FOSTERING STUDENTS' LEARNING OF PROBABILITY THROUGH VIDEO GAME PROGRAMMING

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ABSTRACT

FOSTERING STUDENTS' LEARNING OF PROBABILITY THROUGH VIDEO GAME PROGRAMMING

This study designed and developed an intervention based on video game programming activities; then it investigated the effects of this intervention on primary school students' learning of probability concepts. First, a pilot study was conducted with 15 primary school students. Based on results of the pilot study, the intervention was revised, and the main study was conducted with 30 primary school students. In both studies, the students learned and used Scratch application as a programming tool. In the first few weeks, they learned how to use Scratch, and then they developed video games based on scenarios developed by the researcher. The study collected qualitative as well as quantitative data using three different measurement tools: Probability Achievement Test (PAT), Reflective Thinking towards Problem Solving Scale (RTPSS) for collecting quantitative data and Student Project Assessment Rubric (SPAR) for qualitative data. Analysis of the study data revealed that students were able to learn and use Scratch and develop probability related/based algorithms that generate random results successfully. The effect of Scratch intervention on students' learning of probability was found statistically significant. However, the effect of the intervention on students' reflective thinking towards problem solving was negligible and not statistically significant. Findings are discussed in relation to similar studies reported in the literature. Finally, the study raised a set of further research questions in the conclusion section.

ÖZET

OLASILIK ÖĞRENİMİNİN OYUN PROGRAMLAMA YÖNTEMİYLE GELİŞTİRİLMESİ

Bu çalışmada oyun programlama aktiviteleri üzerine kurulu bir öğrenme ortamı tasarlamış ve geliştirilmiş; daha sonra da bu ortamın ilköğretim okulu öğrencilerinin olasılık konularını öğrenmesine olan etkisi araştırılmıştır. İlk olarak 15 öğrenciyle bir pilot çalışma yapılmıştır. Pilot çalışmanın sonuçları doğrultusunda araştırma deseni ve etkinliklerde iyileştirmeler yapılmış ve ana çalışma 30 ilköğretim okulu öğrencisiyle gerçekleştirilmiştir. Öğrenciler iki çalışmada da programlama aracı olarak Scratch uygulamasını öğrenmiş ve kullanmışlardır. İlk haftalarda Scratch'i kullanmayı öğrenen öğrenciler, kalan haftalarda araştırmacı tarafından hazırlanan senaryolara dayalı olarak bilgisayar oyunları geliştirmişlerdir. Araştırmada üç farklı ölçüm aracı kullanılarak veri toplanmıştır: nicel veri için Olasılık Başarı Testi ve Problem Çözmeye Yönelik Yansıtıcı Düşünme Becerisi Ölçeği, nitel veri için ise Öğrenci Projesi Değerlendirme Çizelgesi. Toplanan verilerin analizi sonucunda öğrencilerin Scratch uygulamasıyla bilgisayar oyunları geliştirmeyi öğrenebildikleri ve rastgele sonuçlar üretebilen, olasılık kavramlarına dayalı algoritmalar geliştirebildikleri görülmüştür. Scratch çalışmasının öğrencilerin olasılık öğrenimi üzerinde istatistiksel olarak anlamlı bir etkisi olduğu bulunmuştur. Öte yandan, problem çözmeye yönelik yansıtıcı düşünme becerisi üzerinde kayda değer bir etki bulunamamıştır. Bulgular literatürdeki benzer çalışmalarla karşılaştırılarak değerlendirilmiştir. Araştırma sonunda yeni araştırma problemleri ortaya çıkmış ve sonuç bölümünde açıklanmıştır.

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LIST OF SYMBOLS

#	Number of items
df	Degrees of freedom
n	Sample size
n/a	Not applicable
sd	Standard deviation

LIST OF ACRONYMS/ABBREVIATIONS

3D	Three dimensional
DIY	Do-it-yourself
ICC	Intraclass correlation coefficient
ISDP	Instructional Software Design Project
IWB	Interactive white board
Logo	Language of Graphical Output
MIT	Massachusetts Institute of Technology
PAT	Probability Achievement Test
RPG	Role playing game
RTPSS	Reflective Thinking towards Problem Solving Scale
SPAR	Student Project Assessment Rubric
VKV	Vehbi Koç Foundation

1. INTRODUCTION

Learning through programming is not new in educational landscape. Seymour Papert and colleagues initiated first attempts in late 1960s (Papert & Solomon, 1971; Papert, 1980, 1993) and many researchers followed during the last four decades (e. g., Ackermann, 2010; Bar-On & Or-Bach, 1988; Boyer, 2010; Ioannidou, Repenning, Lewis, Cherry, & Rader, 2003; Kafai, 1996; Resnick, 1997; Olive, 1991; Wilensky, 1993). This enthusiasm of researchers was very high, especially in the 1980s. However, due to the emergence of personal computing and encouraging results of preliminary studies, Logo, or programming activities in general, never became a widespread practice (Maloney, Peppler, Kafai, Resnick, & Rusk, 2008; Resnick, 2012). Let alone embracing findings of aforementioned studies, computers in schools were mostly used as presentation and information machines. Far from revolutionizing learning, most computer-based applications took traditional classroom activities and simply reimplemented them on computers (Resnick, 1998, p. 45).

On the other hand, remarkable improvements in computational tools have triggered a cultural shift in the new millennium. Once the mere watchers or consumers of computer-based educational content, students now have opportunities to build their own computational artifacts. The emergence of a Do-It-Yourself (DIY) or a maker culture promises a second push in educational research (Kafai & Peppler, 2011; Peppler & Kafai, 2007; Rusk, Resnick, & Cooke, 2009). There is no doubt that, regardless of the circumstances and provided media, kids have great competency on learning when they enjoy the context (Papert, 1984). Nowadays, kids want to learn computer tools and programming in order to create drawings, photo manipulations, videos, games, web pages and animations for personally meaningful projects (e.g., Kafai & Peppler, 2011; Maloney *et al.*, 2008; Resnick, 2012). While computational tools are more powerful, reachable and user friendly than the ones in 1980s and 1990s, taking advantage of these tools for educational purposes is still a challenge.

Of those computational methods, programming is one of the most promising activities. In contrast to pre-developed tools, it provides children freedom to follow alternative pathways in their own learning process (Papert, 1980, 1984). New tools like Scratch (Resnick *et al.*, 2009), Lego Mindstorms (Resnick, 2006) and Smallbasic (Microsoft Corporation, 2012) provide comprehensive and still simple environments to develop computer software. In contrast to the widespread perception of computer programming as a difficult endeavor, even kids at preschool age can now develop their own computer games (Bers, Flannery, Kazakoff, & Resnick, 2013; Fessakis, Gouli, & Mavroudi, 2006).

Traditional programming languages and/or tools are considered to be very complex and require a high level of abstract thinking skills for most of the people (Gomes & Mendes, 2007). Further, programming is often taught in a way that it is isolated from learners' backgrounds and with little relevance to real-world applications (Gomes & Mendes, 2007). Yet, it is safe to claim that these rising generation of tools excel in providing intuitive environments for people who have no background in computer programming (Kafai & Peppler, 2011; Resnick *et al.*, 2009). While many students studying in computing fields struggle in understanding programming concepts such as loops, variables, and parameters (Lahtinen, Ala-Mutka, & Jarvinen, 2005), tools like Scratch enables children to learn them in just minutes and utilize them in their projects right away (Resnick *et al.*, 2009). Children mostly learn Scratch themselves and at their own pace by working on projects related to their interests (Kafai & Peppler, 2011).

In this study, the aim is not to observe effects of using programming to simply support mathematics education. Nor is the aim to create another technological teaching method, either. Rather, this study builds on the question that "Can we use the power of computational methods to make learning probability more intuitive and more meaningful?" Probability is chosen as the subject to study because of its similarities to computer programming: it is abstract and complex; there are many misconceptions and false intuitions about it; most people find it difficult to learn; it is mostly taught in isolation even though it is directly connected to real-world events (Shaughnessy, 1992).

2. LITERATURE REVIEW

This study has two distinct roots. The first root is probability: the need, the challenges and the novel ideas to go beyond the limitations of current practices in teaching and/or learning it. The second root is computation: the powers, the struggles and exciting new ways to integrate it into schooling. While these two are distinct at the beginning, the aim of this study is to find a way to bond these two roots for an active, productive, fun, and powerful way to learn probability. Unfortunately, there are very few studies (Bar-On & Or-Bach, 1988; Resnick & Wilensky, 1998; Wilensky, 1996) in education literature which concentrate on such a connection or at least a somewhat similar one. In this chapter the literature on the each root has been reviewed separately in order to develop structure for the research study.

2.1. Learning and Teaching Mathematics: The Case of Probability

Probabilistic thinking is not a skill that only gamblers use in everyday situations. Having a deep understanding of probability is very important in order to make successful decisions in various occasions (Bar-On & Or-Bach, 1988; Bulut, Kazak, & Yetkin, 1999; Garfield & Ahlgren, 1988; Memnun, 2008; Pratt, 2005; Shaughnessy, 1992). Sports, medicine or weather forecasting are just some examples. It is deeply immersed in life and we experience probabilistic phenomena over and over again without actually realizing it. It is no surprise that people develop beliefs about probability throughout their lives which leads to misconceptions and learning difficulties (Fischbein & Schnarch, 1997; Piaget & Inhelder, 1975). It is also no surprise that many researchers conducted studies on children's understanding of probability concepts, especially since the 1970s (e.g., Fischbein & Schnarch, 1997; Hoemann & Ross, 1971; Kahneman & Tversky, 1972; Kier, Styfco, & Zigler, 1977; Konold, 1989; Tversky & Kahneman, 1973, 1974, 1983). Many others focused on practices of teaching probability (e.g., Abrahamson, 2007; Bar-On & Or-Bach, 1988; Bulut *et al.*, 1999; Fischbein & Gazit, 1984; Memnun, 2008; Watson, 2001; Wilensky, 1993). In this section, such studies are reviewed in an attempt to develop an insight on how to structure a learning environment for studying probability with primary school students.

To begin with, studies that cover problems in probability teaching were reviewed. One of the most comprehensive literature reviews on the subject was performed by Memnun (2008). As a result of the analysis, the researcher categorized her findings of the study in six different topics: importance of age, students' insufficiency of advanced information, students' failure in argumentation, teachers' incompetency, students' negative attitudes, and misconceptions. First, it was concluded that students' ability to understand and learn probability subjects increases over time. Second, the insufficiency of advanced information, or a lack of prerequisite knowledge, on subjects such as percentages, fractions, ratio, and decimals affects their ability to learn probability subjects negatively. Third, students' inability to develop consistent and powerful arguments is a factor that influences their learning negatively. Fourth, teachers' knowledge and experience in teaching probability, their ability to use appropriate methods and their attitudes towards probability are factors that influence student's learning of probability dramatically. Teachers play a very important role in preventing students from developing negative attitudes towards probability, yet they generally fail because most of them are not competent in probability subjects. Lastly, students' misconceptions of probability is a very important factor which educators should always keep in mind.

Unfortunately, the literature demonstrates that traditional methods employed in our schools fail in teaching probability (e. g., Bulut, 1994; Bulut *et al.*, 1999; Fischbein & Schnarch, 1997; Shaughnessy, 1992; Wilensky, 1995). In contrast to the nature of the subject, probability is taught very passively in the school with very basic, non-creative applications. Children are mostly asked to memorize formulas about probability without even understanding the underlying concepts and mechanisms. To analyze teachers' behaviors, Özmen, Taşkın, and Güven (2012) followed 4 primary school mathematics teachers' lessons for one month and found that they mostly prefer verbal problems with little numerical data. Further, teachers did not bring sufficient number of real world applications of probability into classrooms. Similarly, Kayan (2007) conducted a survey with 244 senior undergraduate students studying in Elementary Mathematics Teacher Education programs at 5 different Turkish universities and found that many participants highly value problems that are directly related to the curriculum and require less time for solution.

Moreover, many students lack prerequisite knowledge on rational number concepts and proportional reasoning (Memnun, 2008). They do not like studying probability because of receiving highly abstract and formal instruction in schools (Garfield & Ahlgren, 1988; Wilensky, 1996). Relatedly, studies conducted by Bulut (1994) and Bulut *et al.* (1999) revealed that even some prospective mathematics teachers lacked a robust understanding of most probability concepts. Consequently, most of them developed negative attitudes towards probability.

A final consideration is the lack of support for students' development of problem solving skills. Shaughnessy (1992, p. 467) argues that teaching and learning of probability involves building models of physical phenomena, development and use of strategies, and comparison and evaluation of several different approaches to problems in order to monitor possible misconceptions or misrepresentations. Teachers, on the other hand, stick to the curriculum and avoid complex and/or open ended questions in favor of short questions without any relevance to real world applications (Kayan, 2007; Özmen *et al.*, 2012).

In a nutshell, there are many factors affecting students' underachievement in probability and an intervention designed to help students in learning probability needs to be designed accordingly. In the following subsections, misconceptions in probability and practical studies on teaching probability were analyzed succesively.

2.1.1. Misconceptions in Probability

Because it is difficult to learn and there are false beliefs, probability has been studied by many researchers in a variety of ways (e. g., Fischbein & Schnarch, 1997; Kahneman & Tversky, 1972; Lecoutre, 1992; Memnun, 2008; Tversky & Kahneman, 1983; Piaget & Inhelder, 1975). There are seven commonly accepted and proven misconceptions in probability literature: representativeness, negative and positive recency effects, simple and compound events, the conjunction fallacy, effect of sample size, the heuristic of availability, and the effect of the time axis (Fischbein & Schnarch, 1997). Although this study does not directly concentrate on remedying these misconceptions, related literature is analyzed in order to avoid making mistakes in the intervention that would cause students to form unintended conceptions or reinforce existing misconceptions.

Representativeness stands for the tendency to estimate the probability of an event considering how similar it is to its parent population and reflects the visible features of the process by which it is generated (Kahneman & Tversky, 1972). As an example, given by Tversky and Kahneman (1974), considering successive tosses of a coin people believe the sequence H-T-H-T-T-H is more probable than H-H-H-T-T-T or H-H-H-H-T-H, even though all tree are almost equally possible. They conclude that "the essential characteristics of the process will be represented, not only globally but also locally in each of its parts" (p. 1125).

Negative and positive recency effects, or "the gambler's fallacy", is a misconception that leads people to believe that if the proportions of the two outcomes are to be preserved in short segments, then a long sequence of one outcome must be followed by the other outcome in order to restore the balance (Kahneman & Tversky, 1972, p. 435). In other words, it can be described as the oversensitivity to the probability of prior outcomes. After getting three heads in three tosses, one may predict the result of the fourth toss as tail (negative recency), to balance the results, or another head (positive recency), because it is more frequent, even though both are equally possible (Jones & Thornton, 2005).

When comparing simple events to compound events, people have a tendency to say that both have the same probability. This misconception is also known as equiprobability bias. For instance, there is a tendency to accept the probability of getting 5 and 6 is equal to probability of getting 6 and 6 when two dices are rolled simultaneously (Fischbein & Schnarch, 1997; Lecoutre, 1992).

Tversky and Kahneman (1983) found that even people trained in stochactics tend to assume that the conjunction, or intersection, of two events are more likely than their parent events solely. In other words, we have a tendency to believe that specific conditions are more probable than general ones. A good example to this is thinking that probability of a person being a bank teller is lower than the same person being a bank teller and an active feminist (p. 299). This misconception is called conjunction fallacy.

Further, the same authors earlier noted that people's negligence of sample sizes while estimating probability of an event is accepted as another misconception (Tversky & Kahneman, 1982). As a basic example, consider two experiments in which we toss a coin three times and another 300 times. If someone thinks that the probability of getting at least two heads in former experiment is equal to the probability of getting 200 heads in the latter, s/he has this misconception (Fischbein & Schnarch, 1997).

Availability heuristic is a misconception which explains one's reliance on their memories when calculating probabilities (Tversky & Kahneman, 1973). Put another way, people tend to estimate likelihood of an event based on how easy it is for them to recall (Shaughnessy, 1992). As an illustration, a person reading more case studies about successful business studies may believe that the probability of running a successful business is higher.

The seventh misconception is the time axis fallacy, which is related to difficulty of understanding conditional probabilities and independent events. While people have a better understanding on the fact that outcome of an event can affect the outcome of a later event, some people may assume that knowing the outcome of the latter affect cannot be used to determine the probability of the previous event (Fischbein & Schnarch, 1997). Consider a situation in which there are two white and two black balls in a box. If two balls are drawn without replacing the first one, can we calculate the probability of the second ball being white given that the first ball is white? Or can we calculate the probability of the first ball being white given that the second ball is white? For many students, it is easy to calculate the first question but complicated to answer second question (Shaughnessy, 1992, p. 473).

