (H) reflects negative recency effect, relying on successive same result (main misconception), while alternative "c" (T) reflects "positive recency effect", expecting same results with TTT. Similarly, in the fourth question, alternative "a" reflects "negative recency effect" (main misconception).

Actually, "negative recency effect" is related to representativeness (Kahneman & Tversky, 1972). This misconception emerges because people think even small number of experiments (samples) to reflect the fairness of the laws of chance (Shaughnessy, 1977). However," positive recency effect" emerges because of the assumption that the conditions were not fair (Fischbein, 1975). The justifications given by students seem to confirm these explanations. For example, in the written justifications in post-PCT, one student from experimental group and three students from control group stated that "I expect the son wins more than he loses because correct response rate of the son is low". Similarly, one student from control group stated that "by the help of the previous days, we can make estimation related to next days". Similarly, justifications of the students who selected correct alternative reflects correct reasoning about the questions. For example, one student from experimental group stated that "the probability of obtaining head and obtaining tail is always equal in each trial. It does not matter how many times the dice is thrown". And also, three students from experimental group pointed out that "the event of the fourth time dice tossing is independent from previous events". Similarly, one student from control group expressed the same idea, but differently, as the following: "previous outcomes do not affect the result".

As a result, in question 3and 4, some students tend to estimate probabilities based on "negative and positive recency", although in both questions, all events are equally likely to occur. Justifications of the students also supported this conclusion. However, according to post-test results, it can be stated that "negative recency effect" was almost absent in the experimental group. Moreover, the proportion of students with "positive recency effect" misconception in experimental group was less than that of in control group after the treatment.

4.3.3 Misconception on Simple and Compound Events

Third type of the misconception observed in the study was misconception on simple and compound events. Question 5 and 6 was used to reveal simple and compound events misconception. Table 4.26 presents percentages of students' responses for the fifth question.

Question 5: Suppose one rolls a dice simultaneously. Which of the following has a greater chance of happening?
a) Getting the pair of 6-6
b) Getting the pair of 5-6
c) Both have the same chance

Table 4.26 Percentages of students' responses in terms of Simple and Compound Events (1)

Response	Experimental Group (n=59)				Control Group (n=59)			
	Pre-PCT		Post-PCT		Pre-PCT		Post-PCT	
	n	%	n	%	n	%	n	%
Correct (b)	1	1.7	23	39	3	5.1	5	8.5
Misconception(c)	57	96.6	21	35.6	56	94.9	52	88.1
Incorrect (a)	1	1.7	15	25.4	0	0	2	3.4
TOTAL	59	100	59	100	59	100	59	100

In the 5^{th} question, the proportion of students having misconception was quite high in both groups (96.6% in experimental group and 94.9% in control group) before the treatment. After the treatment, the correct alternative was selected by 39% of the students in the experimental group and 8.5% of the students in the control group. Nevertheless, even after the treatment, 35.6% of the students in the experimental group had still misconception of "simple and compound events". However, it was less than the proportion of students having this misconception in control group (88.1%). Table 4.27 presents percentages of students' responses for the sixth question. Question 6 was:

The letters in the word "CICEK" are written one by one on the cards and then these cards are placed in a bag. What is the probability of getting the letter "C" from this box at random?
a) 2/5 b) 2/3 c)1/4

Table 4.27 Percentages of students' responses in terms of Simple and Compound Events (2)

Response	Experimental Group (n=59)				Control Group (n=59)			
	Pre-PCT		Post-PCT		Pre-PCT		Post-PCT	
	n	%	n	%	n	%	n	%
Correct (a)	48	81.4	58	98.3	48	81.4	50	84.7
Misconception(c)	10	16.9	1	1.7	9	15.3	3	5.1
Incorrect (b)	1	1.7	0	0	2	3.4	6	10.2
TOTAL	59	100	59	100	59	100	59	100

Before the treatment, the percentage of the students who correctly answered the sixth question was 81.4% in both groups. After the treatment, the percentage of the students who answered the question correctly in the experimental group (98.3%) was higher than those of control group (84.7%). Morever, the percentage of the students who had misconception in the experimental group (1.7%) was lower than those in the control group (5.1%).

In the fifth question of PCT, alternative "c" (both 5-6 and 6-6 have equal chance) reflects this misconception type. Actually, obtaining 5-6 have a greater possibility to occur. In the sixth question, the alternative "c" (1/4) reflects misconception. In this question, the misconception is seen when "C" is counted only one time while determining sample space (CICEK). It can be stated that in this question, misconception was almost absent in both groups after the treatment while the misconception in question 5 was very strong. Thus, following explanations was mainly about the misconception observed in the question 5.

Interpreting probabilities in compound events is one of the difficulties of students (Shaugnessy, 1992). This type of misconception seems related to defining the sample space. While defining sample space, some students did not count the possible orders of results separately (e.g., HT and TH or 5-6 and 6-5) (Fischbein et al., 1991). The justifications given by students seem to confirm these explanations. All interviewees from control group (Int1C, Int2C, Int3C, and Int4C) and two interviewees from experimental group (Int1E, Int2E) had "simple and compound event" misconception. Three interviewees from control group (Int1C, Int2C, 4C) and two interviewees from experimental group (Int1E, Int2E) justified their answer as the following: "The probability of obtaining each number is 1/6. Thus, the probability of obtaining 5-6 and 6-6 is the same". Similarly, one interviewee from control group (Int3C) stated that "both obtaining 5-6 and 6-6 is equal to 1/36". Since students did not determine the sample space of the compound event in the question 5, they did not interpret this question correctly during the interviews. During the interview, all interviewees in control group stated that the probability of obtaining (6, 6) was equal to the probability of obtaining (5, 6) in rolling two dice simultaneously. According to interview results, it can be stated that this type of misconception was mainly based on the deficiencies in defining the magnitude of sample space. The students did not think separately 5-6 and 6-5 while determining the sample space. However, two interviewees from experimental group (Int3E, Int4E) gave correct answer and justified it correctly. They stated that"the probability of obtaining (5, 6) is 2/36 while the probability of obtaining (6, 5) is 1/36".

As a result, in question 5 and 6, students had difficulties in determing sample space. Justifications of the students also supported the conclusion that some students in both groups have misconception on simple and compound events. Also, this misconception was very frequent among the students even after the instruction. This type of misconception was very resistant to change. Some other studies also showed that several approaches to overcome it did not have a significant effect (Lecoutre & Durand, 1988 as cited in Fischbein et al., 1991). However, according to post-test results, it can be stated that the proportion of students with this misconception in experimental group was less than that of in control group after the treatment.

4.3.4 Misconception on Effect of Sample Size

The seventh and eighth questions were related to misconception on effect of sample size. Table 4.28 presents percentages of students' responses for the seventh question. The question 7 was:

> A doctor keeps the records of newborn babies. According to his records, which of the following options has a greater chance of happening?
> a) Out of the first 10 babies, the gender of 8 or more of them is female.
> b) Out of the first 100 babies, the gender of 80 or more of them is female.
> c) Both have the same chance.

Table 4.28 Percentages of students' responses in terms of Effect of Sample Size (1)

Response	Experimental Group (n=59)				Control Group (n=59)			
	Pre-PCT		Post-PCT		Pre-PCT		Post-PCT	
	n	%	n	%	n	%	n	%
Correct (a)	3	5.1	23	39	4	6.8	3	5.1
Misconception(c)	52	88.1	21	35.6	52	88.1	54	91.5
Incorrect (b)	4	6.8	15	25.4	3	5.1	2	3.4
TOTAL	59	100	59	100	59	100	59	100

In the seventh question, the percentages of students'' correct answers were very low both in control group (6.8%) and in experimental group (5.1%) before the treatment. Similarly, the percentages of the students' responses on misconception were quite high in both groups (88.1%). After the treatment, the percentage of the students who had misconception in the experimental group (35.6%) decreased. However, there was an increase in the percentage of the students with misconception in control group (91.5%). Table 4.29 presents percentages of students' responses for the eighth question.:

The question 8 was: Event 1: Getting tails at least 200 times when tossing a coin 300 times
Event 2: Getting tails at least twice when tossing three coins
Which of the following options has a greater chance of happening?
a) Event 1
b) Event 2
c) Both have the same chance.

Table 4.29 Percentages of students' responses in terms of Effect of Sample Size (2)

Response	Experimental Group (n=59)				Control Group (n=59)			
	Pre-PCT		Post-PCT		Pre-PCT		Post-PCT	
	n	%	n	%	n	%	n	%
Correct (b)	4	6.8	27	45.8	4	6.8	7	11.9
Misconception(c)	45	76.3	20	33.9	50	84.7	49	83.1
Incorrect (a)	10	16.9	12	20.3	5	8.5	3	5.1
TOTAL	59	100	59	100	59	100	59	100

Just like in the seventh question**,** in the eighth question, the percentage of students' correct answers was very low in both groups (6.8%). After the treatment, there were still students with misconception. However, the percentage of the students who had this type of misconception in control group (83.1%) was quite higher than that of in experimental group (33.9%) after the treatment.

In question 7 and 8, the alternative "c" reflects the misconception on effect of sample size. According to this alternative, both events are equally likely to occur. In fact, according to the law of large numbers, as the sample size increases, empirical probability converge the theoretical probability. However, "students are apparently misled by their belief that one must use ratios to solve this problem" (Fischbein & Schnarch, 1997, p.103). Some people are prone to neglect the effect of sample size while comparing probabilities (Tversky &Kahneman, 1982). The justifications given by students seem to confirm these explanations. All interviewees in control group (Int1C, Int2C, Int3C, and Int4C) and two interviewees in experimental group (Int1E and Int4E) had misconception on effect of sample size. Their justification was “two events are equiprobable because the ratio of them is equal”. However, two interviewees in experimental group who selected correct alternative (Int2E and Int3E) explained their reason by stating “as the sample size increases, the relative frequencies tend toward the theoretical probability”. According to interview results, it can be concluded that this type of misconception takes it’s source from students’ confusion on ratio and proportion subject with probability of events.

As a result, in question 7 and 8, some students were prone to neglect effect of sample size. However, according to post-test results, it can be stated that the proportion of students with this misconception in experimental group decreased while in the control group it was observed almost no change.

4.3.5 Misconception on Conjunction Fallacy

The ninth question was related to misconception on conjunction fallacy. The results related to this question and also this type of misconception was presented following table (Table 4.30) in terms of experimental and control groups both before and after the treatment. The question 9 was:

> Fatih likes to help people and dreams of becoming a doctor. When he was in high school, he volunteered for Kizilay organization and worked in medical service in summer camps. Now, Fatih is registered at the university. Which seems to you to be more likely?
> a) Fatih is a student of the medical school
> b) Fatih is a student

Table 4.30 Percentages of students' responses in terms of Conjuction Fallacy

Response	Experimental Group (n=59)				Control Group (n=59)			
	Pre-PCT		Post-PCT		Pre-PCT		Post-PCT	
	n	%	n	%	n	%	n	%
Correct (b)	43	72.9	52	88.1	44	74.6	51	86.4
Misconception(a)	15	25.4	7	11.9	15	25.4	8	13.6
TOTAL	59	100	59	100	59	100	59	100

Before the treatment some students in both groups had misconception (25.4%). Correct alternative was selected by 88.1% of the students in the experimental group and by 86.4% of the students in the control group after the treatment.

In the question 9, the alternative "a" reflects conjunction fallacy. The conjunction rule is "the simplest and the most basic qualitative law of probability" (Tversky &Kahneman, 1983, p.293). If sets A and B are given, the conjunction set (A and B) is a subset of A and of B, thus P (A and B) cannot exceed both P (A) and P (B). However, people often disregard this rule and assign higher probabilities to combined events (Tversky & Kahneman, 1983). The justifications given by students seem to confirm these explanations. For example, in the written justifications in post-PCT, one student in experimental group stated that "Fatih is a student of medical school because If you want to anything much, it happens". Similarly, three students from control group stated that "according to mentioned properties, it is more probable to be a medical student".

As a result, in question 9, some students tend to assign higher probabilities to combined events. Justifications of the students were also supported this conclusion. Even after the treatment, both groups had still misconception.

4.3.6 Misconception on Availability

The tenth question was related to misconception on heuristic availability. The results related to this question were presented in Table 4.31. The tenth question was:

K: The number of groups composed of 2 members from among 10 candidates.
L: The number of groups composed of 8 members from among 10 candidates.
According to the given information above, which of the following is correct?
a) K is greater than L
b) K is smaller than L
c) K is equal to L

Table 4.31 Percentages of students' responses in terms of Heuristic Availability

Response	Experimental Group (n=59)				Control Group (n=59)			
	Pre-PCT		Post-PCT		Pre-PCT		Post-PCT	
	n	%	n	%	n	%	n	%
Correct (c)	16	27.1	42	71.2	27	45.8	37	62.7
Misconception(a)	34	57.6	13	22	22	37.3	15	25.4
Incorrect (b)	9	15.3	4	6.8	10	16.9	7	11.9
TOTAL	59	100	59	100	59	100	59	100

According to Table 4.31, while the percentages of the students who selected correct alternative were 27.1% in the experimental group and 45.8% in the control group before the treatment, these percentages changed to 71.2% in the experimental group and 62.7% in the control group after the treatment. Morever, after the treatment, decrease in the proportion of the students who had misconception was greater in experimental group than in control group.

In question 10, the alternative "a" reflects availability heuristic. Actually, two events have equal number of groups. People who have this type of misconception tend to evaluate frequency or probability "by the ease with which instances or associations could be brought to mind" (Tversky & Kahneman, 1973, p. 164). The justifications given by students seem to confirm these explanations. For example, one students from control group stated that "The number of group composed of eight members is only one".

As a result, in question10, some students tend to rely on availability heuristic. Even after the treatment, both groups had still misconception. However, according to post-test results, it can be said that, decrease in the proportion of the students who had misconception was greater in experimental group than in control group after the treatment.

4.3.7 Misconception on Time Axis Fallacy

Seventh misconception type observed in this study was time axis fallacy. Questions 11 and 12 were related to misconception on the time axis fallacy. Actually, they together tested this type of misconception. The answers for these questions were examined in three categories:

Category I: Both responses are correct

Category II: The response for the 11th question is correct while that for the 12th question is incorrect

Category III: both responses are incorrect

Category II reflects the main misconception, time axis fallacy. The results related to these questions were presented in Table 4.32. The questions 11 and 12 were:

> Question 11: Dilek receive a box containing two white marbles and two black marbles. Dilek extracts a marble from her box and finds out that it is a white one. Without replacing the first marble, she extracts a second marble. According to given informations, which of the following is correct?
> a) The likelihood that the second marble is also white equal to the likelihood that it is a black marble.
> b) The likelihood that the second marble is also white greater than the likelihood that it is a black marble.
> c) The likelihood that the second marble is also white smaller than the likelihood that it is a black marble.

Question 12: Ahmet receive a box containing two white marbles and two black marbles. Ahmet extracts a marble from his box and puts it aside without looking at it. He then extracts a second marble and sees that it is white. According to given informations which of the following is correct?
a) The likelihood that the first marble he extracted is white is greater than the likelihood that it is a black.
b) The likelihood that the first marble he extracted is white is smaller than the likelihood that it is a black.
c) The likelihood that the first marble he extracted is white is equal to the likelihood that it is a black.