To conclude, all of these misconceptions, or heuristics, are based on our intuitions and experiences. Thus, they are obstacles to be mindful in teaching probability at the primary school level (Fischbein & Gazit, 1984) even when the aim is not directly to help students develop secondary intuitions (Jones & Thornton, 2005) or change their existing intuitions. In this study, changes in the aforementioned seven heuristics are not measured. However, intervention is designed accordingly in order to avoid developing misconceptions and degrading students' interaction with probability topics to solve fractions or ratio problems.

2.1.2. Current Teaching Techniques, Strategies and Approaches

Due to apparent failure of traditional methods in teaching probability, as mentioned previously and confirmed by many researchers (e.g., Shaughnessy, 1992; Tversky & Kahneman, 1974; Wilensky, 1995), various studies were conducted and alternative approaches were proposed for probability instruction. As expected, owing to the nature of probability, which requires problem solving and abstract thinking skills (Shaughnessy, 1992) combined with a need to run experiments to examine the outcomes of events (Paparistodemou & Noss, 2004), many researchers developed activities with computers such as simulations, games, presentations, spreadsheet activities and drill and practice activities (Pratt, 2005; Shaughnessy, 1992). In this section, some of these studies are analyzed in order to compare different approaches in computer based applications in probability education, as well as to pinpoint successful methods to employ in the intervention phase of this thesis study.

With the intention of teaching formal mathematical concepts and operations to the less able high-school students, Bar-On and Or-Bach (1988) developed an instructional model in which computer programming was used to express, in a formal way, experiments in probability and statistics. The effects of this model was investigated in a field study conducted at a vocational high school with a less able pupil population. Experimental results of this study showed that instructional materials developed according to this model could be effective for remedying faulty patterns of probabilistic thinking.

Paparistodemou and Noss (2004) designed and developed a computer game for 5 and 8 year-old children to manipulate sample spaces in ways that generate corresponding outputs. The game was designed in a way that enabled children to see outcomes of individual events as well as an aggregated view of probability in order to support global understandings. It consisted of a lottery machine and necessary tools to manipulate the sample space of this machine such as the number, the size, or the position of balls. A change in the outcome of an individual event affected the result directly. The findings of this study showed that children were able to realize the need to control the outcome without controlling the random environment.

Abrahamson and Wilensky (2005) designed an experimental study for a middle school unit in probability and statistics called ProbLab. The study included two computer based interactive models developed in NetLogo. The first model, Stochastic Patchwork, includes a square coin that has a red side and a green side. The model enables students to modify parameters of the system, the size of the population and the bias of the coin, and then flip many coins at once. The second model, Sample Stalagmite, simulates the random generation of blocks of red/green squares and their accumulation into columns according to the number of red squares as a histogram. Again, students can manipulate the parameters, block size (e. g., 2x2, 3x3, 4x4) and inclusion/exclusion of duplicates. They implemented these two models in a design based research study with 26 eight grade students. In a following study, Abrahamson, Janusz, and Wilensky (2006) applied the ProbLab unit to 40 sixth grade students. Both studies showed that ProLab was successful in engaging students in probability-related activities and increasing their excitement.

Kazak and Konold (2010) developed a set of classroom activities along with a probability simulation tool, Tinkerplots, in order to support middle school students' learning of data and chance. The study lasted ten weeks and included three different chance related problems. In each task, students made predictions about the outcomes, collected data from the actual situation, modelled the situation with TinkerPlots software, revised their predictions, and tested their predictions again with simulated data. By this way, students were able to build models, run large numbers of repetitions in multiple trials and display the outcomes.

In addition to reviewing successful technology based methods in the literature, the ongoing state of probability instruction in Turkish educational system is analyzed through curriculum materials of the Ministry of National Education. Since the last curriculum revisions in 2005, the primary school level of Turkish mathematics education curriculum covered probability subject in 6$^{\text{th}}$, 7$^{\text{th}}$ and 8$^{\text{th}}$ grades (Turkish National Ministry of Education, 2012). In the 6$^{\text{th}}$ grade, basic aspects of probability are studied in three topics: basic rules of counting, basic concepts of probability, and event types. The basic rules of counting topic covers addition and multiplication rules. The basic concepts of probability topic includes experiment, outcome, sample space, random selection and equiprobability concepts. Three types of events are studied as certain events, impossible events and complementary events. The problems used in this level are very basic and mostly at knowledge level. In the 7$^{\text{th}}$ grade, permutation is introduced along with mutually exclusive and non-mutually exclusive events. The problem sets are more complex in this level. Also, students need to learn some basic formulas. In the 8$^{\text{th}}$ grade, combination is introduced and differences between combination and permutation are clarified. Next, dependent and independent events are studied. Shortly, through all levels of curriculum, Turkish educators are expected to approach probability as special questions for fractions, ratio, permutations or combinations. Even though literature suggests adoption of computational methods, Turkish primary school mathematics curriculum does not contain any computer based activities in probability topics in any levels.

In short, educators of 21st century, as they are teaching probability or designing the curriculum for it, have an arsenal that contains digital tools developed throughout four decades of research. Nonetheless, based on the slow rate of adoption by educators, one can conclude that a methodology which is suitable for more than one level and/or topic of probability is still a challenge.

2.2. Using Technology for Student Centered Environments

Harel and Papert (1990) claim that computers cannot produce "good" learning, but children can do "good" learning with computers. Although many researchers and educators developed technological methods to support or mimic traditional classroom practices, another approach is "to give children control over their learning with computers" (p.2). Hannafin and Land (1997) summarize that technology enhanced, student centered learning environments provide interactive, complimentary activities that enables individuals to address unique learning interests and needs, study multiple levels of complexity, and deepen understanding. The focus of this study is to create a student centered probability learning environment with the help of computer supported game programming activities. Therefore, related literature is reviewed in this chapter.

2.2.1. Learning by Programming

In 1967, Seymour Papert and his colleagues started working on Logo programming language at MIT Media Lab, which was the first visual programming language designed for educational use (Papert, 1980). Far more primitive than today's digital tools, it enabled the user to control a mechanical robot called turtle. With a pen mounted to the turtle and very basic commands of turtle language such as LEFT, RIGHT, DRAW or FORWARD, one could draw simple images on a surface. Moreover, even though it was very complicated back then, one could connect some sensors to the turtle like touch sensors, sound detectors and accelerometers. The aim was to create a dialogue between the computer and the turtle (Papert & Solomon, 1971). Along with many other applications of Logo programming language, turtle geometry and its derivatives attracted attention of many researchers and a lot of studies had been conducted on teaching and learning with it since the 1970s. There have been positive results with Logo programming activities on developing an understanding of mathematics subjects such as geometry, arithmetic, algebra and ratio (e. g., Clements & Battista, 1989; Clements & Sarama, 1997; Edwards, 1991; Harel & Papert, 1990; Olive, 1991; Papert, 1980, 1984, 1993). Moreover, its positive effects on children's spatial thinking and higher order thinking abilities, creativity, social-emotional development and language arts have been supported by the literature (Clements & Sarama, 1997).

In parallel to development of Logo programming language and research on learning through programming, Papert (1980) advocated constructionism, an educational practice built on top of constructivist theory, which claims that people learn better when they work on personally meaningful products. In a constructionist learning environment, students are not given formal, traditional instructions. Instead, they have appropriate tools to build their own knowledge by constructing a public entity (Papert & Harel, 1991). While it is not the only option, computation is the most widely used method for this purpose. Using tools like Logo, students enter a microworld, in which they can develop various models and test them repeatedly. Like an inventor, they can see what is working and what is not working (Edwards, 1991; Papert, 1980, 1993). In many research studies, computer game design and programming activities were used in order to provide such microworlds and foster a culture of self-motivation, self expression, creativity, and knowledge construction (e. g., Harel & Papert, 1990; Hoyles & Noss, 1992; Kafai, Franke, Ching, & Shih, 1998; McCue, 2011; Resnick, 1996).

Originally, the Logo turtle was a physical device connected to the computer with an "umbilical cord" which transmitted Logo commands to it (Papert & Solomon, 1971; Papert, 1980). However, this physical turtle gave its place to screen turtles very quickly after the advent of personal computers in the late 1970s (Resnick, 1997). Moreover, a lot of Logo derivatives, both commercial and non-commercial, were developed for various purposes. For example, Starlogo is a specialized fork of Logo focusing of parallel programming and decentralization. In StarLogo, it is possible to create thousands of objects acting in parallel and interacting with each other (Resnick, 1996, 1997). LEGO/Logo, which was named as Lego Mindstorms and produced as a commercial product, is another Logo based tool particularly aiming to enable children to construct their own buildings and machines using both classical Lego blocks and special ones such as motors, sensors or processors and then develop programs with Logo commands to control them (Resnick & Ocko, 1990; Resnick, 1997).

Since 1970s, Logo and its derivatives have been very popular among educators and researchers. Many researchers have tried to teach mathematics subjects such as ratio and proportion, geometry, fractions, addition etc. in more intuitive and motivating learning environments in which children can challenge their mathematics knowledge, learn new things and use it to create personally meaningful artifacts (Clements & Battista, 1989; Clements & Sarama, 1997; Edwards, 1991; Harel & Papert, 1990; Olive, 1991).

Harel and Papert (1990) conducted a study called Instructional Software Design Project (ISDP) in which fourth grade students developed educational software to teach fractions. In addition to learning to program in Logo, the study investigated the effects of these activities on students' learning of fractions and their metacognitive skills. In this 15-week study, there was two control groups (C1 and C2) and one experimental group. Students of the experimental group studied fractions in their regular mathematics lessons and developed programs in Logo to teach fractions. Students in the C1 studied fractions in their regular mathematics lessons and developed generic programs in Logo. However, the students in C2 only studied only fractions in their mathematics lessons but did not learn Logo. The results of the data analysis showed that the experimental group students learnt fractions better than both control groups.

Edwards (1991) conducted a research study with 12 middle school students from 6th, 7th and 8th grades in an effort to investigate the learning of children who interacted over a short period of time with a computer microworld dealing with transformation geometry. The aforementioned microworld, which was a set of simple Logo commands, enabled children to see the visual representation of each transformation effect. Over the course of the study, the students worked with the researcher in pairs. They received 7 hours of instruction in transformation geometry and 6 hours of experience with the microworld. The results indicated that the microworld and associated activities were effective in assisting the students to construct a working knowledge of the transformations. Also, the intervention was effective to help students correct their tendency to overgeneralize symbolic patterns in transformation geometry.

Aiming to map the relationship between pedagogy and student behavior in a mathematical microworld, Hoyles and Noss (1992) designed a set of Logo programming based activities in which students tried to accomplish a specific goal by manipulating a given computational object. For the main study of this project, the researcher have taught the ratio and proportion microworld to a class of 28 13-year-old pupils over a period of 6 weeks. This required students to manipulate a Logo procedure in order to enlarge a house sketch by a given factor. Before this intervention, all students learned to use Logo competently in a 20-hour training. The researchers collected data using marked homework assignments, print-outs of all procedures, and observation notes. Throughout the process, students developed a better understanding on ratio and proportion by using trial and error.

Resnick (1996) designed StarLogo programming language, as an environment for exploratory learning in statistics and randomness. His objective was to provide a powerful tool for developing an understanding of de-centralized parallel situations that people have misconceptions and difficulty in understanding. By creating a microworld to design and test such situations, StarLogo provided an opportunity to explore ideas about statistics and randomness. In order to assess its effects on people's mindsets, Resnick (1996) carried out a case study with two 16-year-old high school students. The students worked together to create a traffic jam simulation in StarLogo. Results showed that, they developed better intuitions about traffic jams in this process, recognizing how decentralized interactions can indeed cause the formation of larger-scale traffic patterns.

2.2.2. Learning by Designing Games and Multimedia

Even though computer programming is widely used, it is not a must to create a powerful microworld. Another student centered method in education, which is also based on constructionist principles, is to give students the role of an active designer (e. g., Harel & Papert, 1990; Kafai, 1996; Kafai, Ching, & Marshall, 1997; Kafai *et al.*, 1998; McCue, 2011; Robertson & Howells, 2008). Kafai *et al.* (1998) argue that game design activities provide a learning environment for both students and teachers in which they can build on and challenge their existing understandings, engage in relevant and meaningful learning contexts, and develop connections among the curriculum subjects and real world contexts. In such activities, students get an opportunity to think like planners, problem solvers and designers in a continuum (Kafai, 1996; Kafai *et al.*, 1998).

In order to examine the effects of multimedia design for learning, Kafai *et al.* (1997) conducted a study in which seven design teams created interactive multimedia resources about astronomy. For three months, a class of 26 students (Grade 5 and 6) was divided into teams that met regularly to program multimedia applications using Microworlds Logo programming environment. The researchers analyzed the final projects of these groups in terms of the usage of programming functions and multimedia content. They found that students' understanding of astronomy concepts and Logo programming was increased significantly. In terms of design efforts, students made extensive use of multimedia in various parts of their projects such as menu options, title screens, introductions, content overviews and final screens.

In another study conducted by Kafai *et al.* (1998), the effects of designing video games with pen and paper on understanding of fractions were analyzed. Both students and pre-service teachers participated to the project. During the project, students and teachers were asked to design games to teach fraction. In contrast to other studies, participants did not develop their game designs on computer. At the beginning fraction content and game ideas were separate in projects of most participants but after various design activities, participants were better able to integrate fractions content into their ideas. The complexity of their designs also improved after the workshops.

In a more recent study, Robertson and Howells (2008) conducted an exploratory field study in which 30 6th grade (10 year-old) primary school students used the game engine of Neverwinter Nights for 8 weeks. This software enabled them to create characters, change landscapes, and write interactive dialogues in a virtual 3D space. The researchers analyzed the effects of this intervention on students' enthusiasm and motivation for learning, determination to reach high standards of achievement, independent and group learning, and linking and applying learning in new situations. Data were collected through interviews with students, teachers, visiting educationalists and parents. They used thematic analysis to identify the sorts of learning which took place during the study. They found that during the intervention, children displayed motivation and enthusiasm for learning, determination to reach a high standard of achievement, and independent learning skills. Also, students were able to link and apply their learning in new situations.

All in all, computing, with or without computers, has proved to be a viable alternative in education that allows students to practice and develop problem solving, algorithmic thinking, logical reasoning, computational thinking and reflective thinking skills (Brennan, 2011; Lai & Yang, 2011; Papert, 1980, 1993; Siever, Heeler, & Heeler, 2011; Wolz, Stone, Pulimood, & Pearson, 2010). The literature reviewed in the last two sections provides the basis for recent studies on learning through programming, as well as this thesis study which aims to develop a modern computational method for studying probability at primary school level.

2.2.3. Commonly Available Tools and Scratch

Logo and its derivatives became very popular among children, educators, and researches for a long period. There are, however, other alternative programming environments which aim to lower the bar of learning programming. Especially after the 1990s, with the advent of Internet and rich media technologies, many different tools were developed for the purposes of education, research and trade. Some of them are similar to Logo while some of them are entirely different; but all of them aim to take the advantage of multimedia capabilities of new generation computing tools. For example, Toontalk is more like a computer game than a programming environment. It visualizes the computational process by enabling users to train virtual robots visually to accomplish particular goals (Kahn, 1999). Stagecast Creator follows a totally different approach, as well, which eliminates the need of formal programming languages and uses two visual methods: programming by demonstration and before-after rules (Denner, Werner, & Ortiz, 2011; Habgood, Ainsworth, & Benford, 2005). There are many more similar environments such as Alice, Greenfoot, RPG Maker and Gamefroot. Furthermore, there are many research studies on the use of such programming languages for educational purposes (e. g., deHaan, 2011; Denner *et al.*, 2011; Habgood *et al.*, 2005; Mor & Sendova, 2003; Robertson & Howells, 2008; Robertson, 2012; Vos, van der Meijden, & Denessen, 2011).

For example, Mor and Sendova (2003) studied the effects of using Toontalk, an animated programming language in which a character manipulates objects or trains robots for accomplishing a particular goal, on primary school students' attitude towards mathematics and mathematical achievement. They conducted a pilot study which took place in London and Sofia simultaneously. The main topic of this study was constructing and analyzing numerical sequences. Students trained robots in Toontalk to create number sequences to solve mathematical problems given by researchers. As a result, participants' motivation has increased and they were able to create complex sequences. They were able to develop insights about the relationship between modeling and the underlying mathematical structure. Moreover, students who found it hard to verbalize the rules behind sequences were able to construct the robots for generating them.