Table 4.32 Percentages of students' responses in terms of Time-Axis Fallacy

Categories	Experimental Group (n=59)				Control Group (n=59)			
	Pre-PCT		Post-PCT		Pre-PCT		Post-PCT	
	n	%	n	%	n	%	n	%
Correct	15	25.4	31	52.5	9	15.3	14	23.7
Misconception	30	50.8	22	37.3	33	55.9	25	42.4
Incorrect	13	22	5	8.5	16	27.1	19	32.2
Others	1	1.7	1	1.7	1	1.7	1	1.7
TOTAL	59	100	59	100	59	100	59	100

While the percentages of the students who selected correct alternative for the both questions (Category I) were 25.4 % in the experimental group and 15.3% in the control group before the treatment, they changed to 52.5% in the experimental group and 23.7% in the control group after the treatment. Similarly, after the treatment, the percentage of students who had misconception was lower in experimental group (37.3) than in control group (42.4).

Time-axis fallacy is regarding conditional probability. This type of misconception is seen when the individuals experience difficulties in perceiving that an outcome that has already happened can be affected by later event or outcome (Fischbein & Schnarch, 1997). For the question 12, generally, students disregard the information about the later event. In this situation, generally their justifications are "the first ball does not care whether the second is white or black" (Falk, 1986, p. 292). In other words, most students easily understand that outcome of an event can affect the outcome of a later event. However, they do not easily perceive it can affect another outcome that has already happened. The justifications given by students seem to confirm these explanations. Interview results showed that three interviewees in control groups (Int1C, Int3C, and Int4C) had this misconception type. They explained their response as stating that "at the beginning, there are two white and two black marbles. That is, the probabilities are the same at the beginning". Similarly, in their written justifications, some students from both groups stated that "at the beginning, the sample space is equiprobable".

As a result, in question 12, some students tend to disregard the infromation about later event. Even after the treatment, both groups had still misconception. However, according to post-test results, it can be stated that the proportion of students having "time-axis fallacy" in experimental group was less than that of in control group after the treatment.

4.3.8 Misconception on Equiprobability Bias

The last misconception type observed in this study was equiprobability bias. The question 13 and 14 in PCT were related to misconception on equiprobability bias. Table 4.33 shows the results related to 13th question. The question 13 was:

> There are six fair dice each of which is an ordinary cube with one face painted white and the other faces painted black. If these dice are tossed which of the following would be more likely?
> **a)** You would observe 5 black and 1 white
> **b)** You would observe 6 black
> **c)** One is as likely as the other

Table 4.33 Percentages of students' responses in terms of equiprobability bias (1)

Response	Experimental Group (n=59)				Control Group (n=59)			
	Pre-PCT		Post-PCT		Pre-PCT		Post-PCT	
	n	%	n	%	n	%	n	%
Correct (a)	9	15.3	28	47.5	10	16.9	17	28.8
Misconception(c)	15	25.4	11	18.6	23	39	19	32.2
Incorrect (b)	35	59.3	20	33.9	26	44.1	23	39
TOTAL	59	100	59	100	59	100	59	100

In the 13th question, while the percentages of the students who selected the correct alternative were %15.3 in experimental group and 16.9% in control group before the treatment, after the treatment they changed as 47.5% in the experimental group and as 28.8% in the control group. After the treatment, the students in control group and also the students in experimental group had still misconception. However, the percentage of misconception was lower in experimental group (18.6%) than in control group (32.2%). Table 4.34 shows the results related to 14th question. The question 14 was:

> A robot, which is placed in a labyrinth with eight same types of traps in it, is programmed to always go forward and never to come back. In every cross road, the robot chooses the road that he is going to follow at random. Which one is the most possible?
>
> a) being catched the first trap
> b) being catched the third trap
> c) being catched the fifth trap
> d) One is as likely as the others

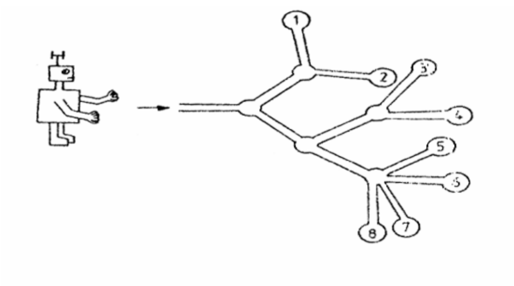

Table 4.34 Percentages of students' responses in terms of Equiprobability Bias (2)

Response	Experimental Group (n=59)				Control Group (n=59)			
	Pre-PCT		Post-PCT		Pre-PCT		Post-PCT	
	n	%	n	%	n	%	n	%
Correct (a)	29	49.2	48	81.4	27	45.8	34	57.6
Misconception(d)	26	44.1	10	16.9	26	44.1	20	33.9
Incorrect (b)	2	3.4	0	0	4	6.8	1	1.7
Incorrect (c)	2	3.4	1	1.7	2	3.4	4	6.8
TOTAL	59	100	59	100	59	100	59	100

In the 14th question, about half of the students in both experimental and control group selected correct answer before the treatment. Similarly, both groups (44.1%) had misconception before the treatment. However, after the treatment, the percentage of students having misconception in experimental group (%16.9) was less than that of in control group (33.9%).

In question 13 and 14, alternatives which states each event is equally probable reflects equiprobability bias. According to equiprobability bias, all results of an experiment are equiprobable. The logic under this heuristic is related to chance factor, as a result of this logic people think random events are equiprobable "by nature" (Lecoutre, 1992). The justifications given by students seem to confirm these explanations. Interview results showed that one interviewee in control group (Int2C) had equiprobability misconception. This interviewee stated that "since there are 8 traps, the robot can be catched in any of these traps. Thus, the probability of catching each trap is equal".

As a result, in question13 and 14, some students tend to evaluate probabilities as equiprobable. Even after the treatment, both groups had still misconception. However, according to post-test results, it can be stated that the proportion of students having "equiprobability bias" in experimental group was less than that of in control group after the treatment.

4.4 Summary of the Results

Results of the current study can be summarized as the following:

- There was no statistically significant mean difference between the groups in terms of students' mathematics achievement, probability achievement, understanding of probability concepts, prerequisite knowledge for probability, attitudes toward probability and attitudes toward mathematics in the pre-tests.
- There was a statistically significant overall effect of conceptual change based instruction and traditional instruction on the population means of the collective dependent variables of tenth grade students' post-test scores of the probability concept, probability achievement and attitudes toward probability when previous mathematics achievement scores are controlled. Effect size of treatment is large. So, difference between experimental and control group had a practical value.
- There was a statistically significant mean difference across students' levels in pre-PCT on the collective dependent variables of the post-PCT, post-PAT, and post-PAS when the pre-MAch scores were controlled.
- There was a statistically significant difference between the post-test mean scores of experimental group and those of control group on the population means of the probability concept post-test scores in favor of the experimental group when the students' previous semester mathematics achievement scores were controlled. Effect size for post-PCT is large. So, difference between experimental and control group had a practical value.
- There was a significant difference among the levels of pre-PCT with respect to post-PCT.
- There was no significant difference between the post-test mean scores of tenth grade students instructed with conceptual change model and those instructed with traditional instruction on the population means of the attitudes toward probability post-test scores when the students' previous semester mathematics achievement scores were controlled.

- There was no significant difference among low-, medium-, and high-achieving students in pre-PCT with respect to students' population means of the attitudes toward probability post-test scores when previous mathematics achievement scores were controlled.
- There was a statistically significant difference between the post-test mean scores of tenth grade students instructed with conceptual change model and those instructed with traditional instruction on the population means of the probability achievement post-test scores. Effect size for post-PAT is moderate.
- There was a statistically significant difference among the levels in pre-PCT with respect to post-PAT.
- There was a statistically significant interaction effect between treatment and students' probability concept pre-test scores on the collective dependent variables of the post-PCT, post-PAT, and post-PAS when the Pre-MAch scores were controlled.
- There was no statistically significant interaction effect between treatment and students' probability concept pre-test scores with respect to tenth grade students' population means of probability achievement post-test scores when previous mathematics achievement scores are controlled.
- There was no a significant interaction effect between treatment and students' probability concept pre-test scores with respect to post-PAS scores.
- There was a statistically significant interaction effect between treatment and students' probability concept pre-test scores with respect to post-PCT scores.
- The proportion of misconceptions held by students in experimental group was less than that of in control group.

CHAPTER 5

DISCUSSION, CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

This chapter presents discussion and conclusions of the results, implications of the study and recommendations for further research.

5.1 Discussion and Conclusions of the Results

The purpose of the current study is to investigate the effect of conceptual change based instruction (CCBI) and traditional instruction (TI) on 10th grade students' understandings of probability concepts, probability achievement and attitudes toward probability as a school subject.

Before the treatment, the equivalence of the experimental and control groups was tested in terms of mathematics achievement, probability achievement, understanding of probability concepts, prerequisite knowledge for probability, attitudes toward probability and attitudes toward mathematics. To test the equivalence of the groups in terms of mathematics achievement, students' mathematics grades in the previous semester were obtained. Moreover, "Probability Achievement Test", "Probability Concept Test", "Prerequisite Knowledge Test for Probability", "Probability Attitude Scale" and "Mathematics Attitude Scale" was administered to test the equivalence of the groups in terms of probability achievement, understanding of probability concepts, prerequisite knowledge for probability, attitudes toward probability and attitudes toward mathematics. According to pre-test analyses, there was no significant difference between experimental and control groups in terms of pre-MAch, pre-PCT, pre-PAT, pre-MAS, pre-PAS and pre-PKT. However, pre-MAch and pre-PCT were determined to use as covariates because pre-MAch and pre-PCT had a significant correlation with at least one of the dependent variables and correlations among these independent variables were less than 0.80 (Stevens, 2002). To conduct MANCOVA, firstly, assumptions of MANCOVA were checked. In order to guarantee the assumption of homogeneity of regression, students' pre-test scores on PCT was added in fixed factors. Results of the MANCOVA showed that there was a significant mean difference between groups on the collective dependent variables of the post-PCT, post-PAT, and post-PAS.

Post-test mean differences between groups were tested statistically by the help of MANCOVA. MANCOVA results revealed that probability achievement post-test mean scores of tenth grade students instructed with conceptual change model were significantly higher than those instructed with traditional instruction in favor of the experimental group. The proportion of variance of the achievement explained by the treatment was 6.3%. That is, this value indicated the difference between experimental and control group was moderate (Cohen, 1988). In other words, conceptual change based instruction caused a significantly higher achievement in probability than the traditional instruction. Many other studies reported similar results about effect of CCBI or similar strategies on students' science or mathematics achievement (Basili & Sanford, 1991; Bilgin & Geban, 2006; Cankoy, 1998; Castro, 1998; Esiobu & Soyibo, 1995). Properties of conceptual change based instruction may have resulted in a better achievement in probability. In other words, during the treatment in experimental group, conceptual change based instruction including several activities, simulations and discussions was used to promote acquisition of new concept. Conceptual change based instruction provided a learning environment in which students' misconceptions were activated by the help of activities and /or problems. Also, dissatisfaction with misconceptions, mathematical explanation of the concept, and opportunity to practice new concept was provided in the learning process. According to observations of the researcher, in the learning process of CCBI, students actively participated in the activities and discussions. They also seemed more enthusiastic about learning than students in the control group. In the lessons of CCBI, especially computer simulations increased the attention to the lesson.

The descriptive statistics also indicated that students' probability achievement post-test mean scores in the experimental group were higher than those in the control group. Students' probability achievement post-test mean scores were 36.77 (SD= 7.48) in experimental group and 34.13 (SD= 9.00) in control group. When these scores were compared to students' probability achievement pre-test mean scores, it was seen an improvement in students' probability achievement in both groups. Nevertheless, these mean scores was still low when compared to maximum score of PAT which was 54.

Results of the current study indicated that the probability concept post-test mean scores of tenth grade students instructed with conceptual change model were significantly higher than those instructed with traditional instruction in favor of experimental group. This result also has practical significance. According to results of the study, it can be stated that conceptual change instruction caused a significantly better understanding of the probability concepts than traditional instruction. This result supported the conclusions of many other national and international studies which stated that conceptual change based instruction improved students' understanding of science concepts (Bilgin & Geban, 2006; Niaz, 2002; Pınarbaşı et al., 2006) and mathematics concepts (Cankoy, 1998; Castro, 1998; Stoddart, Michael, Stofflett, & Peck, 1993). When the properties of the conceptual change based instruction are considered, this finding can be thought as an expected outcome. Because of the properties of instruction, conceptual change based instruction may have resulted in a better understanding of probability. In the experimental group, conceptual change based instruction accompanied with computer simulations, activities and discussions was applied. In this process, the conceptual change model developed by Posner et al. (1982) was followed by considering four conditions for conceptual change, dissatisfaction, intelligibility, plausibility, and fruitfulness. The instructions in experimental group were prepared for the purpose of addressing students' probability misconceptions and eliminate them. During the experimental lessons, firstly, students were confronted with an activity sheet or a problem. Each activity sheet included relatively difficult problems containing a conceptual obstacle. Students were encouraged to discuss their ideas on the activity in order to help them develop awareness with their misconceptions and experience dissatisfaction with their current concepts. Then, the teacher presented the mathematical explanation of the concept for the purpose of making concept more intelligible. After that, the lesson continued with computer simulations. Students also participated in discussions during the simulation. Since, throughout this process, students had an opportunity observing sample events about the concept, the concepts were aimed to be more intelligible. Then, new examples about the concept were presented to the students to improve their understanding of probability. Lastly, teacher encouraged students to use the new concept in explaining a new situation. Morever, according to observations of the researcher, it can be stated that CCBI also formed enthusiastic and exciting learning environment.

The descriptive statistics revealed that students' probability concept post-test mean scores in the experimental group were higher than those in the control group. Students' post-test mean scores were 10.01 (SD= 1.40) in experimental group and 7.81 (SD= 1.65) in control group. Although the mean score of the experimental group was statistically higher than that of control group, this mean score was not at desired level when compared to maximum score of PCT which was 14.

The current study suggested an interaction between treatment and students' probability concept pre-test scores on post-PCT scores. According to results of the study, there was a statistically significant interaction effect between treatment and students' probability concept pre-test scores with respect to post-PCT scores. Results revealed that in the experimental group, the mean differences among the levels of pre-PCT almost disappeared after the treatment while the mean differences still appeared in the control group. So, it can be concluded that CCBI was effective in closing the gap among the levels of pre-PCT scores.