Robertson and Howells (2008) conducted an exploratory field study in which 30 6th grade (10 year-old) primary school students made their own computer games. The study lasted 8 weeks and students used the game engine of Neverwinter Nights. This software enabled them to create characters, change landscapes, and write interactive dialogues in a virtual 3D space. The researchers analyzed the effects of this intervention on students' enthusiasm and motivation for learning, determination to reach high standards of achievement, independent and group learning, and linking and applying learning in new situations. The researchers interviewed students, teachers, visiting educationalists and parents for data collection. They used thematic analysis to identify the sorts of learning which took place during the study. They found that during the intervention, children displayed motivation and enthusiasm for learning, determination to reach a high standard of achievement, and independent learning skills. Also, students were able to link and apply their learning in new situations.

deHaan (2011) conducted two different projects with a total of 11 students in a digital game library at a rural Japanese University, for the purpose of investigating game construction activities on students' learning of English as a foreign language. In the first project, the researcher worked with three students for four months to design and develop English language role-playing games using RPG Maker software on the library PCs. In the second study, the he worked with eight students for four months on the creation of an issue of a print and online English game magazine. In this descriptive study, the researcher claims that the projects motivated the students, challenged the students, provided opportunities for authentic discussions in the foreign language and gave the students concrete language, technology, teamwork and creative experiences.

Scratch, on the other hand, is another very popular programming tool developed by Lifelong Kindergarten Group in MIT Media Lab. It visualizes the computational process but with a different approach. Built on top of the principles of Logo, it provides programming blocks, similar to puzzle pieces, to put together in order to create algorithms just like speaking and without worrying about syntax errors. These blocks are separated into six categories: motion, control, looks, sensing sound, operators, pen and variables. It comes with a large multimedia object database (including backgrounds, characters, tools, music and sounds), and it allows users to import their own multimedia files. Moreover, the Scratch Website (http://scratch.mit.edu) allows users to share their projects with other users (Resnick, 2007; Resnick *et al.*, 2009; Resnick, 2012). After 2007, when the Scratch Website was publicly launched, more than two million projects were uploaded to Scratch Website by nearly three hundred thousand project creators in just one year (Monroy-Hernandez & Resnick, 2008). Parallel to this huge growth of Scratch, a lot of research was carried on using Scratch. Although most research concentrated on digital literacy and programming instruction, there is some research on how to use Scratch in teaching content such as mathematics and science (e. g., Baytak & Land, 2011b; Boyer, 2010; Lai & Yang, 2011; Meerbaum-Salant, Armoni, & Ben-Ari, 2010; Taylor, Harlow, & Forret, 2010; Wolz *et al.*, 2010).

2.2.4. Scratch and Creative Computing

Arguing that most learning environments today are not designed to help students develop as creative thinkers, Resnick (1998, 2007) claims that the traditional kindergarten approach, in which children are constantly designing, creating, experimenting, and exploring is well-matched to the needs of the current society, and it should be extended to learners of all ages. He proposes a learning environment in which children continuously imagine, create, play, share and reflect. The first step of the spiral cycle, *imagine*, represents a learning environment, digital or physical, in which provided learning tools and materials are powerful enough to be used in multiple ways, leaving more room for children's imaginations. The second step, *create*, is about providing children opportunities to design and create things by themselves. Thirdly, *play* stands for integrating play, design and learning in a way that children continuously experiment, explore and test the boundaries. Fourth, *share* means, in a wider sense, creating a learning environment in which children can share their constructions with others in order to get children to be become engaged with both construction process and the community. And lastly, *reflect*, emphasizes the importance of critical reflection on the ideas that guided the design, or strategies for refining and improving the design, or connections to underlying scientific concepts and related real-world phenomena. However, reflection is not the last step of this process. In contrast, this process gives raises ideas, triggering another cycle starting with imagining, making it an iterative process.

Additionally, Resnick (1998, 2006) argues that children use computers mostly in a passive, consumption based way. In order to realize the real potential of computers, we should start thinking of them more like paintbrushes than televisions. In other words, we should think of computers as a new medium fore creative design and expression rather than a machine to retrieve information. Instead of taking traditional classroom activities and simply re-implementing them on the computer, technology should be used to create learning environments in which children, as active participants, are engaged in creative tasks.

In parallel with Resnick's ideas, Brennan (2011) introduces the concept of creative

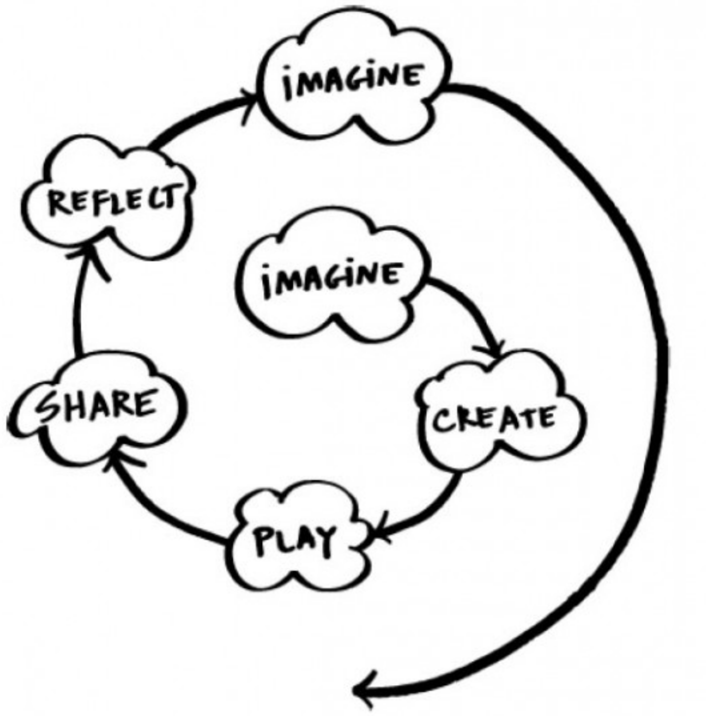


Figure 2.1. The Creative Learning Spiral (Resnick, 2007).

computing, a design based approach to engage young people in creation of computational artifacts. The aim of creative computing is to support young people's development as computational thinkers - individuals who can use computational skills in their everyday lives.

Although it is not the only solution for creative computing, Scratch has been built on top of this philosophy, the kindergarten approach, to foster creative computing by Mitchel Resnick's Lifelong Kindergarten group at MIT Media Lab (Resnick, 2007). It was built to create a more tinkerable, more meaningful, and more social programming environment that would give young people an opportunity to easily learn programming and create multimedia artifacts (Resnick *et al.*, 2009).

2.2.5. Place of Creative Computing in Learning Mathematics

Even though Scratch has been actively used in the scene of education since 2007 (Resnick, 2007; Resnick *et al.*, 2009; Resnick, 2012), most applications in literature focus on its effects on computational thinking, digital literacy and perception of computer-based majors (e. g., Baytak & Land, 2011a; Blau, Zuckerman, & Monroy-Hernandez, 2009; Brennan, 2011; Kafai, Peppler, & Chiu, 2007; Maloney *et al.*, 2008; Meerbaum-Salant *et al.*, 2010; Wolz *et al.*, 2010). Unfortunately, there are very limited number of studies focusing on applications of Scratch in mathematics education and none of these studies were able to prove positive effects of creative computing on learning mathematics.

Boyer (2010) investigated the effects on learning when fifth graders design multimedia artifacts that demonstrate an understanding of math content. In this study, students used Scratch programming environment to create projects on geometric solids. In contrast to studies conducted with Logo or its derivatives (e. g., Edwards, 1991; Harel & Papert, 1990; Hoyles & Noss, 1992), this study had mixed results, which showed that learning is not guaranteed when students are engaged in design tasks on Scratch. On the other hand, the researcher suggests that this approach could be used as an alternative form of formative or summative assessment.

Taylor *et al.* (2010) investigated the effects of using Scratch on mathematical thinking. While doing so, they used an interactive white board (IWB) along with computers to encourage collaboration, sharing and discussion among students. They conducted three case studies in which they analyzed students' use of mathematics in order to accomplish some tasks such as moving objects or changing speed. Then they collected opinions of both teachers and students. According to their findings, Scratch programming activities improved student motivation and they had an opportunity to explore and use sophisticated mathematical concepts. However, it was again not clear how much mathematical content students learned. Teachers did not believe that Scratch strongly supported learning mathematics, too.

Lewis and Sarah (2012) approached uses of Scratch in mathematics education in another way. In a summer enrichment program for 47 sixth grade students, they conducted a study to find out the correlation between student sores on a standardized test for mathematics and their scores on Scratch programming quizzes. During the enrichment program, majority of time was allocated to Scratch activities but students learnt Logo, too. At the end of the study, they found that the correlation between these two constructs was positively high.

2.2.6. Creative Computing Activities, Problem Solving and Reflection

It is generally accepted that mathematics education, including probability, is not simply about mathematical concepts and skills but also concerns the processes (Hoyles & Sutherland, 1992). These concepts and skills are learnt and employed in the process of a variety of situations. Though different problem solving strategies have been taught in mathematics classrooms (e. g., Polya, 1954; Schoenfeld, 1985; Bransford & Stein, 1984), more attention has been paid to encouraging students to shift from a product-oriented approach which is concerned only with a superficial involvement with the problem to one that is more reflective and demands efforts and time commitment. Hoyles and Sutherland (1992) argued that "that shift in the didactical relations in mathematics classroom and move to a more student autonomy and responsibility - where students actively involved in the construction of their own knowledge and make their own decisions as to strategy and explanation" (p.56). This shift implies more group interaction and interaction with thought provoking tools and manipulatives, including virtual toolkits, and argumentative collaboration either between students and/or between student and toolkits as a vehicle for developing problem solving skills. Researchers (Brown & Walter, 1983; Lave, Murtaugh, & de la Rocha, 1984; Hoyles & Sutherland, 1992) also stress the need for a structural knowledge base to problems and contextual influences on problem solving approaches. Hoyles and Sutherland (1992) highlights that when student knows about the context in which problem is embedded, it will be easier to solve rather than decontextualized problem solving strategies.

Problem solving is the ability to apply one's developed knowledge and skills in different situations. It requires students to integrate skills and concepts to deal with mathematical situations and problems. Students are taught many different problem solving strategies along with concepts and procedures of a learning unit. Gagne and Briggs (1974) put this reality as complex combinations of hierarchically ordered intellectual skills. Process of mathematical problem solving was comprehensively codified by Polya (1954) in his classical work. He proposed a generic four step problem solving: (i) understanding the problem, (ii) devising a plan, (iii) carrying out the plan, (iv) looking back at work. Much later, Bransford and Stein (1984) developed a problem solving model with five steps briefly known as IDEAL: (i) identifying problems and opportunities, (ii) defining goals, (iii) exploring possible strategies, (iv) anticipating outcomes, (v) looking back and learning. In similar vein, but in a narrower context, as outlined earlier, Resnick (2007) proposed a spiral learning cycle which requires an iterative process to be designed to reinforce critical thinking in the context of problem solving. The steps of the learning cycle are (i) *imagine*: think about what one wants to do, (ii) *create*: translate one's ideas into product, (iii) *play and act*: try out one's new creation and observe what works and what does not work, (iv) *share*: demonstrate one's creation to others and listen to what they think in order to get engaged in their creative process, (v) *reflect*: think about what one has learnt through the process of creation. A student may gain new knowledge from his or other's plays or acts, students will be re-engaged in the learning spiral by re-entering the imagine phase (Resnick, 2007). Resnick's spiral model is an extension of Papert's microworld model of learning through Logo programming (Papert, 1980), where learning is defined as an active process of planning, developing, reflection and debugging. In Papert's model, the planning phase is parallel to Resnick's imagine phase, the developing phase to create and play phases, the reflection and the debugging phases to share and reflect phases.

When it is considered to transfer problem solving skill developed in computer programming to mathematics, the two should not be separated but considered together in task, context and activity specification. Further, the programming activity and the outcomes of the activity should allow students to externalize their own thinking and reflect on it. This sort of metacognition in the problem solving process can be developed when content, context and task are appropriated for students' level of progress and the support through computer artifacts are provided. The Scratch environment provides such artifacts, and the learning environment to be designed around Scratch may provide facilities to students to select strategies, to try out ideas, to initiate challenging solutions, to organisation, to sequence, to implement and to reflective evaluation.

It is critical to promote reflective thinking during learning of any domain in order to assist a learner to develop strategies to employ new knowledge to more complex cases (Calder, 2010; Hsieh, Jang, Hwang, & Chen, 2011). Reflective thinking helps learners develop problem solving skills by prompting learners to step back and think about how they solve problems and how a particular set of problem solving strategies helped for accomplishing their goals. Reflective thinking is a process of referring particularly to the process of analyzing and making judgements about what has happened. According to Dewey (1933), reflective thinking is an active consideration of approach, knowledge and further conclusions to which that knowledge results in. Reflective activity in learning requires students to think about what they know, what they did, and learnt and what they needed to know or do to progress through their exploration (Moon, 1999; Schön, 1983). Hence, reflection may be studied as the synthesis of experience into knowledge and understanding (Calder, 2010). That is discussed by Schön (1983) as the concept of reflection in action which is a process a problem solver goes backward and forward between levels of a problem solution. For reflection, mapping a set of reference frames is necessary in learning processes both in concept formation and exploration of procedural knowledge (Rosenbaum, 2009).

Students' thinking evolves through problem solving processes. Along with relational and reference based (to imagine/plan, command sets and output) thinking, students may use logical reasoning to interpret and to evaluate the situation/task. Then, reflective thinking helps them determine the right commands and value of variables that produces the desired effect as well as desired outcome. In such a process, the feedback provided by the technological environment, students' peers and teachers play a great role. Feedback helps students to articulate the actions and gets them to re-engage in the process of creation as well as debugging or correcting mistakes. This connection has a positive effect in that the errors prompt further experimentation to achieve the desired output, leading to learning from errors and learning the consequences of different actions or approaches in the task domain. In the Scratch environment, students' problem sets will be compared to the outcomes, which are generally visual objects or animated objects.

In this study, the intention is to bring foundational principles of Scratch, creative computing and the kindergarten approach into mathematics education in order to build an engaging learning environment for students to study an abstract and/or unpopular mathematics subject, probability. Many software tools for learning probability are either too complex to learn or too simple so that students have very limited opportunities to understand the underlying concepts (Paparistodemou & Noss, 2004; Resnick & Wilensky, 1998; Shaughnessy, 1992; Wilensky, 1995). Scratch, while it does not bring any ready-made tools for learning probability, provides a great development environment which is easy to learn, fun to use, and intuitive for especially primary level students. Once basic tools are learned, students can develop their own applications on probability, such as simulations, games and experiments. By trying to develop algorithms for their projects, manipulating these algorithms and changing structures, they can improve their probabilistic thinking. Moreover, such a learning environment can increase students' motivation on learning, enabling educators to include explicit and formal aspects of probability more easily than traditional teaching practices.

3. SIGNIFICANCE OF THE STUDY

Further than mathematical studies, scientific applications and engineering problems, probability is immersed in our everyday lives directly. For example, we use probabilistic judgements when we choose to safeguard our children by living in a "low-crime" neighborhood or when we change our diet and exercise habits to lower the risk of heart disease (Wilensky, 1993). In other words, understanding probability is very important for one's ability to make decisions in life. Similarly, the necessity of developing a robust understanding of probability concepts is stressed many times by researchers and educators (e. g., Garfield & Ahlgren, 1988; Memnun, 2008; Pratt, 2005; Shaughnessy, 1992).

Nonetheless, the research shown that teaching probability does not guarantee to remedy people's false intuitions or misconceptions (Shaughnessy, 1992; Wilensky, 1995). Besides, new computer-based methods could not gain a common ground in schools in spite of exponentially increasing usage of technology in education. Combined with teachers' attitudes and formula-based questions in standardized tests, students struggle to develop deeper understandings, better intuitions of probability or even just a good taste of probability subjects (Memnun, 2008; Wilensky, 1993).

As mentioned by many researchers, developing powerful tools and methods to increase students' enthusiasm towards studying probability is definitely a need and a challenge (Abrahamson & Wilensky, 2005; Abrahamson *et al.*, 2006; Bar-On & Or-Bach, 1988; Resnick & Wilensky, 1998; Wilensky, 1995, 1996). Instead of trying to design better presentations of it, educators should concentrate on developing opportunities for students to engage with probability by modifying parameters, representations and even underlying systems of events (Abrahamson & Wilensky, 2003; Paparistodemou & Noss, 2004; Wilensky, 1995). To address such issues, many researchers developed simulations or games and studied success of their tools (e.g., Abrahamson & Wilensky, 2005; Gürbüz & Birgin, 2012; Kazak & Konold, 2010; Paparistodemou & Noss, 2004), yet there is a shortage of studies that analyze effects of using computer programming in probability instruction (Bar-On & Or-Bach, 1988; Wilensky, 1996). Besides, none of these studies were conducted with Scratch and/or primary school students. As of the date this thesis was written, there was a very limited number of studies on effects of Scratch programming on learning any topic in mathematics at primary school level (e.g., Boyer, 2010; Lewis & Sarah, 2012; Taylor *et al.*, 2010). To sum up, creating a learning environment based on principles of constructionist learning (Papert, 1980) and creative learning spiral (Resnick, 2007) for primary school students to study probability, using Scratch programming environment, is considered as a unique and worthwhile attempt.

4. STATEMENT OF THE RESEARCH PROBLEM

In this study, effects of developing video games on primary school 6^{th} grade students' learning of independent events are investigated. Particularly the following research questions frame the study: What are the effects of primary school students' development of video games with Scratch on their (i) achievement of independent events in probability, and (ii) reflective thinking towards problem solving?

4.1. Variables

There are two dependent variables in this study: independent events achievement and reflective thinking towards problem solving. Developing video games using Scratch Programming Environment is the independent variable of the study.

4.2. Research Questions

In order to investigate effects of video-game development in Scratch platform on students' learning of probability, two studies, a pilot study and a main study improved upon the results of the pilot study, were conducted. Effects of the learning activities were studied with pretests and posttests for measuring students' learning gain. In addition, reflective thinking towards problem solving was measured with a scale

The research questions of this study are:

(i) Will there be any significant difference between students' pretest and posttest scores of Probability Achievement Test?
(ii) Will the intervention significantly affect students' reflective thinking towards problem solving?

4.3. Hypotheses

The hypotheses of this research study are:

(i) There will be a statistically significant difference between students' pretest and posttest scores of Probability Achievement Test.

(ii) The intervention will significantly affect students' reflective thinking towards problem solving.

5. METHODOLOGY

This research is divided into two phases. Before the full application of the research design, a pilot study was conducted in the spring of 2012. The goal of the pilot study was to gain experience with a risk group to identify any possible limitations with the learning and teaching approach, and technical issues to be raised in the experimental studies. Consequently, the researcher was able to see the effectiveness of the first research design and make some adjustments for the final application. There are many common parts of both studies. However, the final study included some fine tunes to improve the effectiveness of interventions.

5.1. Instrumentation

In order to test the research hypotheses for the pilot study, quantitative data were collected through two different instruments: Probability Achievement Test (PAT) and Reflective Thinking towards Problem Solving Scale (RTPSS).

5.1.1. Probability Achievement Test

In order to measure participating students' achievement in probability, probability achievement tests developed by Kavasoglu (2010) were used in both pilot study and main study. The instrument by itself consisted of three different tests to measure the achievement of students at primary school 6^{th}, 7^{th}, and 8^{th} grades separately. 8^{th} grade questions of the instrument were excluded for this study because no 8^{th} grade students participated to either the pilot or the main study. Each question of the instrument was developed to measure a particular objective in primary school mathematics curriculum (see Table 5.1 and Table 5.2). Sixth grade probability test included 32 multiple-choice questions (see Appendix A). Kavasoglu (2010) found that the 6^{th} grade test has a high internal consistency (KR-20) = 0.90 and mean item difficulty (Pj) = 0.50 after a study conducted with 120 students. Seventh grade probability test, on the other hand, included 44 multiple-choice questions (see Appendix A). The researcher found that the 7th grade test also has a high internal consistency (KR-20) = 0.93 and mean item difficulty (Pj) = 0.54 after a study conducted with 111 students.

For this study, both 6th and 7th grade tests were split into two tests as pretest and posttest, according to objectives of the unit. In other words, questions used in a pretest for a particular objective are equivalent to questions used in a posttest for the same objective. The distribution of questions are presented in Table 5.1 and Table 5.2.

Table 5.1. Objectives of 6th grade probability unit and corresponding Probability Achievement Test questions (see Appendix B).

Objective	Pretest	Posttest
Being able to use basic principles of counting in solving problems	1, 2	1, 2
Being able to explain experiment, outcome, sample space, event, random selection, and equiprobability concepts	3, 4	3, 4
Being able to explain an event and probability of it	5	5
Being able to build and solve problems associated with probability of an event	6, 7, 8, 9	6, 7, 8, 9
Being able to explain certain and impossible events	10, 11, 12, 13	10, 11, 12, 13
Being able to explain complementary events	14	14

5.1.2. Reflective Thinking towards Problem Solving Scale

In order to measure changes in students' reflections on their problem solving processes, the Reflective Thinking towards Problem Solving Scale (RTPSS) developed by Kizilkaya and Askar (2009) was used. The scale consists of 14 items in three dimensions: questioning, reasoning and evaluation (Appendix B). Students can answer

Table 5.2. Objectives of 7^{th} grade probability unit and corresponding Probability Achievement Test questions (see Appendix B).

Objective	Pretest	Posttest
Being able to explain and calculate permutation	1, 2, 3, 4, 5, 6, 7	1, 2, 3, 4, 5, 6, 7
Being able to determine experiment, sample space and outcome for mutually exclusive and non-mutually exclusive events	8, 9	8, 9
Being able to explain mutually exclusive and non-mutually exclusive events	10	10
Being able to calculate probability of mutually exclusive and non-mutually exclusive events	11, 12, 13, 14, 15, 16, 17	11, 12, 13, 14, 15, 16, 17
Being able to solve probability problems using geometry knowledge	18, 19, 20	18, 19, 20

each question as always, often, sometimes, rarely and never. The test is scored as always = 5, often=4, sometimes=3, rarely=2 and never=1. The researchers applied this scale to 339 7^{th} grade primary school students and analyzed the data statistically. They estimated internal consistency of the scale as $\alpha = 0.83$.

5.1.3. Student Project Assessment Rubric

In addition to quantitative analysis of students' achievement in probability and changes in their reflective thinking towards problem solving, students' Scratch projects were collected to qualitatively analyze their experiences in the main study. There are two reasons behind this decision. First, there is not a quantitative measurement tool to ensure that students learned Scratch as a tool. If students did not learn Scratch enough, it may have become a demotivating factor for them in learning probability, as opposed to intended fostering and encouraging effects. Secondly, it is important to check if students were able to convert their probabilistic thinking skills to Scratch projects. Moreover, how important is it to be able to develop robust algorithms in learning probability? Do students who develop algorithms successfully achieve higher than those who can't, or is it enough to be a part of probabilistic thinkers?

In order to draw a framework for qualitative analysis, similar studies conducted in recent years were studied. For instance, in order to analyze projects created by 5^{th} grade students using Scratch to demonstrate their understanding of the properties of geometric solids, Boyer (2010) created a spreadsheet and he recorded the number of sprites, the number of backgrounds, the number of scripts, the number of command blocks used by students in their projects. Also, he recorded his reflections on students' progress each week. In another study, Baytak and Land (2011b) investigated 5^{th} grade students' usage of Scratch programming for studying environmental science. To analyze 100 projects developed by students, they used an evaluation rubric with four dimensions: game genre, graphics and character development, control options and duration of the game. Besides, they analyzed students' use of different Scratch programming concepts utilizing the methodology developed by Maloney *et al.* (2008). Thirdly, Denner *et al.* (2011) created a coding scheme, based on International Society for Technology Education (ISTE) National Education Technology Standards for Students and another similar scheme created by Martin, Walter, and Barron (2009) (cited in Denner *et al.* (2011)). They coded each game in three categories (programming, documenting and understanding software, and designing for usability) and 24 subcategories.

Unfortunately, the number of studies is low and none of these studies are conducted on learning/teaching probability. Still, they are found to be helpful in choosing a proper analysis method. In consequence, an assessment rubric was designed to analyze students' projects. After designing the first draft of the rubric, it was revised according to feedback of four mathematics educators and three educational technology experts. The final form of the rubric (Table 5.3) contains two dimensions: developing video games and developing strategies for solutions of probability problems. All items of the rubric are rated as not evident, insufficient, successful, and creative. In this section, items of the rubric are explained firstly and then selected projects developed by the students were analyzed according to the rubric. In the end, analysis of all projects were shared.

Table 5.3. Student Project Assessment Rubric.

		Not Evident	**Insufficient**	**Successful**	**Creative**	**Researcher Comments**
DEVELOPING VIDEO GAMES	Usage of Sprites					
	Usage of Scratch Blocks					
	Development of Algorithms					
	User Input					
	User Feedback					
	Variables					
	Overall Project Completion					
DEVELOPING STRATEGIES FOR SOLUTIONS OF PROBABILITY	Representation of Sample Space					
	Experiment Design					
	Experiment Implementation					
	Multiple Experiment Simulations					
	Representation of Outcomes					

5.1.3.1. Developing Video Games. This dimension includes the following seven items:

(i) Usage of sprites item, which is adopted from Boyer (2010) and Baytak and Land (2011b), considers students' utilization of sprites (characters, objects, backgrounds and costumes) in Scratch. If a student used no sprites, did not create anything visual with Scratch in other words, it is categorized as "usage of sprites is not evident". If there are some sprites but they are irrelevant or not enough to create the project successfully, it is categorized as insufficient. If the student was able to import a good number of sprites, which are relevant to the task, it is categorized as successful. Lastly, if a student used more than required number of sprites, which are also relevant to the task, it is categorized as creative.

(ii) Usage of scratch blocks item, which is adopted from Boyer (2010), evaluates students' practices of scripting in their projects, regardless of algorithm design. If a project consists no command blocks, it is signed as not evident. If there are command blocks in the project but they are inadequate or irrelevant, the project is considered as insufficient in terms of scratch blocks. If the project contains all command blocks that are required to run the task, it is evaluated as successful. Lastly, if a student used additional command blocks that are relevant to the task, the project is evaluated as creative.

(iii) Development of algorithms item, which is adopted from Baytak and Land (2011b), weighs up students' success in putting command blocks together to create algorithms. If there are no algorithms, the evaluator checks not evident column. If there are algorithms in project that are unfinished or unable to run properly, it is checked as unsuccessful. Projects that contain algorithms that run as expected are signed as successful. And, if a student designed an algorithm in an unexpected, alternative way but still run successfull, it is considered as creative.

(iv) User input item, which is also adopted from Baytak and Land (2011b), is to check if students took advantage of user input methods such as keyboard, mouse, webcam or microphone in their projects. If they did not, their projects are evaluated as not evident. If they included user input but did not integrate it with the task, their projects are signed as insufficient. If a project takes user input properly, it is considered as successful. A project that gives user more control than required by the task is evaluated as creative.

(v) User feedback item, which is adopted from Denner *et al.* (2011), checks a projects' inclusion of visual feedback such as text messages, image changes or alert sounds. If there is no visual feedback, the project is marked as not evident. If the feedback in the project is irrelevant to the task, it is marked as insufficient. A project containing visual feedback that is designed as expected is marked as successful. Beyond implementing basic requirements of the task, if a student adds additional feedback, her or his project is considered as creative.

(vi) For variables item, which is adopted from Baytak and Land (2011b) and Denner *et al.* (2011), a students' use of data is analyzed. If a student did not add any variables to the project, it is marked as not evident. Projects that have irrelevant variables are marked as insufficient. If a project contains just the required number of variables that are used correctly, it is marked as successful. For a project to be marked as creative, it has to include more variables than required by the task and those extra variables should be relevant to the project.

(vii) Overall project completion item, which is also adopted from Denner *et al.* (2011), as a measure of developing video games, evaluates if a project is working properly. If there is a project file but it is not working at all, the field is marked as not evident. If the project works but it is incomprehensible or buggy, the field is marked as insufficient. If it is working consistently, the field is marked as successful. If a project goes beyond the given task, adds new features and runs them successfully, the field is marked as creative.

<u>5.1.3.2. Developing Strategies for Solutions of Probability Problems.</u> This dimension includes the following five items:

(i) Representation of sample space field evaluates students' competence in visually representing the sample space of the task. This item is included to the rubric because sample space is one of the most important constructs of probability. If a student has a misconception or learning difficulty related to sample space, s/he would fail in understanding other related constructs such as fairness, impossible events or equiprobability, as well as having difficulty in assessing probabilities of particular events (Fischbein & Schnarch, 1997; Jones & Thornton, 2005; Tversky & Kahneman, 1982). If there is no visual to represent the sample space, this field is marked as not evident. Projects that show incorrect number of sprites to represent the sample space are marked as insufficient. If the sample space is presented as expected, the field is marked as successful. If a student uses more than one methods to represent sample space successfully, this field is marked as creative.

(ii) Experiment design field examines the project in terms of overall visual design for placement of objects, buttons, variables, on screen instructions and user feedback.

Without a complete experiment design, a project would fail to reflect the student's understanding of the problem situation (Wilensky, 1995). Also, without a complete experiment design, students might not be able to complete the tasks. Projects that does not include any experiment design elements are marked as not evident. If some of the mentioned elements are existing but some of them are missing or irrelevant tot the task, the project is ticked as insufficient. The projects that contain all necessary elements required by the particular task are marked as successful. In order for a project to be marked as creative, it has to include an alternative, unexpected designs for the task that works properly.

(iii) Experiment implementation item is to check if a student successfully created algorithms that generate random results. This item is particularly important because by developing their own algorithms for probability problems, running those algorithms multiple times and fixing bugs, students get a chance to build mental models of probabilistic phenomena through interacting with underlying structures of probabilistic experiments (Wilensky, 1995). If there are no algorithms or algorithms that are irrelevant, this field is marked as not evident. If there are relevant algorithms but they do not run randomly, the field is marked as insufficient. If the algorithms with simple blocks run as expected, generate random results based on the sample space, the project is marked as successful. Finally, if a student develops a code block which consists more abstract blocks such as custom blocks, logic operators, advanced mathematical blocks or sensing blocks, her or his project is marked as creative.

(iv) Multiple experiment simulations, as expected by its name, checks if a project gives the user necessary tools to conduct multiple probability experiments and see the results cumulatively. Simulating a particular probability experiment many times, seeing results of both individual experiments and all experiments cumulatively is very important for developing local and global meanings of randomness (Paparistodemou & Noss, 2004). If there is no opportunity to make more than one experiment, the project is ticked as not evident. If it is possible to conduct multiple experiments but the user is unable to see the results cumulatively, the project is ticked as insufficient. Projects that run multiple experiments and reports the results are marked as successful. A creative project, lastly, has to include alternative mechanisms such as drawing graphs or simultaneous experiments.

(v) Representation of outcomes, as the last item of the rubric, considers a project's achievement in representing outcomes of events as words, images, sounds etc. Wilensky (1993) states that "the richer the set of representations of the object, the more ways we have of interacting with it, the more concrete it is for us" (p. 58). Therefore, if a student does not spend enough time in designing representations for outcomes of experiments, it means that s/he does not interact with the experiment enough. Projects that does not show anything visually after an experiment are marked as not evident. If a project has some visuals but they do not work properly, it is marked as insufficient. If a project gives just enough visual feedback and the feedback works for each experiment, it is considered as successful. If a project contains multiple and unexpected visual representations for outcomes of the experiment, it is marked as creative.

5.2. Pilot Study

Before the main application, a pilot study was conducted with a group of 6^{th} and 7^{th} grade students in order to identify the flaws of the research design, instruments, materials and activities.

5.2.1. Sample

The pilot study was conducted at an economically disadvantaged district of Istanbul, Turkey. It was conducted at a Bagcilar public school with 6^{th} and 7^{th} grade students. Bagcilar was randomly selected from a pool of similar districts. Then Cumhuriyet Primary School was selected randomly from the pool of primary schools in the same district. The students that will participate to the study were chosen from a pool of underachieving students by the school's administration in a non-random fashion. Unfortunately, the researcher had no influence in selection of students.

In the beginning, the treatment group included 20 6^{th} grade and 22 7^{th} grade students. However, some students dropped out during the semester due to various reasons and only 8 sixth grade and 7 seventh grade students attended every session. None of them had computers or internet connection in their homes. None of them had any previous Scratch programming knowledge. Similarly, the control group included 40 sixth grade and 43 seventh grade students in the pretest phase, but only 9 sixth-grade and 8 seventh-grade students answered all post tests because the posttests were applied at last week of the semester, many students were absent. With the same reason, most students in the control group did not attend any lessons in the last two weeks of the semester.

5.2.2. Design

Owing to the lack of control in sample selection process, the design of the pilot study was determined as nonequivalent control group quasi-experimental design. In such designs, two or more groups are pretested, administered a treatment and posttested. Members of groups are not chosen randomly but groups are randomly assigned to treatments (Campbell & Stanley, 1963; Gay, 2000).