According to results of the study, it can be stated that the proportion of misconceptions held by students in experimental group was less than that of in control group. Many researchers emphasize the significant effect of CCBI and similar approaches in improving conceptual understanding and overcoming misconceptions (Başer, 1997; Cankoy, 1998; Chambers & Andre, 1997; Çetingül

& Geban, 2011; Eryılmaz, 1996; Hewson & Hewson, 1993; Perso, 1992; Stoddart et al., 1993). Before the treatments, both groups had probabilistic misconceptions. However, when compared to other types of misconceptions, the percentages of students who had "representativeness heuristic" and "negative recency effect" were not very high before the treatment; the reason of this can be related to findings which state that these misconceptions decrease with age (Fischbein & Schnarch, 1997). Results also indicated that many students in both groups still had misconceptions on probability even after the instruction. Many other researchers reported similar results about resistance of misconception even after instruction (Anderson, 1986; Bilgin & Geban, 2006; Çalık et al., 2010; Driver & Easley, 1978; Duit, 2007). For example, interview results showed that after the instruction some students from both experimental and control groups still thought obtaining 5-6 and 6-6 as equiprobable in rolling of two dice (misconception on simple and compound events). This type of misconception is very resistant to change. And, some other studies also showed that several approaches to overcome it did not have a significant effect (Lecoutre & Durand, 1988 as cited in Fischbein et al., 1991). According to post-test results, it can be said that negative recency effect was almost absent in the experimental group while above 15% of the students in experimental group had this misconception before the treatment. Similarly, it can be also concluded that CCBI is more effective than TI in eliminating probability misconceptions, especially on "simple and compound events", and "effect of sample size". Although students from both groups had still probabilistic misconceptions, the proportion of misconceptions held by students in experimental group was less than that of in control group. The properties of traditional and conceptual change based instruction may have caused this difference in students' understanding of probability concepts. During the instruction of experimental group, students were participated in activities which supported them activate their prior knowledge and struggle with them. In order to overcome misconceptions on probability, students firstly experienced dissatisfaction with existing conception. Then, more intelligible and plausible mathematical conceptions were presented. The important part of conceptual change based instruction was the interactions between student-student and teacher-student since they supported to share ideas on the activities and simulations. The teacher-guided discussions were also used. Discussions of the probability concepts could facilitate students' understanding and their conceptual restructuring. Conceptual change based instruction encouraged students to alter their misconceptions. During the conceptual change based instruction, the teacher was aware of students' existing knowledge and misconceptions of probability. Similarly, instruction helped students realize their misconceptions. All the lessons were planned by taking into consideration misconceptions. However, in the control group, traditional instruction was used during the instruction of probability. The teacher gave the explanation of the concept and solved problems. The teacher did not take into consideration of their students' misconceptions. However, it is important to emphasize that the problems presented in the activity sheets to experimental group were also solved in the control group. However, they were covered as a part of regular problem solving session but not as an activity format. Since the problems were discussed in CCBI, it can be concluded that discussion of the problems may have contributed to improving students' understanding of probability concepts.

Attitude is another factor affecting mathematics learning in addition to cognitive factors. For this reason, at the beginning of the study, students' attitudes both toward probability and toward mathematics were examined. At the beginning of the study, the students' attitudes mean scores in experimental group were close to those in control group. Results of the independent-t test analysis also showed that mean difference between experimental and control group was not statistically significant in terms of attitudes toward probability and attitudes toward mathematics. So, it can be stated that students' previous attitudes both toward probability and toward mathematics influenced their probability learning in the same way in both experimental and control groups. However, there was no statistically significant difference between the post-test mean scores of tenth grade students instructed with conceptual change model and those instructed with traditional instruction on the population means of the attitudes toward probability post-test scores. This result supported the conclusions of many research studies on CCBI or similar strategies which indicated that traditional instruction and conceptual change instruction developed the similar attitude toward science or mathematics (Başer & Çataloğlu, 2005; Başer & Geban, 2007; Castro, 1998; Çelikten et al., 2012; Pınarbaşı et al., 2006). The reason of this situation can be related to limited duration of treatment. The duration of treatment, three week, may not be enough to change attitudes of students which are based on students' long experience with the probability (Castro, 1998).

5.2 Implications

According to results of the study, there were statistically significant mean differences between experimental and control groups in terms of understanding of probability concepts and probability achievement in favor of CCBI. Thus, CCBI may be used to improve students' understanding and achievement in probability. In order to use CCBI in mathematics classrooms, teachers should be helped to develop ideas about conceptual change in learning/teaching probability. A guidebook which includes information and sample applications on CCBI may be prepared for the teachers. Also, mathematics teachers should increase their abilities with respect to the applications of CCBI. In order to achieve this, they should have experience about conceptual change based instruction. They may also be trained by inservice programs. Based on classroom observations, it can be stated that this inservice training may be given by using cognitively guided instruction.

During the current study, in developing lessons in CCBI, students' misconceptions in probability were taken into consideration. Results showed that there was a significant contribution of CCBI to students' achievement and understanding in probability. Thus, while designing lessons, teachers should also take into consideration misconceptions of their students. In order to reveal and address students' misconceptions, they can design activities which including conceptual obstacles and teacher-guided discussions. In addition, students should also be active in the learning process. Similarly, textbooks should address common misconceptions held by students. The teacher guidebooks should also include common probabilistic misconceptions. Textbooks should include activities based on CCBI. Textbook writers should prepare a guidebook for teachers to help them prepare and use activities based on CCBI.

Similarly, curriculum developers should address common probabilistic misconceptions held by students. In order to achieve this, objectives in the curriculum should be written to address students' probabilistic misconceptions. Mathematics curriculum should also incude some cues related to activities in CCBI. Also, curriculum should give information about how measurement and evaluation can be done in CCBI.

5.3 Recommendations for Further Research

The current study suggested an interaction between students' pre-PCT scores and treatment (CCBI versus TI) with respect to post-PCT scores. This interaction can be used to perform research studies. For example, different achievement levels can be determined based on students' pre-instructional probability concept test scores. Then, interaction between instructions and students' concept achievement levels can be investigated.

The current study investigated the effect of CCBI on students' probability learning. The further research studies in which other instructional strategies are used can be designed to compare the effect of these strategies with CCBI on students' understanding of probability, probability achievement and attitudes toward probability. For example, cognitive conflict, concept map, or conceptual change texts may be used to design instructions.

The current study was conducted with 118 tenth grade students from one Anatolian high school in Ankara. The further research studies can be conducted with different school types or different grade levels with a larger sample. Because of the effect of teachers on students' misconceptions, the present study can be replicated with preservice teachers.

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APPENDIX A

PILOT AND MAIN STUDY PERMISSION

T.C.
ANKARA VALİLİĞİ
Milli Eğitim Müdürlüğü

BÖLÜM : İstatistik Bölümü
SAYI : B.B.08.4.MEM.4.06.00.06-312/12641 12/02/2010
KONU : Araştırma İzni
Emel TOPBAŞ TAT

ORTA DOĞU TEKNİK ÜNİVERSİTESİNE
(Fen Bilimleri Enstitüsü)

İlgi : a) MEB Bağlı Okul ve Kurumlarda Yapılacak Araştırma ve Araştırma Desteğine Yönelik İzin ve Uygulama Yönergesi.
b) Üniversiteniz Fen Bilimleri Enstitüsünün 05/02/2010 tarih ve 1570 sayılı yazısı.

Üniversiteniz Fen Bilimleri Enstitüsü Ortaöğretim Fen ve Matematik Alanlar Eğitimi Doktora öğrencisi Emel TOPBAŞ TAT' ın **"Öğrencilerin olasılıkla ilgili kavram yanılgılarını belirleme ve giderme"** konulu tez ile ilgili çalışma yapma isteği Müdürlüğümüzce uygun görülmüş ve araştırmanın yapılacağı İlçe Milli Eğitim Müdürlüğüne bilgi verilmiştir.

Mühürlü anketler (24 sayfadan oluşan) ekte gönderilmiş olup, uygulama yapılacak sayıda çoğaltılması ve çalışmanın bitiminde iki örneğinin (CD/disket) Müdürlüğümüz İstatistik Bölümüne gönderilmesini rica ederim.

Gülçin UYSAL
Müdür a.
Müdür Yardımcısı

EKLER :
Anket (24 sayfa)

İl Milli Eğitim Müdürlüğü-Beşevler
Strateji Geliştirme Bölümü
Bilgi İçin: Kamil COŞGUN

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APPENDIX B

CONTENT OUTLINE OF THE TREATMENT

Lesson Plan1

- Experiment
- Outcome
- Sample Space
- Sample Point
- Event
- Certain Event
- Impossible Event
- Mutually/Non-Mutually Exclusive Events
- Probability Function

Lesson Plan 2 (Activity1, Activity 2)

- Sample Space
- Sample Point

Lesson Plan 3 (Activity 3, Activity 5)

- Equally Likely Sample Space
- Probability in Equally Likely Sample Space

Lesson Plan 4 (Activity 4)

- Equally Likely Sample Space
- Probability in Equally Likely Sample Space

Lesson Plan 5

- Simple and Compound Events

Lesson Plan 6 (Activity 6)

- Simple and Compound Events

Lesson Plan 7 (Activity 7)

Experimental and Theoretical Probability

Lesson Plan 8 (Activity 8)

- Dependent/ Independent Events
- Probability of Independent Events

Lesson Plan 9

- Conditional Probability

APPENDIX C

PROBABILITY CONCEPT TEST

Adınız   ……………………………………   Soyadınız:..................................

Cinsiyetiniz:...

Okulunuzun İsmi:..Sınıfınız:................

Son Dönem Matematik Ders Notunuz: ....

Babanızın Öğrenim Durumu:...

Annenizin Öğrenim Durumu:..

Babanızın Mesleği:...

Annenizin Mesleği: ....

Olasılık Konusunu Önceden Öğrendiniz mi? ....

Cevabınız "Evet" ise, Nerede ve Ne Zaman Öğrendiniz?...............................

Sevgili Ögrenciler :

Bu test sizin olasılık konusu üzerine nasıl düşündüğünüzü ölçmek için hazırlanmıştır. Bu test sonuçları **sadece araştırma amaçlı** kullanılacaktır. Testten alacağınız puanlar ve bilgiler kesinlikle **açıklanmayacaktır** ve **not verilmeyecektir**. Bütün soruları dikkatli okumaya ve kendiniz cevaplamaya özen gösteriniz. Her soru icin en uygun buldugunuz seçeneği işaretlemeniz ve altına o seçeneği **neden** işaretlediğinizi açıklamanız gerekmektedir. Test toplam **14** sorudan oluşmaktadır.

Teşekkür eder, başarılar dileriz.

Prof. Dr. Safure BULUT & Araş. Gör. Emel TOPBAŞ TAT

ODTÜ Eğitim Fakültesi

SORULAR

1) Hilesiz bir madeni para 5 defa arka arkaya havaya atılıyor. **Y** *yazıyı* **T** *turayı* temsil ettiğine göre bu atışlarda sırasıyla aşağıdakilerden hangisinin gelme olasılığı en büyüktür?

a) YYYTT **b)** YTTYT **c)** TYTTT

d)YTYTY **e)** a, b, c ve d şıklarının gelme olasılıkları eşittir.

Neden?

....

2) Bir sayısal loto oyununda bir kişi **1**'den **40**'a kadar olan sayılardan 6 tanesini seçmek zorundadır. Ahmet 1, 2, 3, 4, 5 ve 6 sayılarını, Nuray 39, 1, 17, 33, 8 ve 27 sayılarını seçmiştir. Sizce kimin kazanma olasılığı daha büyüktür?

a) Ahmet **b)** Nuray **c)** İkisinin kazanma olasılıkları eşittir.

Neden?

....

3) Özge, hilesiz bir madeni parayı üç kez havaya atmış ve hepsinde yazı gelmiştir. Özge, 4.kez parayı havaya attığında asağıdakilerden hangisi doğru olur?

a) Yazı gelme olasılığı, tura gelme olasılığına eşittir.

b) Yazı gelme olasılığı, tura gelme olasılığından küçüktür.

c) Yazı gelme olasılığı, tura gelme olasılığından büyüktür.

Neden?

....

4) Bir baba ve oğul her gün bir oyun oynuyorlar. Oyunda baba, eline bir madeni para alır ve ellerini arkasına saklar.Eğer çocuk paranın babasının hangi elinde olduğunu bilirse parayı kazanır. Geçen 14 gün içinde çocuk 5 defa doğru, 9 defa yanlış tahminde bulunmuştur. Gelecek 14 günde aşağıdakilerden hangisinin olmasını beklersiniz?

a) Çocuğun doğru tahmin sayısının yanlış tahmin sayısından fazla olmasını

b) Çocuğun doğru tahmin sayısının yanlış tahmin sayısından az olmasını

c) Çocuğun doğru tahmin sayısının yanlış tahmin sayısına eşit olmasını

Neden?

....

5) Hilesiz iki zar aynı anda havaya atılıyor. Aşağıdakilerden hangisinin olma olasılığı daha büyüktür?

a) 6 ve 6 rakamlarının gelmesi (başka bir deyişle 6-6 çiftinin gelmesi)

b) 5 ve 6 rakamlarının gelmesi (başka bir deyişle 5-6' nın gelmesi)

c) "a" ve "b" şıklarının olma olasılıkları eşittir.

Neden?

....

6) " **ÇİÇEK** " kelimesini oluşturan harfler kağıtlara yazılıp bir torbaya atılıyor. Bu torbadan rastgele seçilen harfin "**Ç**" olması olasılığı aşağıdakilerden hangisidir?

a) $\frac{2}{5}$ **b)** $\frac{2}{3}$ **c)** $\frac{1}{4}$

Neden?

....

7) Bir hastanede yeni doğanların kayıtları tutuluyor. Buna göre aşağıdakilerden hangisinin olma olasılığı daha büyüktür?

a) İlk doğan 10 bebekten 8 veya daha fazlasının kız olması.

b) İlk doğan 100 bebekten 80 veya daha fazlasının kız olması.

c) a ve b şıklarının olma olasılıkları eşittir.

Neden?

....

8) **Olay 1:** Hilesiz bir madeni paranın **300** kez havaya atılması deneyi sonucunda en az **200** kez yazı gelmesi.

Olay 2: Hilesiz bir madeni paranın **3** kez havaya atılması deneyi sonucunda en az **2** kez yazı gelmesi.

Yukarıdaki deneylerden hangisinin sonucunun olma olasılığı daha büyüktür?

a) Olay 1 **b)** Olay 2 **c)** Olay 1 ve Olay 2' nin olma olasılıkları eşittir.

Neden?

....

9) Fatih insanlara yardım etmeyi sevmekte ve doktor olmayı istemektedir. Lisedeyken Kızılay Kolu'nda görev almış ve yaz kamplarında sağlık hizmetlerinde çalışmıştır. Şu anda bir üniversiteye kayıtlıdır. Buna göre aşağıdakilerden hangisi daha olası görünmektedir?

a) Fatih Tıp Fakültesinde öğrencidir. **b)** Fatih öğrencidir.

Neden?

....

10) **K:** 10 kisilik bir topluluk içinden oluşturulacak 2 kişilik gurupların sayısı,

L: 10 kişilik bir topluluk içinden oluşturulacak 8 kişilik gurupların sayısı,

olduğuna göre **K** ve **L** sayıları arasında nasıl bir ilişki vardır?

a) K, L' den büyüktür. **b)** K, L' den küçüktür. **c)** K, L' ye esittir.

Neden?

....

11) Dilek'in elinde, içinde iki siyah ve iki beyaz bilye bulunan bir torba var. Dilek torbadan bir bilye çekiyor ve bilyenin beyaz olduğunu görüyor. Elindeki bilyeyi geri koymadan bir bilye daha çekiyor. Buna göre aşağıdakilerden hangisi doğrudur?

a) İkinci bilyenin beyaz olma olasılığı, siyah olma olasılığına eşittir.

b) İkinci bilyenin beyaz olma olasılığı, siyah olma olasılığından büyüktür.

c) İkinci bilyenin beyaz olma olasılığı, siyah olma olasılığından küçüktür.

Neden?

....