There are four groups in this study: 6^{th} grade treatment group, 6^{th} grade control group, 7^{th} grade treatment group and 7^{th} grade control group. All groups were given pretests of Probability Achievement Test and Reflective Thinking towards Problem Solving scales at the beginning of the semester. The treatment group students studied probability unit only during the intervention. They did not receive any formal instruction on probability. The intervention lasted for 10 weeks, 10 hours in total, but the first four weeks were dedicated to learning basics of Scratch programming. Students studied probability for 6 hours by developing video games with Scratch. On the other hand, the control group received formal classroom instruction on probability. They studied probability for three weeks, 10 hours in total. All groups were given posttests of the same scales after the intervention. The difference between pretest and posttest scores provided an indication for learning gain, and were statistically analyzed.

Table 5.4. Change of sample size throughout the pilot study.

Grade	Group	Pretests	Intervention	Posttests
6^{th}	Treatment	20	11	8
	Control	40	39	9
7^{th}	Treatment	22	9	7
	Control	43	41	8

5.2.3. Role of the Researcher

In the first four weeks, the researcher's role in the pilot study was to teach how to develop games with Scratch. Throughout this process, the students received 15 minutes of instruction on basics of Scratch programming and then worked on a related task for 45 minutes. The researcher continuously monitored students' progress and helped them whenever they needed. He also made sure that all students completed these four tasks successfully.

When students started developing projects based on pre-developed game scenarios, the researcher's role was to help students when they failed to convert their ideas into a Scratch project. In other words, he helped students when they struggled to use a particular interface command or a programming block. However, there was no probability or Scratch teaching during this period. Also, the researcher did not help students in developing algorithms.

5.2.4. Procedure

Both 6^{th} and 7^{th} grade students attended the intervention for ten weeks. Workshops were conducted as 60-minute after school meetings once a week, every Thursdays, at the school's computer lab. In the first four weeks, students learned how to develop projects in Scratch. After fourth week activities, pretests were given to the students. In the following six weeks, the researcher gave students three open ended game scenarios on real world applications of probability. Each student worked alone and spent two weeks for each task. At the end of workshops, the students were given posttests. The schedule of workshops is shared in Table 5.5 and Table 5.6.

In the first four weeks, both 6th and 7th grade students worked on the same activities. None of these activities included any mathematics contents. They were designed to teach basics of Scratch programming to students. In this period, students were taught designing visuals, developing algorithms by putting together command blocks and functionalities of many blocks in six categories: movement, looks, control, sensing, operators and data. On the other hand, sound blocks were not taught to students because of technical problems in sound output of computers and pen blocks were skipped because students did not need them to finish activities. Each meeting, the researcher gave step-by-step instructions for 15 minutes about these topics and gave students the task. In the next 45 minutes, students worked on their projects individually. In all meetings students developed a different project. However, these projects were not collected for data analysis.

Figure 5.1. Example screenshots of two projects developed by students in the pilot study: (i) lotto number generator, (ii) wheel of fortune.

In the remaining six weeks, students developed video games based on one-paragraph game scenarios written by the researcher. These scenarios were designed according to particular objectives of the learning unit (see Table 5.5 and Table 5.6). In the 5th week, treatment group students were given the first game scenario. In the beginning, they were asked to create visuals of their projects. Most of the time, students finished design before the end of the session and started coding. In the 6th week, they finished their projects by developing necessary algorithms. In the last 10 minutes, the researcher asked students to play with their projects. There was no discussion or formal probability teaching. Similarly, students developed one game in 7^{th} and 8^{th} weeks and another game in 9^{th} and 10^{th} weeks. All projects developed by students were collected by the researcher but these projects were not used for data analysis. One week after the 10^{th} week, the researcher collected posttest data.

5.2.5. Data Collection

Using pretest version of the two tests, data collected from both experimental and control groups on the same day, seven days before control groups started studying probability and the experimental groups started probability activities. In one hour, each student answered Reflective Thinking Scale towards Problem Solving firstly and Probability Achievement Test secondly. Pretest data was gathered from 20 6^{th}, 22 7^{th} grade experimental group students and 40 6^{th}, 43 7^{th} grade control group students respectively.

The posttests were applied to the control group seven days after probability instruction ended. On the other hand, experimental group students answered post tests three weeks later, one week later than the end of activities. Data collection, again, lasted one hour in the same order. Unfortunately, due to absenteeism and technical problems, only 8 6^{th} grade and 7 7^{th} grade students from the experimental group could participate in post data collection. Similarly, only 9 6^{th} grade and 8 7^{th} grade students could participate in post data collection.

Table 5.5. Schedule of 6^{th} grade activities in the pilot study.

Week	Subject	Content	Task	Objective	Description	Mathematics Content
1	Introduction to Scratch	Characters, backgrounds, movement blocks,control blocks	Aquarium Animation	n/a	Students will learn how to use Scratch basically. They will develop an aquarium animation in which at least three fishes flocks around the screen.	n/a
2	Introduction to Scratch	Costumes, look blocks, user input	Dancing Game	n/a	Students will learn how to change costumes and appearance of characters. They will also learn how to use keyboard input in their projects. They will develop a dancing game in which the character makes a different move for each key in the keyboard.	n/a
3	Advanced Scratch	Sensing blocks, operators, conditional blocks,	Escaping from the Witch	n/a	Students will learn how to detect if a character touches another as well as how to use if-else conditional blocks. They will develop a catching game, in which the main character will try to escape from a witch.	n/a
4	Advanced Scratch	Calculations, broadcasting, variables	Pet Feeding	n/a	Students will learn how to make calculations, use variables and broadcast messages for communication between characters. They will develop a pet feeding game in which the user controls a pet to eat or avoid various things and collect points to grow.	n/a
5 & 6	Probability Task	Basic Principles of Counting	Dress Suggester	1	Students will develop a dress suggesting game which consists a set of t-shirts and jeans. The user will press a button and the game will suggest a random pair of t-shirts and jeans.	This task is designed to motivate students to study on basic principles of counting, the first objective of the learning unit.
7 & 8	Probability Task	Experiment, outcome, sample space, event, random selection	Safari in Africa	1, 2	Students will develop a game in which the pratoganist travels in africa and game shows him/her random animals.	This task is designed to make students think of the basic concepts of probability, probabilistic events and random selection.
9 & 10	Probability Task	Certain and impossible events, calculating probability of an event	Lotto Number Generator	1, 2, 3, 4, 5	Students will develop a Lotto Number generator which will suggest a new random number after pressing a specific keyboard button.	This task is designed to cover all objectives of the learning unit.

Table 5.6. Schedule of 7^{th} grade activities in the pilot study.

Week	Subject	Content	Task	Objective	Description	Mathematics Content
1	Introduction to Scratch	Characters, backgrounds, movement blocks,control blocks	Aquarium Animation	n/a	Students will learn how to use Scratch basically. They will develop an aquarium animation in which at least three fishes flocks around the screen.	n/a
2	Introduction to Scratch	Costumes, look blocks, user input	Dancing Game	n/a	Students will learn how to change costumes and appearance of characters. They will also learn how to use keyboard input in their projects. They will develop a dancing game in which the character makes a different move for each key in the keyboard.	n/a
3	Advanced Scratch	Sensing blocks, operators, conditional blocks,	Escaping from the Witch	n/a	Students will learn how to detect if a character touches another as well as how to use if-else conditional blocks. They will develop a catching game, in which the main character will try to escape from a witch.	n/a
4	Advanced Scratch	Calculations, broadcasting, variables	Pet Feeding	n/a	Students will learn how to make calculations, use variables and broadcast messages for communication between characters. They will develop a pet feeding game in which the user controls a pet to eat or avoid various things and collect points to grow.	n/a
5 & 6	Probability Task	Permutation	Dress Suggester	1	Students will develop a dress suggesting game which consists a numerous t-shirts. The user will press a button and the game will suggest a pair of t-shirts.	This task is designed to cover permutation, the first objective of the learning unit.
7 & 8	Probability Task	Mutually Exclusive and Non-mutually Exclusive Events	Wheel of Fortune	1, 2, 3	Students will develop a wheel of fortune. Two players will roll the well one by one pressing to a button and they will collect points.	This task is designed to push students to try to understand of mutually exclusive and non-mutually exclusive events.
9 & 10	Probability Task	Calculating Probability of Mutually exclusive and Non-mutually Exclusive Events	Lotto Number Generator	1, 2, 3, 4	Students will develop a Spin the Bottle game. There will be at least four players in two groups. After spinning the bottle, the game will ask a random question, as well.	This task is designed to motivate students on studying mutually exclusive and non-mutually exclusive events.

5.2.6. Data Analysis and Results

Due to smallness of sample size, means of pretests and posttests were not compared using classical parametric or non-parametric tests such as t-test or Wilcoxon Signed-Rank Test. Instead, effect size analysis, which is defined as "a standardized, scale-free measure of the relative size of the effect of an intervention" by Coe (2002), was used. In order to measure the changes in dependent variables, Cohen's d and Hedge's g effect size values were calculated on the results of both scales.

As effect size measures show, the effect of intervention on 6^{th} grade students' probability achievement was negative and at medium level. In contrast, the effect was positive for 7^{th} grade students at medium level. For the control groups, 6^{th} grade students' results yielded no effect at all while 7^{th} graders' results show a large positive effect. To sum up, the results indicate that the intervention fell behind traditional classroom teaching in terms of formal and procedural probability knowledge.

Table 5.7. Effect size analysis of probability achievement data for pilot study.

		Pretest		Posttest		Effect Size		
	n	mean	sd	mean	sd	Cohen's d	Hedge's g	
6^{th} Grade Treatment	8	4.63	1.30	3.63	1.41	-0.74	-0.70	medium
6^{th} Grade Control	9	4.67	1.58	4.67	3.50	0.00	0.00	negligible
7^{th} Grade Treatment	7	2.57	2.15	4.14	2.27	0.71	0.69	medium
7^{th} Grade Control	8	5.38	2.50	7.13	1.64	0.83	0.78	large

In contrast to two PAT, the effect of this intervention on both 6^{th} and 7^{th} grade students' RTPSS was better than traditional classroom settings. In both levels, the effect on treatment group students was small but positive. However, the effect was negligible for the control group students.

Table 5.8. Effect size analysis of reflective thinking towards problem solving data for pilot study.

		Pretest		Posttest		Effect Size		
	n	mean	sd	mean	sd	Cohen's d	Hedge's g	
6^{th} Grade Treatment	8	51.5	4.24	53.25	6.43	0.32	0.30	small
6^{th} Grade Control	9	55.33	5.63	55.67	6.75	0.05	0.05	negligible
7^{th} Grade Treatment	7	52.29	8.20	53.86	7.13	0.20	0.19	small
7^{th} Grade Control	8	55.88	14.41	56.75	10.28	0.07	0.07	negligible

To conclude, the results of the pilot study showed that the intervention was not effective enough to produce desired outcomes. Even though the data collected is not enough to make interpretations based on statistical analysis, the analysis of the size of the effect of the intervention revealed that activities were unsuccessful to increase students' probability achievement or problem solving reflection.

5.2.7. Limitations of the Pilot Study

In the beginning, the intervention was planned as a series of complementary activities for students' regular mathematics courses. Unfortunately, the researcher's proposal of using one of four weekly hours of mathematics course was rejected by the school administration. Therefore, the study had to be conducted as an after school activity. Another major problem was not not being able to choose a random sample of students for the intervention. The school administration wanted to choose the participants of the study among underachieving students. These two major problems gave birth to some other problems that affected the robustness of data collection and intervention processes.

Firstly, no mathematics teacher supported the researcher in the study because their shift ended before workshops begun. Secondly, because there were two different intervention groups, each workshop had to last a maximum of 60 seconds because school was being closed at 16:00 and parents did not want their children to be late. Lastly, because there was a one hour break between the end of school time and beginning of workshops for 6^{th} graders and two hours break for 7^{th} graders, it was impossible to have a control on students' attendance. As a result, there was a huge difference between the number of students who started workshops and the number of them who finished successfully.

5.3. Main Study

5.3.1. Lessons Learnt for the Study

The results of the pilot study indicated that, even though there are many studies in favor of computer programming as a very powerful method to gain attention of students (e.g., Kafai & Peppler, 2011; Papert, 1980; Resnick, 2006), expected learning outcomes does not follow automatically. Based on the aforementioned results, in order to increase the effectiveness of the research design some major and minor tweaks were made on the activities, the research settings, and the procedure.

Firstly, activities that were designed to teach basics of Scratch programming were revised. One of the problems in the pilot study was the fact that students paid attention to design, development and play much more than mathematical thinking and probability content. The reason behind this situation might be the fact that the students perceived activities more like a game development workshop rather than a set of mathematical activities because first four activities were just simple animations and games without any probability content. Further, since the activities of the research was conducted as an after-school activity, the students were tired and may have perceived activities as game activities. The main study was conducted as a part of the mathematical applications course and students started using ratio, fractions, mathematical operations, probability concepts and randomness right away.

Secondly, the lack of connection between probability content and game scenarios in the pilot study was considered as another problem in the research design. In the main study, a mathematics teacher took part in all activities with the researcher, to conduct explicit discussions and problem solving activities about probability concepts and randomness.

Thirdly, the total study time was increased. In the pilot study, there were 4 hours dedicated to Scratch programming and 6 hours dedicated to probability activities. On the other hand, the control group students took traditional probability instruction in classroom for 10 hours. In the main study, the intervention lasted for a total of 13.5 hours and duration of the meetings were increased from 60 minutes to 90 minutes.

Lastly, all tasks of the main study were revised. Instead of just giving scenarios that do not include much formal probability applications, new activities designed to encourage students to think about probabilistic concepts and calculations rather than just design and programming. There were three pre-designed game scenarios and two tasks in which students are provided a simple probability question to solve by developing a Scratch project.

All in all, the main intervention of this research study was designed in order not to repeat the mistakes of the pilot study, and aimed to give students more opportunities to use programming to their increase probability achievement.

5.3.2. Design

The design of the main study is a one-group pretest-intervention-posttest pre-experimental design. This design involves a single group that is pretested, exposed to a treatment, and posttested. There is not any random assignment of groups of individual members in this design (Campbell & Stanley, 1963; Gay, 2000). This research design is utilized because as in pilot study, the researcher had no control in choosing the sample for the research study.

Participating students were administered pretests of PAT and RTPSS seven days prior to beginning of courses, and posttests of the same scales three weeks after the last course. Because 5^{th} and 6^{th} grade students attended the main study and they studied 6^{th} grade contents, 7^{th} grade questions of PAT was not used.

Each week, students attended mathematics application course in two periods for 90 minutes. In the first four meetings, they learned basics of Scratch programming environment. Contrary to the pilot study, in which students developed basic projects in Scratch without any mathematics content, students were engaged in mathematics concepts and problem solving activities right away (see Table 5.9). In the 5^{th}, 7^{th}, and 8^{th} weeks, students developed games according to a pre-developed game scenario. Additionally, they developed applications to reflect on a given mathematics problem in the 6^{th} and 9^{th} weeks. In all sessions, students were given a worksheet describing the learning content and the task (see Appendix C).

5.3.3. Sample

The research was conducted in VKV Koc Schools, a private school in Istanbul. Participants of the study were 18 5^{th} grade and 12 6^{th} grade students. Students were not separated according to their grade levels and participated meetings together. In terms of prior mathematics achievement, based on students' PAT pretest scores, the group was heterogenous. Mean of 5^{th} grade students' scores was 3.56 (sd=2.332) and mean of 6^{th} grade students' scores was 3.25 (sd=2.768). Furthermore, the PAT pretest scores of two groups were compared using the Kruskal-Wallis H Test and it was found that there was no statistically significant difference between them ($H(2) = .242$, $p > .05$), with a mean rank of 16.15 for the 5^{th} grade students and 14.54 for the 6^{th} grade students.

5.3.4. Participants

The students and the researcher were not the only people who contributed to this study. First of all, three experienced mathematics teachers from VKV Koç Schools took part in interventions and conducted discussions with students. In addition, all three of them, along with an independent mathematics education researcher, reviewed all activities and items of developing strategies for solutions of probability problems dimension of SPAR and provided feedback to the researcher before the study. Items of developing video games dimension of SPAR, on the other hand, was revised by three

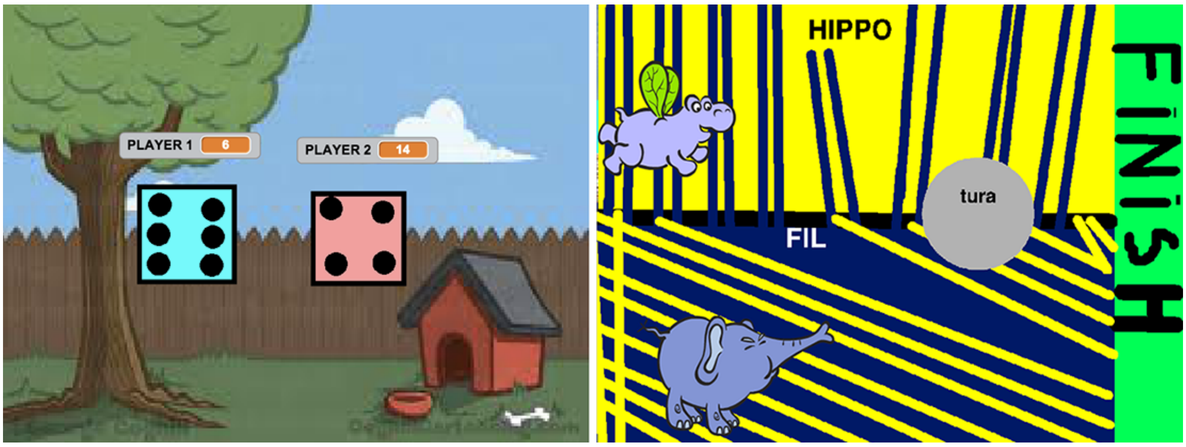


Figure 5.2. Example screenshots of two projects developed by students in the main study: (i) dice experiment, (ii) probability race experiment.

educational technology experts. Lastly, two independent evaluators rated the students' projects.