12) Ahmet'in elinde içinde iki siyah ve iki beyaz top bulunan bir torba var. Ahmet torbadan bir top çekiyor ve bakmadan topu bir kenara koyuyor.Torbadan başka bir top daha çekiyor ve bunun beyaz olduğunu görüyor. Buna göre aşağıdakilerden hangisi doğrudur?

a) İlk çektiği topun beyaz olma olasılığı, siyah olma olasılığından büyüktür.

b) İlk çektiği topun beyaz olma olasılığı, siyah olma olasılığından küçüktür.

c) İlk çektiği topun beyaz olma olasılığı, siyah olma olasılığına eşittir.

Neden?

....

13) 5 yüzü siyaha, 1 yüzü de beyaza boyanmış 6 tane hilesiz zar atıldığında aşağıdakilerden hangisinin olma olasılığıdaha büyüktür?

a) 5 zarın siyah, 1 zarın beyaz gelmesi.

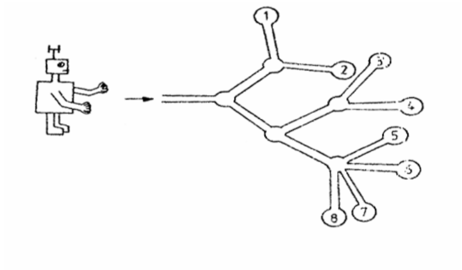
b) 6 zarın siyah gelmesi.

c) “a” ve “b” şıklarının olma olasılıkları eşittir.

Neden?

....

14) Sonunda 8 tane aynı çeşit tuzak bulunan bir labirente bırakılan robot devamlı ileri gitmek üzere hiç geri gelmeyecek sekilde programlanmıştır. Robot her bir yol ayırımında devam edeceği yolu rastgele seçmektedir. Bu robotun hangi tuzağa yakalanma olasılığı daha büyüktür?



a) 1. Tuzak **b)** 3. Tuzak **c)** 5. Tuzak

d) Bütün tuzaklara yakalanma olasılığı eşittir.

Neden?

....

APPENDIX D

PROBABILITY ATTITUDE SCALE

AÇIKLAMA: Aşağıda olasılığa ilişkin tutum cümleleri ile her cümlenin karşısında "Tamamen Katılıyorum", "Katılıyorum", "Kararsızım", "Katılmıyorum", "Tamamen Katılmıyorum" olmak üzere beş seçenek verilmiştir. Lütfen cümleleri dikkatle okuduktan sonra her cümle için kendinize uygun olan seçeneklerden birini işaretleyiniz.

	Tamamen Katılıyorum	Katılıyorum	Kararsızım	Katılmıyorum	Tamamen Katılmıyorum
1. Olasılık konularını severim.	O	O	O	O	O
2. Olasılık konuları sevimsizdir.	O	O	O	O	O
3. Olasılıkla ilgili konuları tartışmaktan hoşlanırım.	O	O	O	O	O
4. Olasılıkla ilgili bilgiler can sıkıcıdır.	O	O	O	O	O
5. Olasılıkla ilgili bilgiler zihin gelişmesine yardımcı olur.	O	O	O	O	O
6. Olasılık konusu beni huzursuz eder.	O	O	O	O	O
7. Olasılıkla ilgili ders saatlerinin daha çok olmasını isterim.	O	O	O	O	O
8. Olasılık konusu rahatlıkla öğrenilebilir.	O	O	O	O	O
9. Olasılıkla ilgili sınavlardan korkarım.	O	O	O	O	O
10. Olasılık konuları ilgimi çeker.	O	O	O	O	O

	Tamamen Katılıyorum	Katılıyorum	Kararsızım	Katılmıyorum	Tamamen Katılmıyorum
11. Olasılığın doğru karar vermemizde önemli bir rolü vardır.	O	O	O	O	O
12. Olasılık konuları aklımı karıştırır.	O	O	O	O	O
13. Olasılık konusunu severek çalışırım.	O	O	O	O	O
14. Olasılık konusunu elimde olsa öğrenmek istemezdim.	O	O	O	O	O
15. Olasılık, ilginç bir konu değildir.	O	O	O	O	O
16. Olasılıkla ilgili ileri düzeyde bilgi edinmek isterim.	O	O	O	O	O
17. Olasılık hemen hemen her iş alanında kullanılmaktadır.	O	O	O	O	O
18. Olasılık konusunu çalışırken canım sıkılır.	O	O	O	O	O
19. Olasılık, kişiye düşünmesini öğretir.	O	O	O	O	O
20. Olasılığın adını bile duymak sinirlerimi bozuyor.	O	O	O	O	O
21. Olasılık konusundan korkarım.	O	O	O	O	O
22. Olasılık, herkesin öğrenmesi gereken bir konudur.	O	O	O	O	O
23. Olasılık konusundan hoşlanmam.	O	O	O	O	O
24. Olasılıkla ilgili bilgiler, kişinin tahmin yeteneğini artırır.	O	O	O	O	O
25. Olasılık konusu anlatılırken sıkılırım.	O	O	O	O	O
26. Olasılıkla ilgili bilgilerin günlük yaşamda önemli bir yeri vardır.	O	O	O	O	O
27. Olasılık konusu okullarda öğretilmese daha iyi olur.	O	O	O	O	O
28. Olasılık konuları eğlencelidir.	O	O	O	O	O

APPENDIX E

TABLE OF SPECIFICATION FOR THE PREREQUISITE KNOWLEDGE TEST FOR THE PROBABILITY

Alt Öğrenme Alanı	Bir kümeyi modelleri ile belirler, farklı temsil biçimleri ile gösterir.	Kümelerle birleşim, kesişim, fark ve tümleme işlemlerini yapar ve bu işlemleri problem çözmede kullanır.	Evrensel kümeyi belirler.	Kesirlerle toplama ve çıkarma işlemlerini yapar.	Kesirlerle çarpma işlemini yapar.	Bir kesri modelleyerek gösterir.	Kesirleri karşılaştırır, sıralar ve sayı doğrusunda gösterir.	Pay, payda ve kesir çizgisi kavramlarını açıklar.	Ondalık kesirlerle toplama ve çıkarma işlemlerini yapar.	Doğal sayıların faktöriyellerini bulur.	Permütasyonu hesaplar.	Kombinasyonu hesaplar.
Kümeler	1, 2	3, 5	4									
Kesirler				6a, 6c	6b	7	8a, 8b	9a, 9b				
Ondalık Kesirler									10a, 10b, 10c			
Olası durumları belirleme										12a, 12b, 12c	11, 13	14, 15

APPENDIX F

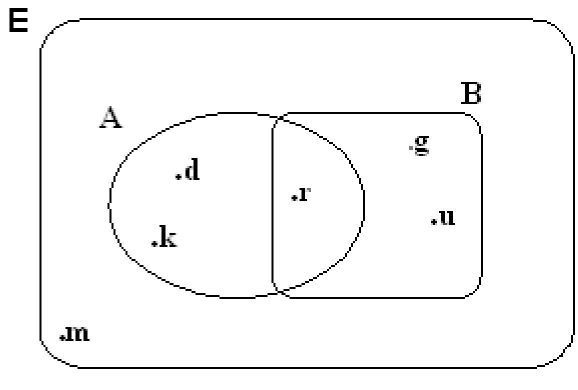
PREREQUISITE KNOWLEDGE TEST FOR PROBABILITY

Yönerge: Soruları dikkatlice okuyunuz ve **<u>cevap kağıdında uygun yere</u>** çözünüz.

Başarılar!

1. Evinizde yaşayan kişilerin isimlerini listeleme yönetmiyle gösteriniz.
2. H = {radyo, video, TV}, K = {video, bilgisayar, teyp} $H \cup K$'yı venn şeması ile gösteriniz.
3. Bir sınıfta ki 15 öğrenci sinemaya gitmekten, 19 öğrenci tiyatroya gitmekten, 12 öğrenci ise hem sinemaya hem de tiyatroya gitmekten hoşlanıyor. Bu sınıfta ki öğrenci sayısı kaçtır?

******* 4. ve 5. soruları aşağıdaki venn şemasını kullanarak cevaplayınız.***



4. Evrensel kümeyi listeleme yöntemini kullanarak yazınız.
5. $A \cap B$ kümesinin elemanlarını listeleyiniz.
6. Aşağıdaki işlemleri yapınız.

a) $\frac{2}{3}+\frac{4}{5}=?$ **b)** $\frac{2}{9}x\frac{5}{3}=?$ **c)** $\frac{3}{7}+\frac{4}{7}=?$

7. $\frac{5}{8}$ kesrini şekil çizerek gösteriniz.

8. Aşağıdaki rasyonel sayıları küçükten büyüğe doğru sıralayınız.

a) $\frac{11}{7}, \frac{2}{7}, \frac{5}{7}, \frac{13}{7}, \frac{15}{7}$ **b)** $\frac{5}{12}, \frac{3}{4}, \frac{1}{24}, \frac{7}{16}$

9. Aşağıdaki ifadeleri tamamlayınız.

a) Bir kesir sayısında bütünün kaç eşit parçaya bölündüğünü gösteren sayı..............olarak adlandırılır.

b) Bir kesir sayısında bütünün eş parçalarından kaç tanesinin alındığını gösteren sayı..................olarak adlandırılır.

10. Aşağıdaki işlemlerin sonucunu hesaplayınız.

a) 0.5 + 0.1 + 0.7 =? **b)** 0.1 + 0.3 - 0.8 =? **c)** - 0.3 - 0.5 - 0.9 =?

11. Bir yarışmaya katılan 10 öğrenciden; 1., 2. ve 3. olanlar kaç farklı şekilde oluşabilir?

12. Aşağıdaki işlemleri yapınız.

a) $\frac{3!.4!}{2!.6} = ?$ **b)** $\frac{12!}{10!} = ?$ **c)** $\frac{5!+4!}{5!-4!} = ?$

13. KİTAP kelimesinin harflerini kullanarak; anlamlı ya da anlamsız, harfleri farklı ve dört harfli kaç değişik kelime türetebiliriz?

14. Matematik öğretmeni sınavda 10 soru sormuştur. Fakat öğrencilerden istedikleri 5 soruyu cevaplamalarını istemiştir. Bir öğrenci cevaplandıracağı 5 soruyu kaç farklı şekilde seçebilir?

15. Ahmet ve Ali'nin de aralarında bulunduğu 7 kişilik grup arasından, aralarında Ahmet'in bulunmadığı ve Ali'nin bulunduğu 4 kişilik bir grup kaç farklı şekilde seçilebilir?

APPENDIX G

SCORING RUBRIC FOR THE PREREQUISITE KNOWLEDGE TEST FOR THE PROBABILITY

1) Evinizde yaşayan kişilerin isimlerini listeleme yöntemiyle gösteriniz.

A={Ali, Ege, ... }

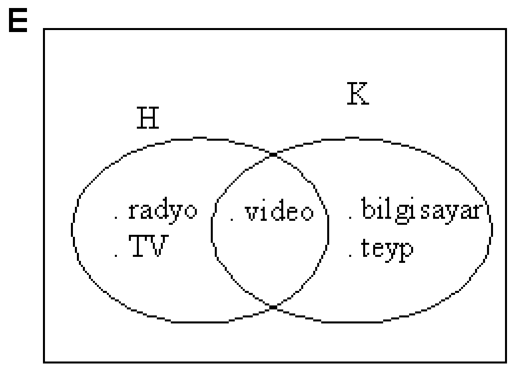
Tam doğru: (2 puan)

Kişilerin isimlerini listeme yöntemiyle ifade eden tüm gösterimler

Yanlış Yanıt: (0 puan)

Tam doğru dışındaki tüm yanıtlar

2) H = {radyo, video, TV}, K = {video, bilgisayar, teyp} $H \cup K$'yı venn şeması ile gösteriniz.



Tam doğru: (2 puan)

$H \cup K$'yı venn şeması ile gösteren ve kümelerin elemanlarını doğru şekilde ifade eden tüm gösterimler

Kısmi doğru: (1 puan)

$H \cup K$'yı venn şeması ile gösteren fakat kümelerin elemanlarını yerleştirmede eksiklik, yanlışlık gösteren tüm gösterimler

Yanlış Yanıt: (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

3) Bir sınıfta ki 15 öğrenci sinemaya gitmekten, 19 öğrenci tiyatroya gitmekten, 12 öğrenci ise hem sinemaya hem de tiyatroya gitmekten hoşlanıyor. Bu sınıfta ki öğrenci sayısı kaçtır?

Tam doğru: (2 puan)

Verilen sorunun cevabını bulmaya yönelik olarak yapılmış eksiksiz tüm işlemler

Örnek Yanıt 1:

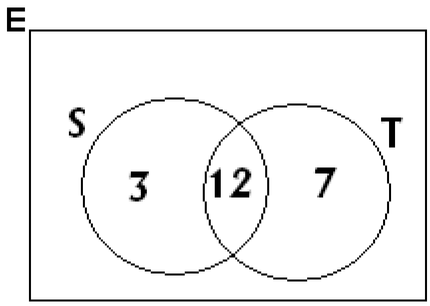
$s(S)= 15$

$s(T)=19$

$s(S \cap T)=12$

$s(S \cup T)= s(S)+ s(T)- s(S \cap T)=15+19-12=22$

Örnek Yanıt 2:



3+12+7 =22

Kısmi doğru: (1 puan)

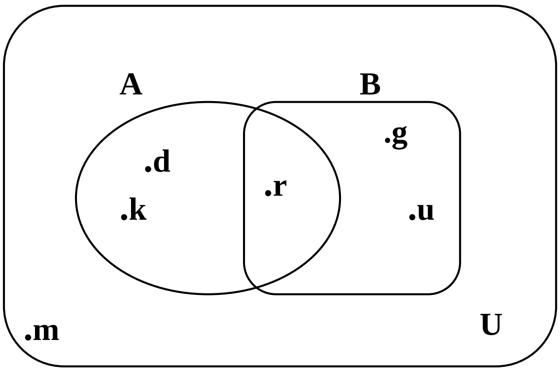
Çözüme yönelik doğru bir başlangıç yapılması ve problemin anlaşıldığının gösterilmesi fakat çözümün eksik bırakılması ya da yanlış olarak devam ettirilmesi

Yanlış Yanıt: (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

****** 4. ve 5. soruları aşağıdaki venn şemasını kullanarak cevaplayınız.**

4) Evrensel kümeyi listeleme yöntemini kullanarak yazınız.



U= {m,d,k,r,g,u}

Tam doğru: (2 puan)

Evrensel kümeyi listeleme yöntemiyle ifade eden tüm cevaplar

Kısmi doğru: (1 puan)

Evrensel kümeyi listeleme yöntemiyle ifade eden fakat eksik ya da yanlış elemanların bulunduğu tüm cevaplar

Yanlış Yanıt: (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

5) $A \cap B$ kümesinin elemanlarını listeleyiniz.