5.3.5. Role of the Researcher

The role of the researcher in this study was to help students learn Scratch programming language and assist them in accomplishing tasks. Only the first four meetings of the study included 30 minutes of programming instruction. While students were working on tasks, he continuously monitored their progress and helped them whenever needed. On the other hand, he were mostly passive in probability discussions. He just helped students when the mathematics teacher asked them to make adjustments in their projects.

5.3.6. Procedure

Even though 5^{th} and 6^{th} grade students participated to the main study, classes were mixed and all students participated in same activities. Workshops were conducted as two 40 minute sections divided by a 10 minute break as part of mathematical applications course. Pretest data for PAT and RTPSS was collected one week before the first activity. Then, students learned how to develop projects in Scratch for four weeks. In contrast to the pilot study, all activities were based on mathematics concepts (see Table 5.9). The projects developed by students in the first four weeks were not collected for analysis. In the following five weeks, the researcher gave students five different tasks each week. All tasks were divided into two phases. In the beginning of tasks, the students developed projects based on the task and their imaginations. After about 40 minutes of development, their teacher conducted discussions with students for 10 minutes. Following the discussions, the students were asked to make several additions or modifications to their projects (see Table 5.10). All five projects developed by the students were collected for data analysis through SPAR. Three weeks after the last lesson, the students were given the posttests.

5.3.7. Data Collection

Using RTPSS and the pretest version of PAT, data collected from participating students 7 days before they started studying probability through video game programming. In a total of 50 minutes, each student answered RTPSS firstly and PAT secondly. Pretest data was gathered from 35 students.

The posttests were answered by the students three weeks after intervention ended. Again, they answered scales in 50 minutes, spending 25 minutes for each scale. Posttest data was collected from 30 students because 5 students were absent in data collection due to personal reasons.

5.3.8. Limitations of the Main Study

In contrast to the pilot study, main study was conducted almost as planned. Still, there were limitations that kept the researcher from collecting more data. Firstly, the school administration asked the researcher not to record sessions because parents would not approve it. Secondly, there was no time to conduct interviews with students to collect qualitative data because their schedule was tight and they had to leave the school just after meetings. It was not allowed for them to miss service bus because the school was far away from city center and public transport was not available.

Table 5.9. Schedule of first four weeks of main study activities.

Week	Subject	Content	Task	Objective	Description	Mathematics Content
1	Introduction to Scratch	Characters, backgrounds, movement blocks,control blocks	Aquarium Animation	n/a	Students will learn how to use Scratch. They will develop and program an aquarium animation in which at least three fishes flock around the screen programmatically.	After developing the aquarium, the teacher will conduct a discussion about the movements of fishes and which mathematical concepts do they need to know in order to change movement of fishes. Then s/he will draw some shapes to the board and will ask students to make their fishes move in such shapes. In the end, students will again discuss the mathematics concepts they utilized and calculate the distance their fishes traveled.
2	Introduction to Scratch	Costumes, look blocks, events, user input	Loves me, loves me not	n/a	Students will learn how to change costumes and appearance of characters. They will also learn how to use keyboard input in their projects. They will develop a "loves me, loves me not" game in which the player will press a keyboard button to decrease the leafs of a flower one by one.	After finishing their initial projects, the students will discuss the relevance of fractions with their flowers and leafs. Then the teacher will write some fractions to the board and ask students to change their according to these fractions.
3	Advanced Scratch	Variables, loops, logic	Lottery Simulation	n/a	Students will learn how to use variables, loops and if-else blocks. They will develop a lottery simulation which can be manipulated by changing values of variables such as digit count or max number.	The teacher will discuss sample spaces with students and ask them about some certain and impossible events. Students will be asked to make experiments with some given variable values. Lastly, they will be asked to manipulate their projects in order to make 1000 experiments at once and find out the probability of each number.
4	Advanced Scratch	Sensing, variables, control blocks	Pet Feeding	n/a	Students will develop a pet feeding game, in which the user controls an animal with keyboard, tries to eat delicious foods and avoid bad ones. The animal will grow or shrink according to the score of the player.	The teacher will conduct a discussion about ratio concept and its relevance to this task. Then s/he will write some ratios to the board and ask students to make their animals grow or shrink according to given ratios.

Table 5.10. Schedule of last five weeks of main study activities.

Week	Subject	Content	Task	Objective	Description	Mathematics Content
5	Game Development	Basic events	Heads and Tails	1, 2, 3, 4, 5	Students will be asked to develop a heads and tails game. There will be a section to make the choice and then a button to flip the coin randomly	The teacher will use one of students' projects and play the game with the whole class. Then s/he will ask them to flip the coin 20 times, note the results and discuss the probability of the event. Furthermore, s/he will collect results of whole students and calculate the total number of heads and tails on the board. In the end, students will be asked to convert their projects into a simulation tool in which one can flip a coin 10, 100 and 1000 times.
6	Game Development	Basic and Independent events	Dice Game	1, 2, 3, 4	Students will develop a dice game in which two players roll a dice in turns. The first player reaching 100 points will win the game.	The teacher will conduct a discussion on probability of getting a number after rolling the dice. She will ask if an event affects the result of its successor. In the end, students will calculate the probability of getting each number after rolling a fair dice.
7	Problem Solving	Basic principles of counting	Finding routes	1	Students will develop a project to solve the 2^{nd} question of Probability Achievement Pretest (see Appendix A).	The teacher will conduct a discussion on basic principles of counting with students and ask them to add another city, D to their projects. Then s/he will calculate the new routes by discussing with students.
8	Game Development	Basic Events	100 meters running	1, 2, 3, 4, 5	Students will develop an olympic 100 meters game. There will be 6 runners and a dice in the game. When the player presses a button, the dice will roll and the runners will run accordingly. For example, if 1 comes, 1^{th} runner will go 10 steps and if 6 comes, 6^{th} runner will go 10 steps.	The students will be asked to form groups of 6 and play the games together. Then they will be asked to convert their games to a simulation in which one can run the game 10, 100 and 1000 times. The results will be stored in variables.
9	Problem Solving	Basic Events	Wheel of Fortune	1, 2, 3, 4, 5, 6	Students will develop a project to solve the 8^{th} question of Probability Achievement Pretest (see Appendix A).	After developing the game, students will be asked to convert their projects into a simulation in which the wheel can be turned 10, 100, and 1000 times. The results will be stored in variables. Then the teacher will conduct a discussion in the classroom about the results.

6. RESULTS

Data collected through quantitative methods (see Table 6.7) were analyzed by both calculating effect size values and conducting statistical analysis and findings are shared in this chapter. In addition, students' projects were analyzed using SPAR and findings (see Table 6.15 and Table 6.21) are shared in this chapter, as well.

6.1. Probability Achievement

In order to test first hypothesis, which claims positive effect of intervention on students' probability achievement, first Cohen's d and Hedge's g values were calculated for the results of Probability Achievement Tests. The results, as in Table 6.1, showed a large effect ($0.80 < d < 1.30$ and $0.80 < g < 1.30$) of intervention on students' probability achievement.

Table 6.1. Effect size analysis of probability achievement data.

	Pretest		Posttest		Effect Size		
n	mean	sd	mean	sd	Cohen's d	Hedge's g	
30	3.43	2.47	5.57	2.11	0.93	0.91	large

To conduct statistical tests, first of all, tests of normality, Kolmogorov-Smirnov and Shapiro-Wilk, were performed on the PAT pretest and posttest results in order to choose the proper statistical test for data analysis. As shown in Table 6.2, results of both normality tests for pretest results showed a normal distribution ($p > .05$). However, the posttest data did not show normal distribution. While the result of Shapiro-Wilk test indicated a normal distribution ($p > .05$), the result of Kolmogorov-Smirnov test resulted in failure ($p < .05$). Therefore, a non-parametric test, Wilcoxon Signed Ranks Test, was used to analyze students' PAT scores.

Table 6.2. Tests of normality for probability achievement data.

	Kolmogorov - Smirnov			Shapiro - Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	0.143	30	0.122	0.937	30	0.075
Posttest	0.172	30	0.023	0.956	30	0.246

Based on the result of Wilcoxon Signed Ranks Test, as shown in Table 6.3, it was concluded that there is a statistically significant difference between students' scores of PAT pretests and PAT posttest ($p < .05$). Therefore, the first hypothesis was verified.

Table 6.3. Non-parametric statistical analysis of probability achievement data.

	N	Mean Rank	Sum of Ranks
Negative Ranks	2	10.75	21.50
Positive Ranks	24	13.73	329.50
Ties	4		
Total	30		
		Z	Assymp. Sig.
Wilcoxon Signed Ranks Test		-3.937	0.000

6.2. Reflective Thinking towards Problem Solving

In order to test the second hypothesis, which claims positive effect of intervention on students' reflective thinking towards problem solving, first Cohen's d and Hedge's g values were calculated for the results of RTPSS, demonstrated in Table 6.4. There was almost no effect, neither positive nor negative, ($0.00 < d = g < 0.20$) of intervention on students' reflective thinking towards problem solving.

Table 6.4. Effect size analysis of reflective thinking towards problem solving data.

	Pretest		Posttest		Effect Size		
n	mean	sd	mean	sd	Cohen's d	Hedge's g	
30	49.50	15.37	50.43	14.28	0.07	0.07	negligible

To conduct further statistical tests, tests of normality, Kolmogorov-Smirnov and Shapiro-Wilk, were performed on the RTPSS pretest and posttest results. Results in Table 6.5 revealed that RTPSS pretest data did not show normal distribution ($p < .05$). Consequently, non-parametric Wilcoxon Signed Ranks Test was used to analyze students' RTPSS scores.

Table 6.5. Tests of normality for reflective thinking towards problem solving data.

	Kolmogorov - Smirnov			Shapiro - Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	0.167	30	0.032	0.930	30	0.049
Posttest	0.118	30	0.200	0.943	30	0.112

Table 6.6. Non-parametric statistical analysis of reflective thinking towards problem solving data.

	N	Mean Rank	Sum of Ranks
Negative Ranks	12	14.92	179.00
Positive Ranks	17	15.06	256.00
Ties	1		
Total	30		
		Z	Assymp. Sig.
Wilcoxon Signed Ranks Test		-0.833	0.405

Non-parametric analysis of data, presented in Table 6.6, revealed that there is no statistically significant difference between students' levels of RTPSS before and after intervention (p >.05). Therefore, the second hypothesis was rejected.

Students' scores in the PAT pretest, the PAT posttest, the RTPSS pretest, and the RTPSS posttest are shared in Table 6.7 with details. PAT scores may vary between 0 and 14. In the PAT pretest, the minimum score was observed as 0, maximum score as 10. On the other hand, all students were able to correctly answer at least 2 questions in the the PAT posttest. Maximum score in the PAT posttest was again 10. RTPSS scores may change between 14 and 70. In the RTPSS pretest, minimum score was observed as 18 and maximum score as 70. Similarly, minimum score was observed as 16 in the posttest and maximum score as 70.

6.3. Reflections on Selected Student Projects

To illustrate the process of evaluation of students' Scratch projects and exemplify the magnitude of their programming skills, three projects were selected as case studies and analyzed by the researcher within the context of Student Project Assessment Rubric (SPAR). Based on evaluation, all projects were categorized as insufficient, successful or creative and one project was selected randomly from each category. Pseudonyms have been substituted for the actual names of the students in this section.

6.3.1. Case 1: Heads and Tails Experiment

The first case is a heads and tails experiment developed by a 5^{th} grade male student, Murat, as the task of 5^{th} week activities (see Table 5.10). In this task, students were asked to develop a simple heads and tails experiment project. After the initial development, the researcher conducted a discussion with students about the results of a particular experiment, successive trials and independent events. The responses provided by students were written to the board and cumulative ratio of heads to tails were calculated. Afterwards, the students were asked to develop a project that enables the user to run more than experiments at once, such as 50, 100, 500 or even 1000 times.

To start with the first dimension of the SPAR, developing video games, Murat's

Table 6.7. Summary of quantitative data.

Student	**Grade**	**PAT Pre.**	**PAT Post.**	**RTPSS Pre.**	**RTPSS Post.**
1	6^{th}	0	9	34	49
2	6^{th}	0	5	30	50
3	6^{th}	2	6	62	47
4	5^{th}	5	6	18	30
5	5^{th}	4	5	70	67
6	6^{th}	8	7	58	60
7	5^{th}	2	5	66	46
8	5^{th}	3	4	55	57
9	6^{th}	1	5	32	51
10	6^{th}	2	4	47	46
11	5^{th}	1	3	52	52
12	5^{th}	4	7	67	16
13	5^{th}	5	5	45	61
14	5^{th}	10	7	20	28
15	5^{th}	6	10	57	70
16	6^{th}	5	7	30	38
17	5^{th}	3	8	39	36
18	6^{th}	1	3	59	66
19	6^{th}	4	5	54	52
20	6^{th}	4	5	55	42
21	5^{th}	0	6	70	59
22	5^{th}	2	2	53	55
23	5^{th}	6	9	40	61
24	6^{th}	8	9	62	70
25	5^{th}	2	3	39	63
26	5^{th}	3	5	70	45
27	5^{th}	3	7	59	68
28	6^{th}	4	4	56	46
29	5^{th}	4	4	59	62
30	5^{th}	1	2	24	20

Figure 6.1. Screenshots from Murat's project: (i) the game itself, (ii) blocks used in his game.

usage of sprites is marked as successful because he used only one sprite, two costumes in it, and a background which is enough to develop the project successfully. Secondly, he used a total of 8 different command blocks in his project, also considered as successful. In his project, there are two nested algorithms, one for tossing the coin randomly and another for tossing it 100 times and recording the results in variables. Both algorithms run as expected, though there are not any creative additions. In terms of user input, Murat's project can be assessed as successful even though there is just one input: pressing the space bar. When you press space bar, the game starts running heads and tails experiment for 100 times, yet it is enough for the task. In terms of user feedback, on the other hand, his project is insufficient. There is only feedback in terms of variables but the user is unable to see the outcomes of individual experiments separately. There are also no instructions for the user about how to use the application. The project is insufficient in terms of variables, as well. There are two variables in the project, one head and one tail, as expected by the task but the variables does not reset at the beginning of each experiment. Lastly, checking overall project completion, Murat's project is considered as successful because sprites, command blocks, algorithms, user input, user feedback and variables of the project are almost as expected.

To evaluate the first item of second dimension of SPAR, developing strategies for solutions of probability problems, Murat's project is successful in representing sample space of the experiment. There is one coin character with two costumes in it: one head and one tail image. The coin cannot be head and tail at the same time. Experiment design of the project is successful. Even though he did not put any instructions on the screen for the user, he draw a human hand flipping the coin instead of showing an isolated coin. His implementation of the experiment is successful, too, because his algorithms work as expected and his project generates random results. Fourth, Murat successfully developed algorithms for running probability experiments more than once and see the results as changes in variables successfully. Yet, representations of outcomes in Murat's project is insufficient because of more than one reasons. First of all, the project does not reset variables properly. Secondly, one cannot see the results of individual experiments. Third, there are not on screen feedback for the results of individual and/or multiple experiments.

To sum up, Murat's project is a good example for a successful project, which follows the worksheet without much deviations. Even though some parts of the project are expected to be better, he succeeds in transferring his understanding of this particular probability experiment into a multimedia artifact. His quantitative probability achievement scores are 2 in the pretest and 6 in the posttest. Putting all of these together, it is fair to say that Murat improved himself in terms of probability knowledge, though there is still room for improvement.

6.3.2. Case 2: Probability Race Game

Aylin, who developed a probability racing game, is a 5th grade female student. She developed her project according to the task of 8th week lesson (see Table 5.10). The task was to develop a racing game based on outcomes of a probability experiment. In order to narrow down the scope and make development easier for the students, they were asked to create a coin toss experiment with two races. If the result is heads, the first racer will go one step, otherwise the second racer will advance. First one to reach the finish line will win.