$A \cap B=\{r\}$

Tam doğru: (2 puan)

$A \cap B$ kümesinin elemanlarını liste yöntemiyle eksiksiz ifade eden yanıtlar

Yanlış Yanıt: (0 puan)

Tam doğru dışındaki tüm yanıtlar

6) Aşağıdaki işlemleri yapınız.

a) $\frac{2}{3}+\frac{4}{5}=?$ **b)** $\frac{2}{9}x\frac{5}{3}=?$ **c)** $\frac{3}{7}+\frac{4}{7}=?$

a) $\frac{10+12}{15}=\frac{22}{15}$ b) $\frac{10}{27}$ c) $\frac{7}{7}=1$

Tam doğru: (2 puan)

Verilen sorunun cevabını bulmaya yönelik olarak yapılmış eksiksiz ve doğru tüm cevaplar

Kısmi doğru: (1 puan)

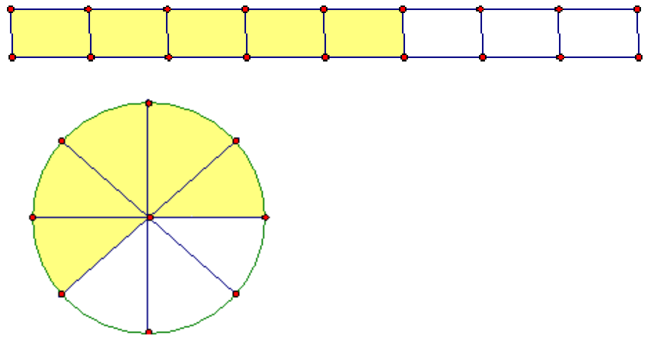
Yalnız a ve c şıklarının aynı anda doğru olduğu cevaplar;

a ve b şıklarının veya b ve c şıklarının aynı anda ya da sadece b şıkkının doğru olduğu cevaplar

Yanlış Yanıt: (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

7) $\frac{5}{8}$ kesrini şekil çizerek gösteriniz.



Tam doğru: (2 puan)

Verilen şeklin $\frac{5}{8}$ sini gösteren tüm gösterimler

Kısmi doğru: (1 puan)

Verilen şekildeki bütünün sekiz parçaya ayrıldıktan sonra bunun beş parçasının taranması gerektiğini ifade etmesi fakat herhangi bir tarama yapmaması yada yanlış tarama yapması

Yanlış Yanıt: (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

8) Aşağıdaki rasyonel sayıları küçükten büyüğe doğru sıralayınız.

b) $\frac{11}{7}, \frac{2}{7}, \frac{5}{7}, \frac{13}{7}, \frac{15}{7}$ **b)** $\frac{5}{12}, \frac{3}{4}, \frac{1}{24}, \frac{7}{16}$

a) $\frac{2}{7}, \frac{5}{7}, \frac{11}{7}, \frac{13}{7}, \frac{15}{7}$ **b)** $\frac{1}{24}, \frac{5}{12}, \frac{7}{16}, \frac{3}{4}$

<u>Tam doğru:</u> (2 puan)

Verilen kesirleri doğru şekilde küçükten büyüğe sıralamaya yönelik tüm cevaplar

<u>Kısmi doğru:</u> (1 puan)

- Verilen kesirleri doğru sıralamaya yönelik girişimlerde bulunmak
- b şıkkı için sıralamada pay veya paydanın eşitlenmesinin gerektiğine yönelik anlayış gösterme ancak pay yada payda eşitlemesi sırasında oluşan yanlış işlem dolayısıyla yanlış veya eksik cevap;,
- a ya da b şıklarından birinin eksik ya da yanlış olması

<u>Yanlış Yanıt:</u> (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

9) Aşağıdaki ifadeleri tamamlayınız.

c) Bir kesir sayısında bütünün kaç eşit parçaya bölündüğünü gösteren sayı…….olarak adlandırılır.

d) Bir kesir sayısında bütünün eş parçalarından kaç tanesinin alındığını gösteren sayı…….olarak adlandırılır.

<u>Tam doğru:</u> (2 puan)

A şıkkında payda ve b şıkkında pay cevaplarının verilmesi

<u>Kısmi doğru:</u> (1 puan)

A ya da b şıkklarından birinin yanlış olması ya da boş bırakılması

<u>Yanlış Yanıt:</u> (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

10) Aşağıdaki işlemlerin sonucunu hesaplayınız.

b) 0.5 + 0.1 + 0.7 =? b) 0.1 + 0.3 - 0.8 =? c) - 0.3 - 0.5 - 0.9 = ?

a) 1.3

b) -0.4

c) -1.7

<u>Tam doğru:</u> (2 puan)

Şıkların hepsinde işlemlerin doğru ve eksiksiz yapılmış olması

<u>Kısmi doğru:</u> (1 puan)

Şıklardan en fazla ikisinin yanlış ya da boş olması

<u>Yanlış Yanıt:</u> (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

11) Bir yarışmaya katılan 10 öğrenciden; 1. , 2. ve 3. olanlar kaç farklı şekilde oluşabilir?

10.9.8=720

<u>Tam doğru:</u> (2 puan)

Çözüme yönelik doğru bir başlangıç yapılması,problemin anlaşıldığını gösterilmesi ve eksiksiz ve doğru sonuca ulaşılması

<u>Kısmi doğru:</u> (1 puan)

Çözüme yönelik doğru bir başlangıç yapılması ve problemin anlaşıldığının gösterilmesi fakat çözümün eksik bırakılması yada yanlış olarak devam ettirilmesi

<u>Yanlış Yanıt:</u> (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

12) Aşağıdaki işlemleri yapınız.

a) $\frac{3!.4!}{2!.6} = ?$ **b)** $\frac{12!}{10!} = ?$ **c)** $\frac{5!+4!}{5!-4!} = ?$

a) $\frac{3!.4!}{2!.6} = \frac{3.4.3.2}{6} = 12$ **b)** $\frac{12!}{10!} = 11.12 = 132$

c) $\frac{5!+4!}{5!-4!} = \frac{4!(5+1)}{4!(5-1)} = \frac{6}{4} = 3/2$

Tam doğru: (2 puan)

Şıkların hepsinde işlemlerin doğru ve eksiksiz yapılmış olması

Kısmi doğru: (1 puan)

İşlemler sırasında yapılan işlem hatalarından dolayı yanlış sonuca ulaşılması ya da şıklardan en fazla ikisinin yanlış ya da boş olması

Yanlış Yanıt: (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

13) KİTAP kelimesinin harflerini kullanarak; anlamlı ya da anlamsız, harfleri farklı ve dört harfli kaç değişik kelime türetebiliriz?

5.4.3.2=120

Tam doğru: (2 puan)

Çözüme yönelik doğru bir başlangıç yapılması,problemin anlaşıldığını gösterilmesi ve eksiksiz ve doğru sonuca ulaşılması

Kısmi doğru: (1 puan)

Çözüme yönelik doğru bir başlangıç yapılması ve problemin anlaşıldığının gösterilmesi fakat çözümün eksik bırakılması yada yanlış olarak devam ettirilmesi

Yanlış Yanıt: (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

14) Matematik öğretmeni sınavda 10 soru sormuştur. Fakat öğrencilerden istedikleri 5 soruyu cevaplamalarını istemiştir. Bir öğrenci cevaplandıracağı 5 soruyu kaç farklı şekilde seçebilir?

$$\binom{10}{5} = \frac{10.9.8.7.6}{5.4.3.2} = 252$$

Tam doğru: (2 puan)

Çözüme yönelik doğru bir başlangıç yapılması,problemin anlaşıldığını gösterilmesi ve eksiksiz ve doğru sonuca ulaşılması

Kısmi doğru: (1 puan)

Çözüme yönelik doğru bir başlangıç yapılması ve problemin anlaşıldığının gösterilmesi fakat çözümün eksik bırakılması yada yanlış olarak devam ettirilmesi

Yanlış Yanıt: (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

15) Ahmet ve Ali'nin de aralarında bulunduğu 7 kişilik grup arasından, aralarında Ahmet'in bulunmadığı ve Ali'nin bulunduğu 4 kişilik bir grup kaç farklı şekilde seçilebilir?

$$\binom{5}{3} = \frac{5.4.3}{3.2} = 10$$

Tam doğru: (2 puan)

Çözüme yönelik doğru bir başlangıç yapılması,problemin anlaşıldığını gösterilmesi ve eksiksiz ve doğru sonuca ulaşılması

Kısmi doğru: (1 puan)

Çözüme yönelik doğru bir başlangıç yapılması ve problemin anlaşıldığının gösterilmesi fakat çözümün eksik bırakılması yada yanlış olarak devam ettirilmesi

Yanlış Yanıt: (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

APPENDIX H

TABLE OF SPECIFICATION FOR THE PROBABILITY ACHIEVEMENT TEST

Alt Öğrenme Alanı	Deney, çıktı, örnek uzay, örnek nokta, olay, kesin olay, imkânsız olay kavramlarını açıklar.	Bir basit olayın olasılığını hesaplar.	Bağımlı ve bağımsız olayların olasılığını hesaplar.	Koşullu olasılığı açıklar ve hesaplar.	Ayrık ve ayrık olmayan olayların olasılığını hesaplar.	Olay çeşitlerini açıklar.	Olasılık değerinin 0 ve 1 arasında değer alacağını anlar.
Temel Olasılık Kavramları	1, 2, 3, 4, 8, 18, 20, 22						19, 21
Olay Çeşitleri						17i, 17ii, 17iii, 17iv, 17v	
Olasılık Hesabı		5, 9, 14	6, 10, 12	23	7, 11, 13, 15, 16		

APPENDIX I

PROBABILITY ACHIEVEMENT TEST

Yönerge: Testte toplam **23** soru vardır. Soruları dikkatlice okuyunuz ve **cevap kağıdında *uygun* yere** çözünüz.

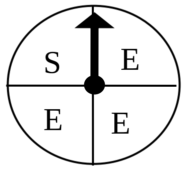
Başarılar!

==

1. "**DÜNYA**" kelimesinden bir harf rastgele seçilmiştir. Bu deneyin mümkün olan bütün çıktılarını listeleyiniz.
2. "**UZAY**" kelimesinden bir harf rastgele seçilmiştir. Sesli harfleri seçme olayının mümkün olan bütün çıktılarını listeleyiniz.
3. "**OLASILIK**" kelimesinden bir harf rastgele seçilmiştir. Bu deneyin mümkün olan toplam çıktı sayısı nedir?
4. Elinizde bir çark ve hilesiz bir bozuk para var. Çark eşit olarak iki parçaya ayrılmıştır. Bu parçalar **r** ve **g** olarak isimlendirilmiştir. Çarkı çevirdiğinizi ve bozuk parayı havaya attığınızı varsayarak aşağıdaki ağaç şemasını tamamlayınız. (**Not:** Y: Yazı, T: Tura).

ÇARK	**PARA**	**ÇIKTILAR**
	…T...	...r T...
r	....	....
	....	....
g	....	....

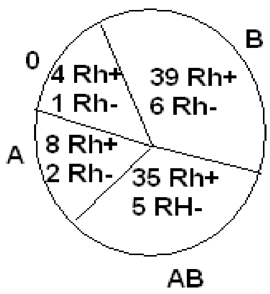
5. Bir çark yanda görüldüğü gibi dört eşit parçaya ayrılmıştır.



Ok çevrildiğinde **E** harfinde durma olasılığı nedir?

6. Kulüp üyelerinin her birinin ismi farklı kağıt parçalarına yazılarak bir torbanın içine konulmuştur. Bu isimler şunlardır: Kerem, Ebru, Murat, Oya ve Meral. Bir kağıt çekildikten sonra tekrar torbaya atılarak ikinci kağıt çekilmiştir. Sırasıyla Murat ve Ebru isimlerini çekme olasılığı nedir?

7. Yandaki şekil **100** kişinin kan grupları ile birlikte Rh çeşitlerini göstermektedir. Bu 100 kişiden rastgele seçilecek olan bir kişinin **AB** grubundan **veya Rh-** olma olasılığı nedir?



8. Bir komite **3 erkek** ve **2 kadından** oluşmaktadır. Komite üyeleri arasından bir başkan rastgele seçilecektir. Kadın bir başkan seçilmesi olayının çıkan sayısı kaçtır?

9. 1997 yılında trafik muayenesinden geçen **630.000** otomobilden **20.300** tanesinin farlarının bozuk olduğu kayıda geçmiştir. Bu arabalar arasından farları bozuk olan bir arabayı rastgele seçme olasılığı nedir?

10. Bir araştırma laboratuvarında **35** tane elektrikli alet üretilmiştir. Bunlardan **4** tanesi bozuktur. Onur, bu elektrikli aletlerden bir tanesini rastgele seçip test ettikten sonra Tuğba, yanlışlıkla bu aleti Onur görmeden tekrar rastegele bu aletler arasına koymuştur. Onur, ikinci kez bu aletler arasından rastgele birini seçerek test etmiştir. Seçilen her iki aletin bozuk olma olasılığı nedir?

11. Ankarada, **sarışın** birini rastgele seçme olasılığı **0.4**, **sarışın ve yeşil gözlü** seçme olasılığı **0.2**, **yeşil gözlü** seçme olasılığı **0.3**'tür. **Sarışın veya yeşil gözlü** birini rastgele seçme olasılığı nedir?

12. Emel'in bir matematik problemini çözme olasılığı **1/3**, Cansu'nun çözme olasılığı **1/5**'dir. Problemin hem Emel hem de Cansu tarafından çözülme olasılığı nedir?

13. Semra'nın kitaplığında 8 tane roman, 4 tane matematik, 3 tane kimya ve 2 tane biyoloji kitabı vardır. Semra kitaplığından rastgele bir kitap seçmek istiyor. Seçeceği kitabın **roman veya matematik** kitabı olma olasılığı nedir?

14. Aynı zayıflama yöntemini kullanarak zayıflamak isteyen bayanlar arasından **16** tanesi kilo kaybetmiş, **4** tanesi kilo almış, **2** tanesi ise aynen kalmıştır. Bu kişilerden biri rastgele seçildiğinde, bu kişinin **kilo kaybeden bayan** olma olasılığı nedir?

15. Aşağıdaki çizelge öğrencilerin aldıkları notlara göre dağılımını göstermektedir.

Not	1	2	3	4	5
Öğrenci Sayısı	4	8	9	7	2

4 'ten düşük veya 3'ten yüksek not alan bir öğrenciyi seçme olasılığı nedir?

16. Bir yarışmada Erkut'un kazanma olasılığı **1/3** ve Suat'ın kazanma olasılığı ise **1/7'**dir. Erkut'un veya Suat'ın bu yarışı kazanma olasılığı nedir? (**Not:** Erkut ve Suat aynı anda kazanamaz.)

17. Yönerge: Aşağıda verilen her bir olayın çeşitlerini belirleyeceksiniz. (Not: Olay çeşitleri (bağımsız, bağımlı, ayrık, ayrık olmayan, kesin, imkansız) bir ya da birden fazla kullanıldığı gibi hiç de kullanılmayabilir.)

i) Gelecek yıl 29 Ekimde Cumhuriyet Bayramı olacaktır.

ii) Bir fabrikada yılda 1 milyon televizyon üretilmektedir. Bunların 5000 tanesinin arızalı olduğunu varsayınız. Test etmek için bu üretilen televizyonlardan biri seçilmiş ve test edildikten sonra tekrar rastgele televizyonlar arasına konulmuştur. Bu işlemden sonra tekrar rastgele televizyonlardan biri seçilip test edilmiştir.

iii) Bir kişi, içinde "w" harfi olan bir ayda doğmuştur.

iv) Bir araştırmada 3 yaşında bir çocuk ya da ilkokul 5. sınıf öğrencisi olan bir çocuk seçilmek isteniyor.

v) Bir bilgisayar programı 1 ve 5 arasındaki rakamları kullanarak, seçtiği rakamı tekrar seçmeden iki basamaklı sayılar üretmektedir.

********* YÖNERGE: 18. - 20. soruları okuyunuz. Evet veya hayır olarak cevaplarken nedenlerini de yazınız.** ************

18. Torbaya **5 pembe(p), 4 yeşil (y) ve 2 mavi (m)** top konulmuştur. Torbaya bakmadan 4 tane top aynı anda çekilmektedir. {m, m, p, y, y} bu deneyin bir olayı olabilir mi? Neden?

19. **5/3** bir olayın olma olasılığı olabilir mi? Neden?

20. 11 tane kart şu şekilde numaralandırılmıştır: 1, 2, 4, 6, 7, 8, 9, 12, 14, 15, ve 20. Bunlar bir kutuya konulmuştur. Bunlardan 4 tanesi aynı zamanda kutuya bakılmaksızın çekilmiştir. {7'nin karesi} bu deneyin bir örnek noktası olabilir mi? **Neden?**

********** YÖNERGE: 21. - 22. sorulardaki cümleleri dikkatli okuyunuz ve boşlukları uygun bir şekilde doldurunuz**. *********

21. Olasılık değerleri .... ve .... arasında değişmektedir.

22. **2/9** olasılık oranında, "**2**" .... sayısıdır.

23. 25 kişilik bir sınıfta tenis oynayanlar 12 kişi, voleybol oynayanlar 16 kişi, her ikisini de oynayanlar 9 kişidir. Bu sınıftan rastgele seçilen bir kişinin voleybol oynadığı bilindiğine gore, bu kişinin tenisde oynayan biri olma olasılığı kaçtır?

APPENDIX J

SCORING RUBRIC FOR THE PROBABILIY ACHIEVEMENT TEST

1) "**DÜNYA**" kelimesinden bir harf rastgele seçilmiştir. Bu deneyin mümkün olan bütün çıktılarını listeleyiniz.

E= {D,Ü,N,Y,A}

<u>Tam doğru:</u> (2 puan)

Deneyin çıktılarını doğru bir şekilde listeleyen tüm yanıtlar

<u>Kısmi doğru:</u> (1 puan)

Deneyin çıktılarını listeleyen ancak eksik ya da yanlış çıktı içeren yanıtlar

<u>Yanlış Yanıt:</u> (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

2) "**UZAY**" kelimesinden bir harf rastgele seçilmiştir. Sesli harfleri seçme olayının mümkün olan bütün çıktılarını listeleyiniz.

Sesli harf seçme olayı S olsun.

S= {U, A}

<u>Tam doğru:</u> (2 puan)

Sesli harf seçme olayının bütün çıktılarını eksiksiz listeleyen tüm yanıtlar

<u>Yanlış Yanıt:</u> (0 puan)

Tam doğru dışındaki tüm yanıtlar

3) “**OLASILIK**” kelimesinden bir harf rastgele seçilmiştir. Bu deneyin mümkün olan toplam çıktı sayısı nedir?

OLASILIK kelimesinden bir harf seçme olayından mümkün olan bütün çıktılar O,L,A,S,I,L,I,K harfleri olduğu için mümkün olan bütün çıktıların sayısı 8 dir.

Tam doğru: (2 puan)

Deneyin çıktı sayısını doğru ifade eden tüm yanıtlar

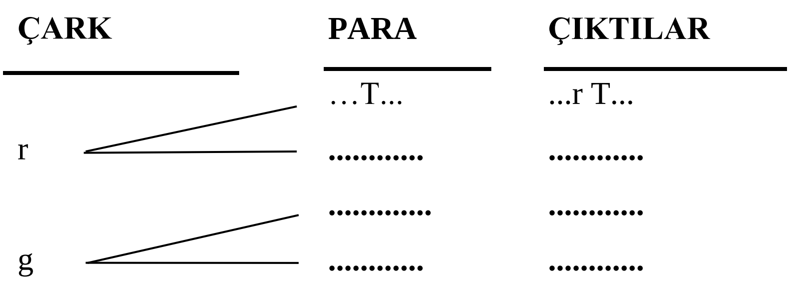
Kısmi doğru: (1 puan)

Deneyin çıktılarını doğru bir şekilde ifade eden ancak çıktı sayısını yanlış veren yanıtlar

Yanlış Yanıt: (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

4) Elinizde bir çark ve hilesiz bir bozuk para var. Çark eşit olarak iki parçaya ayrılmıştır. Bu parçalar **r** ve **g** olarak isimlendirilmiştir. Çarkı çevirdiğinizi ve bozuk parayı havaya attığınızı varsayarak aşağıdaki ağaç şemasını tamamlayınız. (**Not:** Y:Yazı, T:Tura).



Çıktılar sırasıyla rT, rY, gT,gY dır.

Tam doğru: (2 puan)

Çıktıları eksiksiz ifade eden tüm yanıtlar

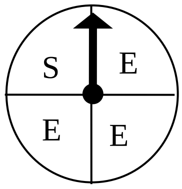
Kısmi doğru: (1 puan)

Çıktılardan ikisini doğru ifade eden tüm yanıtlar

Yanlış Yanıt: (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

5) Bir çark yanda görüldüğü gibi dört eşit parçaya ayrılmıştır. oku çevirildiğinde **E** harfinde durma olasılığı nedir?



P(E)= istenen olayın çıktı sayısı / Mümkün olan tüm çıktıların sayısı = 3/4

Tam doğru: (2 puan)

Olayın olasılığını eksiksiz hesaplayan tüm yanıtlar

Kısmi doğru: (1 puan)

Olayın olasılığını istenen olayın çıktı sayısı / Mümkün olan tüm çıktıların sayısı olarak ifade eden ancak sayı yanlışlıkları dolayısıyla doğru sonuca ulaşamayan tüm yanıtlar

Yanlış Yanıt: (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

6) Kulüp üyelerinin her birinin ismi farklı kağıt parçalarına yazılarak bir torbanın içine konulmuştur. Bu isimler şunlardır: Kerem, Ebru, Murat, Oya ve Meral. Bir kağıt çekildikten sonra tekrar torbaya atılarak ikinci kağıt çekilmiştir. Sırasıyle Murat ve Ebru isimlerini çekme olasılığı nedir?

Murat isminin çekilme olasılığı = istenen olayın çıktı sayısı / Mümkün olan tüm çıktıların sayısı = 1/5

Ebru isminin çekilme olasılığı = istenen olayın çıktı sayısı / Mümkün olan tüm çıktıların sayısı= 1/5

Murat ve Ebru isimlerinin çekilme olasılığı = 1/5 x1/5 = 1/25

Tam doğru: (2 puan)

- Olayın olasılığını eksiksiz hesaplayan tüm yanıtlar
- Çözüme yönelik doğru bir başlangıç yapılan ve ilerleyen ancak işlemsel yanlışlıklardan dolayı doğru sonuca ulaşamayan yanıtlar.Bu tür yanıtlar problemin anlaşılmasına yönelik ya da çözüm stratejisinin nasıl

uygulanacağına yönelik yanlış anlamaları içermeyen sadece küçük hesaplama hatalarını içeren yanıtlardır.

<u>Kısmi doğru:</u> (1 puan)

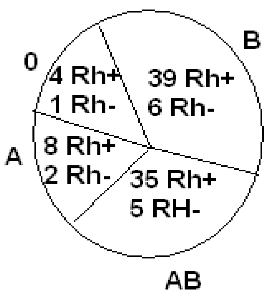
- Murat ismini çekme olasılığını ve Ebru ismini çekme olasılıklarını ayrı ayrı doğru hesaplayan ancak sırasıyla Murat ve Ebru isimlerini çekme olasılıklarını hesaplamayan veya yanlış hesaplayan yanıtlar
- Doğru sonucun yazıldığı, ancak

1) Sonuca yönelik yapılan işlemlerin anlaşılmadığı veya
2) Herhangibir çalışmanın/açıklamanın yapılmadığı yanıtlar

<u>Yanlış Yanıt:</u> (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

7) Yandaki şekil **100** kişinin kan grupları ile birlikte Rh çeşitlerini göstermektedir. Bu 100 kişiden rastgele seçilecek olan bir kişinin **AB** grubundan **veya Rh-** olma olasılığı nedir?



P(AB veya Rh-) = P(AB) + P(Rh-) –P(AB ve Rh-)

= 40/100 + 14/100- 5/100

= 49/ 100

<u>Tam doğru:</u> (2 puan)

- Olayın olasılığını eksiksiz hesaplayan tüm yanıtlar
- Çözüme yönelik doğru bir başlangıç yapılan ve ilerleyen ancak işlemsel yanlışlıklardan dolayı doğru sonuca ulaşamayan yanıtlar.Bu tür yanıtlar problemin anlaşılmasına yönelik ya da çözüm stratejisinin nasıl uygulanacağına yönelik yanlış anlamaları içermeyen sadece küçük hesaplama hatalarını içeren yanıtlardır.

<u>Kısmi doğru:</u> (1 puan)

- Kişinin (AB) grubundan olma, (Rh-) olma ve (AB ve Rh-) grubundan olma olasılıklarından en az ikisini ayrı ayrı hesaplayan ancak AB grubundan veya Rh- olma olasılığını hesaplamayan, ya da yanlış hesaplayan yanıtlar

- P(AB veya Rh-) = P(AB) + P(Rh-) –P(AB ve Rh-) formülünün doğru yazıldığı ancak ilerlemeyen veya yanlış ilerleyen yanıtlar
- Doğru sonucun yazıldığı, ancak

1) Sonuca yönelik yapılan işlemlerin anlaşılmadığı veya
2) Herhangibir çalışmanın/açıklamanın yapılmadığı yanıtlar

Yanlış Yanıt: (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

8) Bir komite **3 erkek** ve **2 kadından** oluşmaktadır. Komite üyeleri arasından bir başkan rastgele seçilecektir. Kadın bir başkan seçilmesi olayının çıktı sayısı kaçtır?

Kadın bir başkan seçilmesi olayının çıktı sayısı komitede 2 tane kadın olduğu için 2 dir.

Tam doğru: (2 puan)

Kadın bir başkan seçilmesi olayının çıktı sayısının komitede 2 tane kadın olduğu için 2 olduğunu ifade eden cevaplar

Yanlış Yanıt: (0 puan)

Tam doğru dışındaki tüm yanıtlar

9) 1997 yılında trafik muayenesinden geçen **630.000** otomobilden **20.300** tanesinin farlarının bozuk olduğu kayıda geçmiştir. Bu arabalar arasından farları bozuk olan bir arabayı rastgele seçme olasılığı nedir?

P(B)= istenen olayın çıktı sayısı / Mümkün olan tüm çıktıların sayısı

= 20.300 / 630.000 = 29/90

Tam doğru: (2 puan)

Olayın olasılığını eksiksiz hesaplayan tüm yanıtlar

Kısmi doğru: (1 puan)

Olayın olasılığını istenen olayın çıktı sayısı / Mümkün olan tüm çıktıların sayısı olarak ifade eden ancak ilerlemeyen veya yanlış ilerlediği için doğru sonuca ulaşamayan tüm yanıtlar

Yanlış Yanıt: (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

10) Bir araştırma laboratuvarında **35** tane elektrikli alet üretilmiştir. Bunlardan **4** tanesi bozuktur. Onur, bu elektrikli aletlerden bir tanesini rastgele seçip test ettikten sonra Tuğba, yanlışlıkla bu aleti Onur görmeden tekrar rastegele bu aletler arasına koymuştur. Onur, ikinci kez bu aletler arasından rastgele birini seçerek test etmiştir. Seçilen her iki aletin bozuk olma olasılığı nedir?

1. aleti ve 2. aleti seçme olayları bağımsız olaylar

1. **Bozuk olması x 2. Bozuk olması= herikisininde bozuk olması**
   = 4 /35 x 4/35 = 16/1225

Tam doğru: (2 puan)

- Olayın olasılığını eksiksiz hesaplayan tüm yanıtlar
- Çözüme yönelik doğru bir başlangıç yapılan ve ilerleyen ancak işlemsel yanlışlıklardan dolayı doğru sonuca ulaşamayan yanıtlar.Bu tür yanıtlar problemin anlaşılmasına yönelik ya da çözüm stratejisinin nasıl uygulanacağına yönelik yanlış anlamaları içermeyen sadece küçük hesaplama hatalarını içeren yanıtlardır.

Kısmi doğru: (1 puan)

- İki aletin bozuk olma olasılıklarını ayrı ayrı doğru hesaplayan ancak her iki aletin bozuk olma olasılığını hesaplamayan, veya yanlış hesaplayan yanıtlar
- Doğru sonucun yazıldığı, ancak

1) Sonuca yönelik yapılan işlemlerin anlaşılmadığı veya
2) Herhangibir çalışmanın/açıklamanın yapılmadığı yanıtlar

Yanlış Yanıt: (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

11) Ankarada, **sarışın** birini rastgele seçme olasılığı **0.4**, **sarışın ve yeşil gözlü** seçme olasılığı **0.2**, **yeşil gözlü** seçme olasılığı **0.3**'tür. **Sarışın veya yeşil gözlü** birini rastgele seçme olasılığı nedir?

P(sarışın veya yeşil Gözlü) = P (sarışın) + P(yeşil gözlü) – P(sarışın ve yeşil gözlü)

= 0.4 + 0.3 – 0.2 = 0.5

Tam doğru: (2 puan)

- Olayın olasılığını eksiksiz hesaplayan tüm yanıtlar
- Çözüme yönelik doğru bir başlangıç yapılan ve ilerleyen ancak işlemsel yanlışlıklardan dolayı doğru sonuca ulaşamayan yanıtlar.Bu tür yanıtlar problemin anlaşılmasına yönelik ya da çözüm stratejisinin nasıl uygulanacağına yönelik yanlış anlamaları içermeyen sadece küçük hesaplama hatalarını içeren yanıtlardır.

Kısmi doğru: (1 puan)

- P(sarışın veya yeşil gözlü) = P (sarışın) + P(yeşil gözlü) – P(sarışın ve yeşil gözlü) formülünün doğru yazıldığı ancak ilerlemeyen veya yanlış ilerleyen yanıtlar
- Doğru sonucun yazıldığı, ancak

1) Sonuca yönelik yapılan işlemlerin anlaşılmadığı veya
2) Herhangibir çalışmanın/açıklamanın yapılmadığı yanıtlar

Yanlış Yanıt: (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

12) Emel'in bir matematik problemini çözme olasılığı **1/3**, Cansu'nun çözme olasılığı **1/5**'dir. Problemin hem Emel hem de Cansu tarafından çözülme olasılığı nedir?

P(Emel ve Cansu)= P(Emel) x p(Cansu) = 1/3x1/5 = 1/15

Tam doğru: (2 puan)

- Olayın olasılığını eksiksiz hesaplayan tüm yanıtlar
- Çözüme yönelik doğru bir başlangıç yapılan ve ilerleyen ancak işlemsel yanlışlıklardan dolayı doğru sonuca ulaşamayan yanıtlar.Bu tür yanıtlar problemin anlaşılmasına yönelik ya da çözüm stratejisinin nasıl uygulanacağına yönelik yanlış anlamaları içermeyen sadece küçük hesaplama hatalarını içeren yanıtlardır

Kısmi doğru: (1 puan)

- P(Emel ve Cansu)= P(Emel) x p(Cansu) formülünün doğru yazıldığı ancak ilerlemeyen veya yanlış ilerleyen yanıtlar
- Doğru sonucun yazıldığı, ancak

1) Sonuca yönelik yapılan işlemlerin anlaşılmadığı veya
2) Herhangibir çalışmanın/açıklamanın yapılmadığı yanıtlar

Yanlış Yanıt: (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

13) Semra'nın kitaplığında 8 tane roman, 4 tane matematik, 3 tane kimya ve 2 tane biyoloji kitabı vardır. Semra kitaplığından rastgele bir kitap seçmek istiyor. Seçeceği kitabın **roman veya matematik** kitabı olma olasılığı nedir?