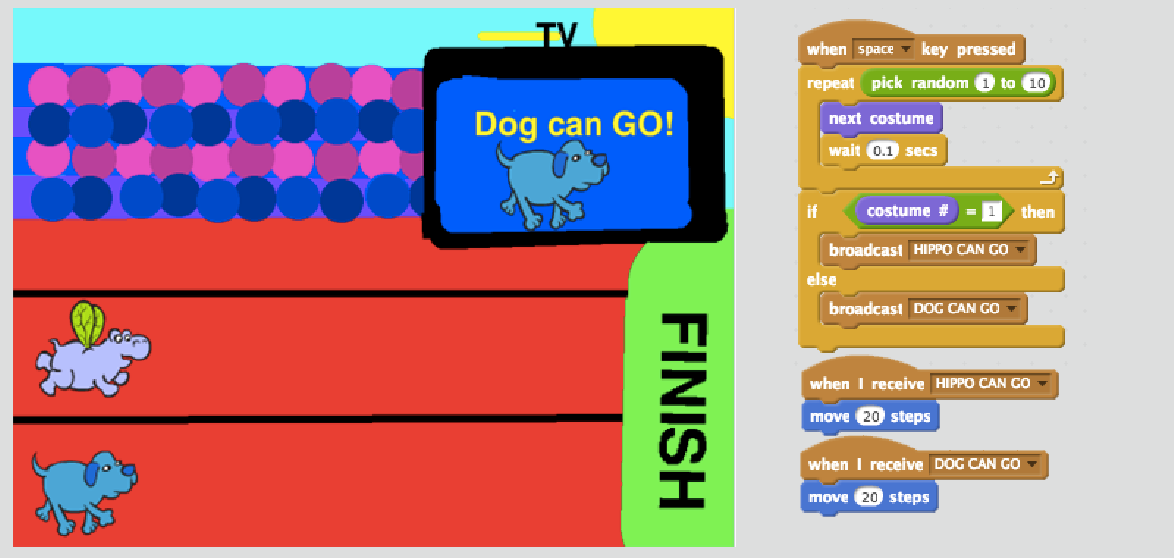


Figure 6.2. Screenshots from Aylin's project: (i) the game itself, (ii) blocks used in her game.

Starting again with the developing video games dimension of SPAR, Aylin's project is enjoyable and creative. She used four different sprites with different costumes in each of them, and created a background which contains a stadium filled with fans, running lanes and a television screen. Her project consists 12 different Scratch blocks, all are relevant to the project. In short, her usage of blocks is successful. Her algorithms are successful, as well. She managed to develop an algorithm for running a probability experiment identical to heads-tails and another algorithm moving characters according to the result of the experiment. User input, pressing spacebar for starting a new experiment, is successful as well because the task did not expect students more. User feedback in her project, though, is creative because there are multiple feedbacks: text feedback on result of the experiment on the TV screen, image of winner character on the screen and movement of the winner character. In this particular project, variables are marked as not evident because she did not create any of them. Yet, it does not effect overall project completion because there is no need to use variables to complete this project. At the end, this project is evaluated as a successful project in terms of overall project completion because it reflects the student's ability to use Scratch' visual tools, blocks and algorithms successfully.

As well as her competence in developing video games, Aylin's project reflects her competence in developing strategies for solutions of probability problems. Instead of using a coin or coins in the project, she designed a television with two different costumes. First costume shows the winner as the dog and the second shows the winner as the hippo, the racers. The system works identical to a coin toss experiment. Thus, representation of the sample space in her project is creative. Experiment design is creative, too. Rather than putting a coin on the screen isolated, she created an authentic scene for her project. Experiment implementation is successful, her algorithms work as expected. Multiple experiment simulations is successful, too, because there is a need to run more than one experiment and the user can see the results of experiments cumulatively as the advancement of racers. Besides, position of each character is reset at the beginning of the race. With a TV to represent outcomes, texts and advancement of characters all together and working successfully, Aylin's project is a good example for a creative project in terms of representation of outcomes.

All in all, Aylin's project is a very good example on how creative a probability project can be developed by students using Scratch. Considering her pretest score was 3 and posttest score was 8 in PAT, it is concluded that Aylin made a good progress in terms of probability knowledge.

6.3.3. Case 3: Wheel of Fortune Experiment

The last case selected is developed by Emek, who is another 5th grade male student. His project is a probability simulation developed to understand a formal mathematics problem, as in 9th week's task (see Table 5.10). For this task, students were asked to create their own projects based on 8th question of PAT pretest. There was no other instructions for students. Emek, for example, developed a gift lottery project in which the user receives a white box or a red box as a christmas gift.

Firstly, he used an arrow, a wheel, and a background text for his project. Thus, his project is marked as successful in terms of usage of sprites because an arrow and a wheel is enough. Secondly, there are 10 different command blocks in his project, which is enough too. Thirdly, he developed two different algorithms for his project: an algo-

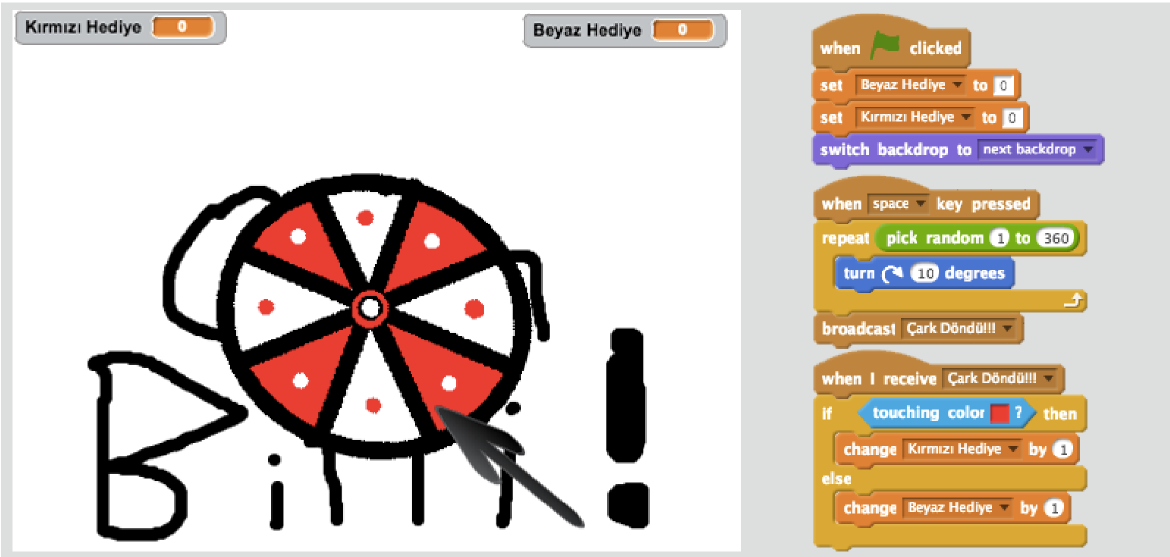


Figure 6.3. Screenshots from Ege's project: (i) the game itself, (ii) blocks used in his game.

rithm to turn the wheel randomly and another algorithm that determines the result of the experiment. The algorithms work as expected, so his development of algorithms is considered as successful. User input in his project is successful, too. However, user feedback is insufficient in Emek's project because there are not any textual or visual feedbacks on the results of the experiments. He uses variables to keep the results of experiments but does not inform the user about results of particular experiments. Variables in his project are successful because he keeps results of experiments cumulatively and resets both variables at the beginning. Overall project completion for Emek's project, in terms of developing video games, is considered as successful because the project contains all necessary sprites, algorithms, input methods and variables.

In terms of developing strategies for solutions of probability problems, Emek's project is unfortunately a bad example. In the question given them for the task, the wheel was divided into 8 parts: 2 As and 6 Bs. Emek divided his wheel to 8 parts but there are 4 reds and 4 whites. Therefore, his representation of the sample space is insufficient. Secondly, experiment design of his project is insufficient because the wheel in his project is incorrect. Experiment implementation, on the other hand, is successful because the wheel turns randomly and results are recorded in variables properly. Multiple experiment simulations in Emek's project are successful. In his project, the user can make more than one experiment, see result of each experiment cumulatively as variables and reset variables when needed. Lastly, his representation of outcomes is successful because results of individual experiments are visible and variables are used properly.

To conclude, Emek's project shows that he lacks a robust understanding of sample space concept. Even though his project is successful as a probability experiment, being able to define sample spaces is crucial to conduct fair probability experiments. His PAT pretest score is 4 and posttest score is 7. It may be concluded that the intervention helped Emek to develop knowledge of probability, however he needs to further develop knowledge of sample spaces and basic events.

6.4. Analysis of Projects Developed by Students

As stated earlier, projects developed by students in the last five weeks of the intervention were collected by the researcher at the end of lessons. All projects (n=115) were rated by two independent raters using SPAR. Mean of each item of each project was calculated because the data was nominal and there were two raters. Inter rater reliability was assessed using a two-way mixed, absolute agreement, average measures intraclass correlation coefficient as ICC=0.613 ($p < .05$) (Hallgren, 2012). The results are shared with tables and discussions as two subsections.

6.4.1. Developing Video Games

Firstly, analysis of the students' projects (Table 6.8) revealed that the students were comfortable in using sprites in their projects. Only one of the collected projects did not include any sprites, and just two of them were marked as insufficient. On the other hand, only three of the collected projects included a creative usage of sprites. In short, data shows that majority of students stuck to the task and did not need to alter it very much.

Table 6.8. Usage of Sprites in Students' Projects.

	#	%
Not Evident	1	0.87
Insufficient	2	1.74
Successful	109	94.78
Creative	3	2.61

Secondly, it is found that students were comfortable in identifying and using necessary command blocks for their projects (Table 6.9). None of the projects included creative usage of command blocks, which is quite understandable due to similarity of tasks in terms of generating random results.

Table 6.9. Usage of Scratch Blocks in Students' Projects.

	#	%
Not Evident	2	1.74
Insufficient	2	1.74
Successful	111	96.52
Creative	0	0.00

It is important to keep in mind that development of algorithms item does not judge development of random experiments in Scratch. Still, seeing that students had little difficulty in developing algorithms for their projects (Table 6.10) is a good indicator that students learned Scratch programming well enough.

Table 6.10. Development of Algorithms in Students' Projects.

	#	%
Not Evident	2	1.74
Insufficient	6	5.22
Successful	103	89.57
Creative	4	3.48

Students' utilization of user input methods (keyboard, mouse, webcam, etc.) in their projects were mostly assessed as successful, as well (Table 6.11). Moreover, almost 25% of projects included creative user input options. It is concluded that students knew how to get user input in Scratch well enough to develop basic probability applications.

Table 6.11. User Input in Students' Projects.

	#	%
Not Evident	2	1.74
Insufficient	2	1.74
Successful	83	72.17
Creative	28	24.35

While students were able to utilize user input blocks in their projects, analysis of their projects indicates that there are problems in their preference of user feedback (Table 6.12). Considering almost half of the projects were found to be insufficient in terms of user feedback, one can infer that students were unable to develop user feedback in Scratch or they were unaware of the importance of user feedback. It is safe to say that being able to develop algorithms for probability experiments is more important than reflecting the results on the screen. However, it is important for students to implement on screen feedback in their projects because of the nature of the process of application development, which requires running the code, checking the results, making arrangements and starting a new debugging cycle by running the code again. Therefore, being able to see the results of their own probability experiments is very important for the students. All in all, lack of proper user feedback in 54 student projects is considered as a negative result.

Similar to user feedback, almost 40% of students' projects were insufficient in terms of usage of variables (Table 6.13). It is not as dramatic as some students' insufficiency in user feedback because some tasks, such as 7th and 8th week activities (see Table 5.10), did not require any usage of variables at all. However, it is still considered as a negative result.

Table 6.12. User Feedback in Students' Projects.

	#	%
Not Evident	3	2.61
Insufficient	51	44.35
Successful	58	50.43
Creative	3	2.61

Overall project completion is the most important item of developing video games dimension of SPAR because it judges internal consistency of a students' project. In other words, it checks if a student was able to identify necessary visuals, command blocks, algorithms, user input methods, user feedback methods and variables to complete his or her project successfully. Fortunately, only 7 projects out of 115 were found to be not evident, or insufficient (Table 6.14). Therefore, it is concluded that students were able to start and finish a Scratch project.

Table 6.13. Variables in Students' Projects.

	#	%
Not Evident	5	4.35
Insufficient	45	39.13
Successful	60	52.17
Creative	5	4.35

To sum up, based on the analysis of their projects according to SPAR, it may be concluded that the students had enough design and programming skills that is required to develop video games in Scratch based on basic events. However, it has to be noted that programming skills are advanced through developing different projects under different conditions, and a complete program is produced with support of others. It is considered, in this project, that students completed only one sort of domain related programming, that is probability. When they conduct programming in providing computational solutions to less abstract domains/problems, many of programming concepts may be more easily mastered by them.

Table 6.14. Overall Project Completion in Students' Projects.

	#	%
Not Evident	2	1.74
Insufficient	5	4.35
Successful	104	90.43
Creative	4	3.48

A summary of analysis of students' projects for developing video games dimension is shared in Table 6.15 with details. The values in the table are based on the average scores of all seven items. Some projects are marked as not applicable (n/a) because of the fact that those students were absent in that week. There are a total of 35 missing projects. In the first week, 8 projects were missing, 4 projects were insufficient, and 18 projects were successful. There was not a creative project in terms of developing video games. In the second week, 4 projects were missing, 5 projects were insufficient, 20 projects were successful and 1 project was creative. In the third week, 8 projects were missing, 4 projects were insufficient, 18 projects were successful and no projects were creative. In the fourth week, 4 projects were missing, no projects were insufficient, 24 projects were successful and 2 projects were creative. In the last week, 11 projects were missing, no projects were insufficient, 16 projects were successful and 3 projects were creative.

6.4.2. Developing Strategies for Solutions of Probability Problems

To begin with, students' representation of sample space in their projects were analyzed (Table 6.16). Understanding of sample space is very important in a project because if a student fails in doing so, s/he would fail in four other dimensions, too. Unsurprisingly, there is not a project that is marked as creative because changing the sample space of a probability experiment would generate unfair results. On the other hand, only 5 of 115 projects had problems in representing the sample space of the

Table 6.15. Summary of developing video games dimension.

Student	**Grade**	**Project 1**	**Project 2**	**Project 3**	**Project 4**	**Project 5**
1	6^{th}	Successful	Successful	Insufficient	Successful	Successful
2	6^{th}	Successful	Insufficient	Insufficient	Successful	Successful
3	6^{th}	Successful	Successful	n/a	Successful	Successful
4	5^{th}	Successful	n/a	Successful	Successful	n/a
5	5^{th}	Successful	Successful	Successful	Successful	Successful
6	6^{th}	Successful	Creative	n/a	Successful	Creative
7	5^{th}	n/a	n/a	Successful	Successful	Successful
8	5^{th}	Successful	Successful	Successful	Successful	Successful
9	6^{th}	Successful	Successful	Successful	Successful	n/a
10	6^{th}	Successful	Successful	Successful	Successful	n/a
11	5^{th}	n/a	n/a	Insufficient	n/a	n/a
12	5^{th}	Successful	Successful	n/a	Creative	Creative
13	5^{th}	Successful	Successful	Successful	Successful	Successful
14	5^{th}	n/a	Successful	Successful	Successful	Successful
15	5^{th}	n/a	Successful	Successful	Successful	Successful
16	6^{th}	Insufficient	Insufficient	n/a	Successful	n/a
17	5^{th}	Successful	Successful	Successful	Creative	Creative
18	6^{th}	n/a	Insufficient	Insufficient	n/a	n/a
19	6^{th}	Successful	Successful	n/a	Successful	n/a
20	6^{th}	n/a	Successful	n/a	n/a	n/a
21	5^{th}	Successful	Insufficient	n/a	Successful	Successful
22	5^{th}	Insufficient	Successful	Successful	Successful	Successful
23	5^{th}	Successful	Successful	Successful	Successful	Successful
24	6^{th}	n/a	Insufficient	Successful	Successful	n/a
25	5^{th}	Insufficient	Successful	Successful	Successful	n/a
26	5^{th}	Successful	Successful	Successful	n/a	n/a
27	5^{th}	Insufficient	Successful	Successful	Successful	Successful
28	6^{th}	n/a	Successful	Successful	Successful	Successful
29	5^{th}	Successful	Successful	n/a	Successful	Successful
30	5^{th}	Successful	n/a	Successful	Successful	Successful

experiment. Therefore, it may be concluded that the students were able to determine sample space of probability experiments given in the tasks and convert them to visuals (sprites, costumes, texts, etc.) in Scratch.