P(roman veya matematik) = p(roman)+ P(matematik)

= 8/17+ 4/17 = 12/17

Tam doğru: (2 puan)

- Olayın olasılığını eksiksiz hesaplayan tüm yanıtlar
- Çözüme yönelik doğru bir başlangıç yapılan ve ilerleyen ancak işlemsel yanlışlıklardan dolayı doğru sonuca ulaşamayan yanıtlar.Bu tür yanıtlar problemin anlaşılmasına yönelik ya da çözüm stratejisinin nasıl uygulanacağına yönelik yanlış anlamaları içermeyen sadece küçük hesaplama hatalarını içeren yanıtlardır.

Kısmi doğru: (1 puan)

- Seçilen kitabın roman olma olasılığını ve matematik kitabı olma olasılıklarını ayrı ayrı doğru hesaplayan ancak roman veya matematik kitabı olma olasılığını hesaplamayan veya yanlış hesaplayan yanıtlar
- P(roman veya matematik) = p(roman)+ P(matematik)- p(roman ve matematik) formülünün doğru yazıldığı ancak ilerlemeyen veya yanlış ilerleyen yanıtlar
- Doğru sonucun yazıldığı, ancak

1) Sonuca yönelik yapılan işlemlerin anlaşılmadığı veya
2) Herhangibir çalışmanın/açıklamanın yapılmadığı yanıtlar

Yanlış Yanıt: (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

14) Aynı zayıflama yöntemini kullanarak zayıflamak isteyen bayanlar arasından **16** tanesi kilo kaybetmiş, **4** tanesi kilo almış, **2** tanesi ise aynen kalmıştır. Bu kişilerden biri rastgele seçildiğinde, bu kişinin **kilo kaybeden bayan** olma olasılığı nedir?

P(Kilo Kaybeden)= istenen olayın çıktı sayısı / Mümkün olan tüm çıktıların sayısı

= 16/22= 8/11

Tam doğru: (2 puan)

Olayın olasılığını eksiksiz hesaplayan tüm yanıtlar

Kısmi doğru: (1 puan)

- Olayın olasılığını istenen olayın çıktı sayısı / Mümkün olan tüm çıktıların sayısı olarak ifade eden ancak ancak ilerlemeyen veya yanlış ilerleyen yanıtlar

Yanlış Yanıt: (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

15) Aşağıdaki çizelge öğrencilerin aldıkları notlara göre dağılımını göstermektedir.

Not	1	2	3	4	5
Öğrenci Sayısı	4	8	9	7	2

4 'ten düşük veya 3'ten yüksek not alan bir öğrenciyi seçme olasılığı nedir?

P(4 'ten düşük veya 3'ten yüksek) = p(4 'ten düşük) + P(3'ten yüksek)

= 21/30 + 9/30= 30/30 = 1

Tam doğru: (2 puan)

- Olayın olasılığını eksiksiz hesaplayan tüm yanıtlar
- Çözüme yönelik doğru bir başlangıç yapılan ve ilerleyen ancak işlemsel yanlışlıklardan dolayı doğru sonuca ulaşamayan yanıtlar.Bu tür yanıtlar problemin anlaşılmasına yönelik ya da çözüm stratejisinin nasıl uygulanacağına yönelik yanlış anlamaları içermeyen sadece küçük hesaplama hatalarını içeren yanıtlardır.

Kısmi doğru: (1 puan)

- Seçilen öğrencinin 4 'ten düşük not alan bir öğrenci olma olasılığını ve 3'ten yüksek not alan bir öğrenci olma olasılıklarını ayrı ayrı doğru hesaplayan ancak 4 'ten düşük veya 3'ten yüksek not alan bir öğrenci olma olasılığını hesaplamayan ya da yanlış hesaplayan yanıtlar
- Doğru sonucun yazıldığı, ancak

1) Sonuca yönelik yapılan işlemlerin anlaşılmadığı veya
2) Herhangibir çalışmanın/açıklamanın yapılmadığı yanıtlar

Yanlış Yanıt: (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

16) Bir yarışmada Erkut'un kazanma olasılığı **1/3** ve Suat'ın kazanma olasılığı ise **1/7'**dir. Erkut'un veya Suat'ın bu yarışı kazanma olasılığı nedir? (**Not:** Erkut ve Suat aynı anda kazanamaz.)

P(E veya S) = P(E) + P(S)

= 1/3 + 1/7 = 10/21

<u>Tam doğru:</u> (2 puan)

- Olayın olasılığını eksiksiz hesaplayan tüm yanıtlar
- Çözüme yönelik doğru bir başlangıç yapılan ve ilerleyen ancak işlemsel yanlışlıklardan dolayı doğru sonuca ulaşamayan yanıtlar.Bu tür yanıtlar problemin anlaşılmasına yönelik ya da çözüm stratejisinin nasıl uygulanacağına yönelik yanlış anlamaları içermeyen sadece küçük hesaplama hatalarını içeren yanıtlardır.

<u>Kısmi doğru:</u> (1 puan)

- P(E veya S) = P(E) + P(S) formülünün doğru yazıldığı ancak ilerlemeyen veya yanlış ilerleyen yanıtlar
- Doğru sonucun yazıldığı, ancak

1) Sonuca yönelik yapılan işlemlerin anlaşılmadığı veya
2) Herhangibir çalışmanın/açıklamanın yapılmadığı yanıtlar

<u>Yanlış Yanıt:</u> (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

17) Yönerge: Aşağıda verilen her bir olayın çeşitlerini belirleyeceksiniz. (Not: Olay çeşitleri (bağımsız, bağımlı, ayrık, ayrık olmayan, kesin, imkansız) bir ya da birden fazla kullanıldığı gibi hiç de kullanılmayabilir.)

i) Gelecek yıl 29 Ekimde Cumhuriyet Bayramı olacaktır.

ii) Bir fabrikada yılda 1 milyon televizyon üretilmektedir. Bunların 5000 tanesinin arızalı olduğunu varsayınız. Test etmek için bu üretilen televizyonlardan biri seçilmiş ve test edildikten sonra tekrar rastgele televizyonlar arasına konulmuştur. Bu işlemden sonra tekrar rastgele televizyonlardan biri seçilip test edilmiştir.

iii) Bir kişi, içinde "w" harfi olan bir ayda doğmuştur.

iv) Bir araştırmada 3 yaşında bir çocuk ya da ilkokul 5. sınıf öğrenci olan bir çocuk seçilmek isteniyor.

vi) Bir bilgisayar programı 1 ve 5 arasındaki rakamları kullanarak, seçtiği rakamı tekrar seçmeden iki basamaklı sayılar üretmektedir.

17-i) Tam doğru: (2 puan) Kesin olay **Yanlış Yanıt:** (0 puan) Tam doğru dışındaki tüm yanıtlar

17-ii) Tam doğru: (2 puan) bağımsız olay **Yanlış Yanıt:** (0 puan) Tam doğru dışındaki tüm yanıtlar

17-iii) Tam doğru: (2 puan) imkansız olay **Yanlış Yanıt:** (0 puan) Tam doğru dışındaki tüm yanıtlar

17-iv) Tam doğru: (2 puan) ayrık olay **Yanlış Yanıt:** (0 puan) Tam doğru dışındaki tüm yanıtlar

17-v) Tam doğru: (2 puan) bağımlı olay **Yanlış Yanıt:** (0 puan) Tam doğru dışındaki tüm yanıtlar

********* YÖNERGE: 18. - 20. soruları okuyunuz. Evet veya hayır olarak cevaplarken nedenlerini de yazınız. **************

18) Torbaya **5 pembe (p), 4 yeşil (y) ve 2 mavi (m)** top konulmuştur. Torbaya bakmadan 4 tane top aynı anda çekilmektedir. {m, m, p, y, y} bu deneyin bir olayı olabilir mi? Neden?

Tam doğru: (2 puan)

Cevabı hayır olarak ifade eden ve nedenini doğru bir şekilde açıklayan tüm yanıtlar

Kısmi doğru: (1 puan)

- Cevabı hayır olarak ifade eden ancak nedenini açıklamayan yanıtlar
- Cevabı hayır olarak ifade eden ancak neden açıklaması anlaşılmayan yanıtlar

Yanlış Yanıt: (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

19) 5/3 bir olayın olma olasılığı olabilir mi? Neden?

Tam doğru: (2 puan)

Cevabı hayır olarak ifade eden ve nedenini doğru bir şekilde açıklayan tüm yanıtlar

Kısmi doğru: (1 puan)

- Cevabı hayır olarak ifade eden ancak nedenini açıklamayan yanıtlar
- Cevabı hayır olarak ifade eden ancak neden açıklaması anlaşılmayan yanıtlar

Yanlış Yanıt: (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

20) 11 tane kart şu şekilde numaralandırılmıştır: 1, 2, 4, 6, 7, 8, 9, 12, 14, 15, ve 20. Bunlar bir kutuya konulmuştur. Bunlardan 4 tanesi aynı zamanda kutuya bakılmaksızın çekilmiştir. {7'nin karesi} bu deneyin bir örnek noktası olabilir mi? **Neden?**

Tam doğru: (2 puan)

Cevabı hayır olarak ifade eden ve nedenini doğru bir şekilde açıklayan tüm yanıtlar

Kısmi doğru: (1 puan)

- Cevabı hayır olarak ifade eden ancak nedenini açıklamayan yanıtlar
- Cevabı hayır olarak ifade eden ancak neden açıklaması anlaşılmayan yanıtlar

Yanlış Yanıt: (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

********YÖNERGE: 21. - 22. sorulardaki cümleleri dikkatli okuyunuz ve boşlukları uygun bir şekilde doldurunuz**. *********

21) Olasılık değerleri ......**0.**..... ve .....**1**..... arasında değişmektedir.

Tam doğru: (2 puan)

Olasılık değerlerinin 0 ve 1 arasında değiştiğini ifade eden yanıtlar

Kısmi doğru: (1 puan)

Olasılık değerlerinin alt ve üst sınırlarından birini doğru ifade eden yanıtlar

Yanlış Yanıt: (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

22) 2/9 olasılık oranında, “**2**” .... sayısıdır.

Tam doğru: (2 puan)

“2” sayısının istenen olayın çıktı sayısı olduğunu ifade eden tüm yanıtlar

Yanlış Yanıt: (0 puan)

Tam doğruların dışındaki tüm yanıtlar

23) 25 kişilik bir sınıfta tenis oynayanlar 12 kişi, voleybol oynayanlar 16 kişi, her ikisini de oynayanlar 9 kişidir. Bu sınıftan rastgele seçilen bir kişinin voleybol oynadığı bilindiğine gore, bu kişinin tenisde oynayan biri olma olasılığı kaçtır?

$\mathbf{P(T \cap V) = 9/25,} \qquad \mathbf{P(V) = 16/25}$

$\mathbf{P(T \backslash V) = P(T \cap V) / P(V) = 9/16}$

Tam doğru: (2 puan)

- Olayın olasılığını eksiksiz hesaplayan tüm yanıtlar
- Çözüme yönelik doğru bir başlangıç yapılan ve ilerleyen ancak işlemsel yanlışlıklardan dolayı doğru sonuca ulaşamayan yanıtlar.Bu tür yanıtlar problemin anlaşılmasına yönelik ya da çözüm stratejisinin nasıl uygulanacağına yönelik yanlış anlamaları içermeyen sadece küçük hesaplama hatalarını içeren yanıtlardır.

Kısmi doğru: (1 puan)

- Kişinin voleybol oynama olasılığını ve hem voleybol hem tenis oynama olasılıklarını ayrı ayrı doğru hesaplayan ancak sonuca ulaşamayan, ya da çözüme devam etmeyen yanıtlar

- $P(T \backslash V) = P(T \cap V) / P(V)$ formülünün doğru yazıldığı ancak ilerlemeyen veya yanlış ilerleyen yanıtlar
- Çözüme yönelik doğru bir başlangıç yapılması ve problemin anlaşıldığının gösterilmesi fakat çözümün eksik bırakılması yada yanlış olarak devam ettirilmesi
- Doğru sonucun yazıldığı, ancak

1) Sonuca yönelik yapılan işlemlerin anlaşılmadığı veya
2) Herhangibir çalışmanın/açıklamanın yapılmadığı yanıtlar

Yanlış Yanıt: (0 puan)

Tam ve kısmi doğruların dışındaki tüm yanıtlar

APPENDIX K

MATHEMATICS ATTITUDE SCALE

AÇIKLAMA: Aşağıda öğrencilerin matematik dersine ilişkin tutum cümleleri ile her cümlenin karşısında "Tamamen Uygundur", "Uygundur", "Kararsızım", "Uygun Değildir" ve "Hiç Uygun Değildir" olmak üzere beş seçenek verilmiştir. Lütfen, cümleleri dikkatle okuduktan sonra her cümle için kendinize uygun olan seçeneklerden birini işaretleyiniz.

	Tamamen Katılıyorum	Katılıyorum	Kararsızım	Katılmıyorum	Hiç Katılmıyorum
1. Matematik sevdiğim bir derstir.					
2. Matematik dersine girerken büyük sıkıntı duyarım.					
3. Matematik dersi olmasa öğrencilik hayatı daha zevkli olur.					
4. Arkadaşlarımla matematik tartışmaktan zevk alırım.					
5. Matematiğe ayrılan ders saatlerinin fazla olmasını dilerim.					
6. Matematik dersi çalışırken canım sıkılır.					
7. Matematik dersi benim için bir angaryadır.					
8. Matematikten hoşlanırım.					

	Tamamen Katılıyorum	Katılıyorum	Kararsızım	Katılmıyorum	Hiç Katılmıyorum
9. Matematik dersinde zaman geçmez.					
10. Matematik dersi sınavından çekinirim.					
11. Matematik benim için ilgi çekicidir.					
12. Matematik bütün dersler içinde en korktuğum derstir.					
13. Yıllarca matematik okusam bıkmam.					
14. Diğer derslere göre matematiği daha çok severek çalışırım.					
15. Matematik beni huzursuz eder.					
16. Matematik beni ürkütür.					
17. Matematik dersi eğlenceli bir derstir.					
18. Matematik dersinde neşe duyarım.					
19. Derslerin içinde en sevimsizi matematiktir.					
20. Çalışma zamanımın çoğu nu matematiğe ayırmak isterim					

APPENDIX L

A SAMPLE LESSON PLAN INCLUDING ACTIVITY SHEETS AND COMPUTER SIMULATIONS

Ders süresi: 2 Ders saati

Kazanım:

Eş olasılı (olumlu) örneklem uzayı açıklar ve bu uzayda verilen bir *A* olayı için $P(A)=\frac{s(A)}{s(E)}$ olduğunu belirtir.

Kavram Yanılgıları:

Eşit Olasılık Yanlılığı Kavram Yanılgısı

Rastgele olayların bütün olası çıktıları eşit olasılığa sahiptir.

(Eşit olasılık durumunun eşit olasılığa sahip olmayan durumlara da aşırı genellenmesi.)

Amaç: Bu dersin amacı öğrencilerin eş olasılı (olumlu) örneklem uzay hakkındaki bilgi ve birikimlerini geliştirmek ve sahip oldukları kavram yanılgılarından arındırmaktır.

Araç-gereç: Etkinlik yaprakları, simülasyonlar

GİRİŞ

Öğretmen bir önceki derste yapılanlarla ilgili tartışmayla derse başlar.

Öğretmen: Önceki ders ne öğrendiniz?

Öğretmen: Bazı öğrenciler muhtemelen bu soruyu basketbol ve masa tenisi etkinliklerine atıfta bulunarak cevaplayacaktır. Daha sonra öğretmen bir tartışma

ortamı yaratmayı amaçlayarak etkinlikte ulaşılan çıkarımları hatırlatacak sorular yöneltecektir. Öğrencilerden cevaplarını aldıktan sonra öğretmen kavramları özetleyecektir.
Bu kısa girişten sonra öğretmen bugünün dersi hakkında öğrencileri bilgilendirecek.

YETERSİZLİK

Sınıftaki her öğrenciye aşağıdaki etkinliğe yönelik etkinlik yaprağını dağıtınız ve yönergede belirtilenleri yapmalarını isteyiniz.

<u>Etkinlik</u>

1) Sınıfınızdaki öğrencilerin (kendi sınıfınızı düşününüz) isimlerinin bir kağıda yazılarak bir torbaya atıldığını düşününüz. Torbadan ismi çekilen kişinin kız olma olasılığı ve erkek olma olasılığı hakkında ne söylersiniz?

Öğrenci cevabı: *Torbadan ismi çekilen kişinin kız olma olasılığı erkek olma olasılığına eşittir.*

Doğru yapılmış:..........,Neden? :
Yanlış Yapılmış:.......... ,Neden? :

2) İki zar atıldığında bu iki zarın üst yüzeyine gelen sayıların toplamının 9 gelme ve 11 gelme olasılıkları arasında nasıl bir ilişki vardır.

Öğrenci cevabı: *Üst yüze gelen sayıların toplamının 9 gelme ve 11 gelme olasılıkları birbirine eşittir.*

Doğru yapılmış:.........., Neden? :
Yanlış Yapılmış:.........., Neden? :

Sınıf Tartışması:

Öğrencilerin sorular üzerinde düşünmelerini sağlayınız. Daha sonra tartışma açarak kimin ne düşündüğünü ve neden öyle düşündüğünü sorunuz. Önemli gördüğünüz noktaları tahtaya yazınız. Karşıt fikirleri savunan grupların kendilerini savunmalarına olanak verin ve ortaya çıkan mantıklı ifadeleri tahtaya yazınız.

Daha sonra öğretmen öğrencilerin mevcut kavramlarıyla ilgili yetersizlik hissetmesi için ilave sorular sorar.

Peki bu sorular için örneklem uzayları belirleseniz, olasılıklar ne olur?

Sınıfınızdaki öğrencilerin oluşturduğu örneklem uzayı ve iki zar atılma deneyinin örneklem uzayını düşünün.

Böylece öğrencilerin mevcut kavramlarından rahatsızlık duymaya başlamaları sağlanır.

ÖĞRETMENE YÖNELİK AÇIKLAMA:

Bu sorularla ilgili kavram yanılgıları:

1.soru: Öğrenci "rastgele olayların bütün olası çıktıları eşit olasılığa sahiptir" çünkü ne olacağını bilemeyiz diye düşünerek ismi çekilen kişinin kız ya da erkek olmasının %50 ihtimale sahip olduğu kavram yanılgısına sahip olabilir.

Sınıf tartışması esnasında bu tür fikirleri ortaya çıkarmaya çalışınız.

Oysa 1. soruda sınıftaki kız öğrenci sayısı erkek öğrenci sayısından fazla olduğu için (14 kız, 16 erkek) ismi çekilen kişinin erkek olma olasılığı daha yüksektir.

2.soru: Öğrenci tek zardaki bütün çıktıların eş olasılı olma varsayımını iki zarın toplamlarının dağılımı gibi her bir farklı çıktının eş olasılı olmadığı durumlara aşırı genellemeye eğilimli olabilir.

Sınıf tartışması esnasında bu tür fikirleri ortaya çıkarmaya çalışınız.

Oysa iki zar probleminde zarın üst yüzüne gelen sayıların toplamının 9 gelme olasılığı 11 gelme olasılığından daha yüksektir çünkü 5ve 4, 4 ve 5, 3 ve 6, 6 ve 3 ile 9 toplamı elde edilirken 11 için sadece 5 ve 6 ile 6 ve 5 ihtimalleri vardır.

ANLAŞILABİLİRLİK

Daha sonra öğretmen 1. ve 2. sorular için olayların örneklem uzayının eş olasılı olduğunu ve eş olasılı örneklem uzayda her bir çıktının meydana gelme olasılığının eşit olduğunu ancak örneklem uzayda aynı çıktıdan birden fazla olması durumunda o çıktıya ait olayın olasılığının değişeceğini açıklar. Ve öğretmen rastgele olayların bütün olası çıktılarının eşit olasılığa sahip olmadığını, örneklem uzayın eş olasılı olma durumunda bile her bir çıktının meydana gelme olasılığının eşit olmasına rağmen örneklem uzayda aynı çıktıdan birden fazla olması durumunda o çıktıya ait olayın olasılığının değişeceğini tekrar vurgular.

Sonra öğretmen eş olasılı örneklem uzayı ve eş olumlu örneklem uzayda olasılık hesaplamayı açıklamaya başlar.

Bir madeni paranın havaya atılması deneyinde üste gelen yüzün yazı (Y) olması ya da tura (T) olması olayların olasılıkları birbirine eşit ve ½ dir
Benzer şekilde, bir zarın havaya atılması deneyinde, zarın üst yüzünde 1, 2, 3, 4, 5 ve 6 sayılarının herbirinin gelme olasılığı birbirine eşit ve 1/6 dır.
Bir madeni paranın veya bir zarın havaya atılması deneylerinde olduğu gibi örneklem noktaların gerçekleşme olasılıkları birbirine eşit ise, bu deneyin örneklem uzayı **eş olumlu (eş olasılı) örneklem uzay**dır.
Her bir örneklem noktasının olasılıkları eşit olan örneklem uzaya, "**eş olumlu (olasılı) örneklem uzay**" denir.

Eş olumlu örnek uzayda, bir A olayının olasılığı, A nın eleman sayısının örneklem uzayın eleman sayısına oranı olarak verilir.

Eş olumlu örneklem uzay $A \subset E$ olsun. Buna göre,

$$P(A)= \frac{s(A)}{s(E)}$$

Bağlantısı ile gösterilir.

Konunun öğrenciye daha anlaşılır olması için etkinlik soruları yeni konu yardımıyla çözülür. Soruları öğrencilerin çözmesini sağlayınız. Ayrıca öğrencilere tek zar atma ve iki zar atma deneyleri için simulasyonlar izletilir**.**

Etkinliğimiz de 1. sorudaki torbadan isim çekme olayında örneklem uzay eş olasılıdır, çünkü torbadan her bir ismi çekmemiz eşit olasılığa sahiptir. Ancak sınıfımızda 16 erkek 14 kız olduğu için;

Eş olasılı örneklem uzayda olasılık hesaplama kurallarını kullanırsak

A={torbadan ismi çekilen kişinin kız olması}

P(A)= $\dfrac{s(A)}{s(E)} = 14/30$

B={torbadan ismi çekilen kişinin erkek olması}

P(A)= $\dfrac{s(A)}{s(E)} = 16/30$

Benzer şekilde 2. soruda iki zar atıldığında deneyin örneklem uzayı eş olasılıdır. Ancak çıktıların herbiri eş olasılı olmasına rağmen çıktılardan birden fazla olduğu için herbir farklı çıktı eş olasılı değildir dolayısıyla;

Eş olasılı örneklem uzayda olasılık hesaplama kurallarını kullanırsak

E={ iki zarın atılması }

A={ iki zarın üst yüzeyine gelen sayıların toplamının 9 gelmesi }

P(A)= $\dfrac{s(A)}{s(E)} = 4/36$

B={ iki zarın üst yüzeyine gelen sayıların toplamının 11 gelmesi }

P(A)= $\dfrac{s(A)}{s(E)} = 2/36$

Dolayısıyla iki zar probleminde zarın üst yüzüne gelen sayıların toplamının 9 gelme olasılığı 11 gelme olasılığından daha yüksektir çünkü 5ve 4, 4 ve 5, 3 ve 6, 6 ve 3 ile 9 toplamı elde edilirken 11 için sadece 5 ve 6 ile 6 ve 5 ihtimalleri vardır.

Daha sonra öğretmen eş olasılı örneklem uzay ile ilgili çeşitli sorular çözer.

Örnek sorular:

1) Bir madeni parayı iki kez havaya attığımızda üste gelen yüzlerin yazı olma olasılığı kaçtır?
2) İki madeni para havaya atıldığında en çok birinin yazı gelmesi olasılığı kaçtır?
3) Bir çift zar atıldığında üste gelen sayıların 3 ve 4 olma olasılığı kaçtır?
4) Bir torbada aynı büyüklükte ve aynı ağırlıkta 5 sarı 4 kırmızı bilye vardır.
   a) Bu torbadan rastgele alınan bir bilyenin sarı olma olasılığı kaçtır?
   b) Kırmızı olma olasılığı kaçtır?
5) 14 kız ve 10 erkek öğrencinin bulunduğu bir sınıfta kızların 6 sı, erkeklerin 4ü gözlüklüdür. Sınıftan rastgele seçilen bir öğrencinin;
   a) kız olma ve erkek olma olasılığı,
   b) gözlüklü kız olma ve gözlüklü erkek olma olasılığı hakkında ne düşünüyorsunuz?

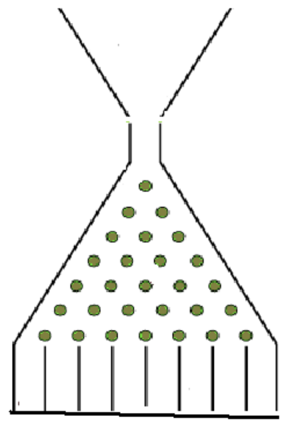
      Eğer iki öğrenci seçilseydi;
   c) İkisininde kız olma olasılığı
   d) İkisininde gözlüklü olma olasılığı
   e) İkisininde erkek olma olasılığı ne olurdu?

MANTIKLILIK

Öğrencilerin eş olumlu örneklem uzay ile ilgili anlayışlarını geliştirmek için öğretmen yeni bir durum ya da günlük hayat örneği sunar.
Öğretmen: Şimdi Galton kutusunu (şans makinesi) düşünelim. Galton kutusu hakkında bilgisi olan var mı?
Öğretmen Galton kutusu etkinlik yaprağını öğrencilere dağıtır.

GALTON KUTUSU

Bu makine yatay sıralarla çakılmış çivilerden ve altta ise bilyelerin içine toplanması için dikey kutulardan oluşmaktadır. Üstte ki huniden atılan her bilyenin çivinin solundan ya da sağından gitme olasılığı eşittir. Buna göre, aşağıdaki kutuda ki huniden atılan bir bilyenin 8 kutucuktan her birine düşme olasılığı hakkında ne düşünüyorsunuz?



Öğretmen öğrencilere durum hakkında düşünmeleri için zaman verir ve onların düşüncelerini alır.
Öğretmen öğrencilr mantıklı açıklamalarda bulunana kadar tartışmaya rehberlik eder.

ÖĞRETMENE YÖNELİK AÇIKLAMA:
Aktivitenin başında öğrencilerin her bir kutucuk için olasılık hesaplaması beklenmemektedir. Sadece öğrencilerden yukardaki huniden atılan bilyaların her bir kutuya düşme olasılığının farklı olduğu ile ilgili mantıklı açıklamalar yapması beklenmektedir.

Cevabı keşfetmek için Galton board simulasyonu öğrencilere izlettirilir**.**
Daha sonra öğrenciler Galton kutusundaki her bir kutucuk için olasılıkları da hesaplar.
Böylece öğrencilere yeni kavramın mantıklılığını test etmek için bir fırsat tanınmış olacaktır. Simulasyon sonunda öğrenciler rastgele olayların bütün olası çıktılarının eşit olasılığa sahip olmadığını olasılığı etkileyen birçok faktör olabileceğini ve hangi durumda bütün olası çıktıların eş olasılı olduğunu görmüş olacaktır.

VERİMLİLİK

Dersin sonunda öğretmen kitaptaki eş olasılı örneklem uzay ve olasılık hesaplama ile ilgili problemleri ödev olarak verecektir. Benzer şekilde öğretmen yeni kavramın yeni durumlarda uygulanması ile ilgili olarak kavramsal ödevlerde verebilecektir.

APPENDIX M

CLASSROOM OBSERVATION CHECKLIST

	Evet	Kısmen	Hayır
1. Sınıfın fiziksel ortamı (aydınlatma, sıcaklık, vb.) öğretim için uygun mu?			
2. Öğretmen derse ilgi çekici bir başlangıçta bulunabiliyor mu?			
3. Öğretmen öğrencilerin mevcut kavramlarını ortaya çıkaracak sorular soruyor/aktiviteler yapıyor mu?			
4. Sorulan soruların bireysel incelenmesi için öğrencilere süre tanınıyor mu?			
5. Öğrenciler küçük gruplar içinde çalışabiliyor mu?			
6. Küçük grup tartışmaları ardından sınıf tartışmalarına zaman ayrılıyor mu?			
7. Öğretmen öğrencilere mevcut kavramlarını tartıştırarak bu kavramların yetersizliğini/ yanlışlığını fark etmelerini sağlıyor mu?			
8. Öğrencilerin derse aktif katılımı sağlanabiliyor mu?			
9. Öğretmen ve öğrenciler arasında etkili bir iletişim var mı?			
10. Öğrenciler kendi arasında etkili bir iletişime sahip mi?			
11. Öğretmen kavramın bilimsel açıklamasını yapıyor mu?			

	Evet	Kısmen	Hayır
12. Öğretmen kavramı açıklarken öğrencilerin mevcut kavramlarını da göz önünde bulunduruyor mu?			
13. Öğretmen kavramla ilgili olarak çeşitli problemler çözüyor mu?			
14. Öğrenciler öğrendikleri kavramı yeni bir durum içinde uygulama fırsatı bulabiliyor mu?			
15. Öğretmen kavramla ilgili olarak günlük hayat örnekleri veriyor mu?			
16. Öğretmen öğretim sırasında bilgisayar similasyonları, etkinlik kağıtları vb. materyalleri etkili bir şekilde kullanabiliyor mu?			
17. Öğrenciler öğretim sürecinde not tutuyor mu?			
18. Öğretmen öğrenciye ödev veriyor mu?			
19. Dersin sonunda öğrencilerle birlikte kavramsal özet yapılıyor mu?			
20. Öğrencilerin dersin işlenişinden hoşlanıyor mu?			

CURRICULUM VITAE

PERSONAL INFORMATION

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EDUCATION

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WORK EXPERIENCE

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FOREIGN LANGUAGE

English