Another pleasing result is the students' experiment design in Scratch. 86% of the students' projects were marked as successful and 10% of the projects were marked as creative (Table 6.17). It shows that students were able to convert a probability task, or an experiment, given them on paper to a video game project.

Table 6.16. Representation of Sample Space in Students' Projects.

	#	%
Not Evident	1	0.87
Insufficient	4	3.48
Successful	110	95.65
Creative	0	0.00

Experiment implementation in students' projects were found to be mostly successful (Table 6.18), too. Probability experiments in 108 out of 115 projects generated random results as expected. This result shows that they were able to transfer their learning of basic events to algorithms. On the other hand, it is important to note that this item assesses implementation of algorithms solely and does not take representation of results into account.

Table 6.17. Experiment Design in Students' Projects.

	#	%
Not Evident	2	1.74
Insufficient	2	1.74
Successful	99	86.09
Creative	12	10.43

Considering importance of conducting multiple experiments independently, seeing results cumulatively and comparing results of these experiments with others' results in learning probability, a partly negative result was found in students' utilization of multiple experiment simulations. Even though in 4 out of 5 tasks (except task 7, see Table 5.10) students were asked to implement multiple experiments in their projects, at least as a follow up activity, unfortunately 40 out of 115 projects were marked as unsuccessful by the evaluators.

Table 6.18. Experiment Implementation in Students' Projects.

	#	%
Not Evident	3	2.61
Insufficient	4	3.48
Successful	106	92.17
Creative	2	1.74

Lastly, representation of outcomes in students' projects were evaluated. Data analysis (Table 6.20) shows that majority of projects were successful in this manner. Even though some students had difficulty in conducting multiple experiments and/or showing results of them, they were still able to show results of particular experiments visually.

Table 6.19. Multiple Experiment Simulations in Students' Projects.

	#	%
Not Evident	3	2.61
Insufficient	37	32.17
Successful	74	64.35
Creative	1	0.87

In conclusion, except running experiments more than once automatically, the students were able to develop strategies for solutions of probability problems in video games they developed using Scratch.

Table 6.20. Representation of Outcomes in Students' Projects.

	#	%
Not Evident	2	1.74
Insufficient	7	6.09
Successful	101	87.83
Creative	5	4.35

A summary of analysis of students' projects for developing strategies for solutions of probability problems dimension is shared in Table 6.21 with details. The values in the table are based on the average scores of all five items. Some projects are marked as not applicable (n/a) because of the fact that those students were absent in that week. There are a total of 35 missing projects. In the first week, 8 projects were missing, 3 projects were insufficient, and 19 projects were successful. There was not a creative project in terms of developing video games. In the second week, 4 projects were missing, 6 projects were insufficient, 19 projects were successful and 1 project was creative. In the third week, 8 projects were missing, 2 projects were insufficient, 20 projects were successful and no projects were creative. In the fourth week, 4 projects were missing, no projects were insufficient, 25 projects were successful and 1 project was creative. In the last week, 11 projects were missing and all remaining 19 projects were marked as successful.

Table 6.21. Summary of developing strategies for solutions of probability problems dimension.

Student	**Grade**	**Project 1**	**Project 2**	**Project 3**	**Project 4**	**Project 5**
1	6^{th}	Successful	Successful	Successful	Successful	Successful
2	6^{th}	Successful	Insufficient	Successful	Successful	Successful
3	6^{th}	Successful	Successful	n/a	Successful	Successful
4	5^{th}	Successful	n/a	Successful	Successful	n/a
5	5^{th}	Successful	Successful	Successful	Successful	Successful
6	6^{th}	Successful	Creative	n/a	Successful	Successful
7	5^{th}	n/a	n/a	Successful	Successful	Successful
8	5^{th}	Successful	Successful	Successful	Successful	Successful
9	6^{th}	Successful	Successful	Successful	Successful	n/a
10	6^{th}	Successful	Successful	Insufficient	Successful	n/a
11	5^{th}	n/a	n/a	Successful	n/a	n/a
12	5^{th}	Successful	Successful	n/a	Successful	Successful
13	5^{th}	Successful	Successful	Successful	Successful	Successful
14	5^{th}	n/a	Successful	Successful	Successful	Successful
15	5^{th}	n/a	Successful	Successful	Successful	Successful
16	6^{th}	Insufficient	Insufficient	n/a	Successful	n/a
17	5^{th}	Insufficient	Successful	Successful	Creative	Successful
18	6^{th}	n/a	Insufficient	Insufficient	n/a	n/a
19	6^{th}	Successful	Successful	n/a	Successful	n/a
20	6^{th}	n/a	Insufficient	n/a	n/a	n/a
21	5^{th}	Successful	Insufficient	n/a	Successful	Successful
22	5^{th}	Successful	Successful	Successful	Successful	Successful
23	5^{th}	Successful	Successful	Successful	Successful	Successful
24	6^{th}	n/a	Insufficient	Successful	Successful	n/a
25	5^{th}	Successful	Successful	Successful	Successful	n/a
26	5^{th}	Successful	Successful	Successful	n/a	n/a
27	5^{th}	Insufficient	Successful	Successful	Successful	Successful
28	6^{th}	n/a	Successful	Successful	Successful	Successful
29	5^{th}	Successful	Successful	n/a	Successful	Successful
30	5^{th}	Successful	n/a	Successful	Successful	Successful

7. DISCUSSION

In this study, the ultimate goal was to create a learning environment based on video game programming activities to facilitate students' learning of basic probability concepts and processes. In order to achieve this goal, a pilot and main intervention were conducted successively, and data were collected on students' probability achievement. Besides the primary goal, changes in students' reflections on their problem solving processes and their competence in developing visual probability experiments were also examined. In this chapter, findings of the main study are discussed in relation to the research questions and previous, related studies conducted by other researchers.

First and foremost, it was hypothesized that video game programming activities would increase students' content learning of basic probability concepts. In order to test this hypotheses, collected data were statistically analyzed. Effect size analysis by calculating both Cohen's d and Hedge's h values showed that the intervention had a large positive effect on students' probability achievement. Moreover, non-parametric analysis of probability achievement data showed that there was a statistically significant difference between students' pretest scores and posttest scores in favor of their posttest scores. Lastly, analysis of students' projects showed that more than 90% of students successfully designed and implemented probability experiments in Scratch. Based on these findings, we can confirm that the intervention had a statistically significant positive effect on students' probability achievement. Hence, the results partially confirms arguments developed by Harel and Papert (1990), Edwards (1991), Clements and Battista (1990), and Lewis and Sarah (2012). However, these results did not agree with Olive (1991), Boyer (2010), and Taylor *et al.* (2010).

From the beginning of 1990s, many researchers reported positive effects of Logo programming activities on learning mathematics. For example, Harel and Papert (1990) reported that students could learn fractions by designing and developing their own projects with computers. Success of programming activities in learning geometry concepts, such as transformational geometry by middle school students (Edwards,

1991) and angles and polygons by primary school students (Clements & Battista, 1990), was also reported by researchers. Still, it cannot be concluded that there was a consensus. For instance, Olive (1991) reported that success in Logo programming was not sufficient for success in geometric aspects of the tasks. Recent studies did not provide enough evidence, as well. Studying the effects of developing multimedia artifacts with Scratch on primary school students' learning of geometric solids, Boyer (2010) reported that increases in content learning were not identified. Similarly, Taylor *et al.* (2010) concluded that it was not clear how much content students learned after developing application with Scratch and an interactive whiteboard. On the other hand, Lewis and Sarah (2012) found a positive correlation between students' scores in a standardized mathematics test and their competence in Scratch programming.

Another particularly important finding of this study was the fact that no significant effect of maturity was observed. Literature on teaching and learning probability indicates that students' ability to understand probability concepts increases over time (Memnun, 2008; Piaget & Inhelder, 1975; Shaughnessy, 1992). For instance, stating that students between ages 7 and 14 have no systematic approach to generating a list of possibilities, Piaget and Inhelder (1975) claimed that those students do not possess "the mathematical maturity to make an abstract model of a probability experiment" (Shaughnessy, 1992, p. 479). In contrast, it was found in this study that students were successful in representing sample space of probability experiments in their projects (see Table 6.21). More particularly, (Fischbein & Gazit, 1984) reported that 5th grade students had more difficulty in learning probability than 6th and 7th grade students. However, neither the quantitative nor the qualitative data collected in this study showed a noticeable difference between 5th and 6th grade students.

Looking deeper into collected data, it was also found that there was no relationship between developing a successful project or failing in doing so (see Table 6.7, Table 6.15, and Table 6.21) and probability achievement. For example, the students numbered 2, 16, and 21 all had projects that were marked insufficient in terms of developing strategies for solutions of probability problems but the difference between their PAT pretest and posttest scores were +5, +2, and +6 respectively. On the other hand, the student numbered 6 had one project rated as creative and all projects of the students that numbered 13, 14, and 22 were marked as successful but the difference between their PAT pretest and posttest scores were -1, 0, -3, and 0 respectively. Therefore, it can be inferred that even though a student cannot accomplish a particular probability task, s/he can still learn probability. This particular finding are in line with findings of Wilensky (1993, 1996) and Abrahamson and Wilensky (2005). Moreover, it supports the primary claim of this study that students should be provided opportunities to spend time on creating, modifying and fixing their own models of probability.

Along with aforementioned encouraging results of this study, it is important to note that results also suggest that there is still room for improvement. Out of 14, means of students' scores were 3.43 in pretest and 5.57 in the posttest. In other words, an average student still failed in answering 8 questions. Secondly, almost half of students failed to develop algorithms for simulating multiple experiments at once in their projects. Thirdly, almost half of projects did not contain proper user feedback. There might be various reasons behind these issues. Konold (1995) claims that students tend to underestimate the time required to adequately simulate a problem. However, the intervention should have given students more time to test their projects, see the results and fix their algorithms for simulations. Moreover, activities should have included more explicit references to multiple simulations. In addition, diSessa (1997) asserts that a programming environment should have a low threshold and a high ceiling. In other words, it should be comprehensible for beginners and helpful to relative experts. There is no doubt that Scratch is one of the most comprehensible tools for beginners (Resnick *et al.*, 2009). However, complexity of developing algorithms for multiple experiments in Scratch could have a demotivating effect on students. To overcome this barrier, students should be given more time to master Scratch programming skills. Another temporary solution could be giving students pre-baked functions/algorithms.

Besides the implications of data analysis, it is also clear that students' learning of probability should have been measured with more methods. In similar studies, researchers used many alternative methods to measure students' learning and/or understanding of probability concepts such as interviewing students (e.g., Wilensky, 1993), administering questionnaires (e.g., Fischbein & Schnarch, 1997), analyzing students' discussions (e.g., Abrahamson & Wilensky, 2005), or conducting experiments with children (e.g., Hoemann & Ross, 1971). Due to the nature of collected data, it was not possible to assess the effects of the intervention on misconceptions. Even though remedying misconceptions was not a direct objective in this study, activities were designed by taking the seven common misconceptions into account. For example, 5^{th} week activity, which was a heads and tails experiment (see Table 5.10), could be used to overcome representativeness, negative and positive recency, and the effect of sample size misconceptions. 6^{th} week activity, which was a dice game, could be used to overcome equiprobability bias and 8^{th} week activity, which was a probability race game, could be used to remedy negative and positive recency. In future studies, more emphasis should be placed on identifying the effects of such interventions on students' misconceptions.

The second hypotheses of this study, even though it was not a direct goal, was that the intervention would have a positive effect on students' reflective thinking skills towards their problem solving processes. However, results of the study failed to support this hypotheses. Neither statistical analysis, nor effect size analysis showed any changes, at all. Acknowledging undeniable natures of both studying probability (Shaughnessy, 1992) and programming (Resnick, 2007) as problem solving activities, it would be unfair to state that students did not solve problems throughout the study. The problem here, might have arisen from the emphasis given to the reflective thinking. In order to promote reflective thinking, an educational activity should encourage students to think about what they knew and what they needed to know or do to progress through their exploration (Kizilkaya & Askar, 2009; Moon, 1999). Focusing too much on probability concepts in discussion sessions is the most probable cause of this result. Activities of the intervention should have made use of explicit references for students to reflect on their problem solving processes and discussion sessions should have been longer to spare more time for reflection. Secondly, the isolation of this intervention from other courses may have been another limiting factor. To put it another way, development of a skill such as reflective thinking is a more demanding task than learning mathematics because it is a set of attitudes (Rodgers, 2002). To obtain better results, students should have experienced a more reflection based learning environment for more extended time periods. Unfortunately, as of now, there has not been any other study that focused on effects of programming on reflective thinking towards problem solving to compare with the results of this study.

8. CONCLUSION

The purpose of this study was to propose an alternative learning environment to help students learn basic concepts of probability at the primary school level by featuring video game development activities. The intervention was built on top of the constructionist learning theory (Ackermann, 2010; Kafai, 1996; Papert, 1980, 1993), which emphasizes the importance of creating tangible products for constructing knowledge. Particularly, the creative learning spiral (Resnick, 2007) model, which is a constructionist approach advocating a continuous learning cycle of imagining, creating, playing, sharing, reflecting, was appropriated for this study. Due to the strong emphasis on the reflection of problem solving processes on constructionism in general, and creative learning spiral itself, changes in students' reflective thinking towards problem solving was also studied.

With the intention to give students opportunities to build their own probabilistic models, design their own experiments and solve the problems creatively, a set of activities were designed by the researcher. For a total of 9 weeks, students attended 90 minute lessons as part of their mathematical applications courses. In the first weeks, students learned how to use Scratch programming tool. During this period, the students developed projects on numbers, ratio, fractions and variables, which are prerequisite subjects for studying probability. In the following five weeks, students developed video games based on three game scenarios designed by the researcher and two multiple-choice questions chosen from pretest questions. In each workshop, the students developed an initial project in the first half of the session. Then their teacher conducted a 10-minute discussion with them about studied concepts and results of their projects. In the second half of sessions, the students were given a follow up task to work on until the end of the workshop.

Effects of the intervention on students' achievement of probability and their reflective thinking skills toward problem solving were analyzed by collecting quantitative data through pretests and posttests of Probability Achievement Test (PAT) and Reflective Thinking towards Problem Solving Scale (RTPSS). Also, projects developed by students in the last five weeks of the study were collected and analyzed by two independent examiners using Student Project Assessment Rubric (SPAR). It was found that there was a statistically significant increase in students' probability achievement. Moreover, students were able to to convert their formal knowledge to video games by designing visuals and developing algorithms. On the other hand, a statistically significant change in students' reflective thinking toward problem solving was not observed.

In summary, this study provides evidence to support video game programming activities for learning basic probability concepts at the primary school level. It is concluded that video game programming is a good alternative for learners to build their own probabilistic models, run tests, analyze results and understand fundamental structures of probability concepts. It is also an alternative to motivate students to spend more time with probability experiments.

8.1. Limitations of the Study

Though promising and encouraging results were obtained in increasing students' knowledge of probability through creative computing activities, there is still room for improvement despite certain limitations. Because of the length of intervention, limitations were experienced in in the both pilot and main studies. It was a big challenge for the researcher to convince administrators to approve a 9 or 10 week research study. For the pilot study, thanks to the Turkish Ministry of National Education, the researcher was able to choose a public primary school randomly. However, administrators of this school did not allow the researcher to choose the sample of the study randomly and they prohibited the use of class hours for the intervention. In order to avoid the same problems, the main study was conducted at a private primary school. Even though it was possible to use class hours in the main study, it was not possible to control sample selection process. In addition, it was not possible to have a control group in the main study because the study was conducted in the fall semester and due to the schedule of the school. This study was conducted at the fall semester, but students was going to study probability in the spring semester.

Another limitation was the fact that this study was conducted by a researcher who is not a mathematics teacher. Although a mathematics teacher conducted discussions with students in the main study, it was for just 10 minutes in sessions that were 90 minutes in total. If a mathematics teacher, who is also a skilled Scratch programmer, conducted this study, it would be possible for the researcher to observe the sessions from a third person's perspective to analyze students' activities. Moreover, it would have been possible to conduct more micro-discussions on probability and problem solving reflection during sessions.

8.2. Suggestions for Further Research

Findings of this research encourage further research in this field. Firstly, it was found that programming video games with Scratch was effective for learning basic probability concepts but students had difficulty in implementing multiple experiment simulations. A study should be conducted solely on multiple experiment simulations to find if the cause of this issue is due to the structure of activities or the Scratch programming environment itself. If the latter is the case, developing extensions to Scratch to facilitate more complex algorithms and big amounts of data simulation can be considered as a future study.

Additionally, further studies should be conducted on the effects of video game programming on students' reflective thinking skills. Besides studying effectiveness of such activities in classroom settings, students' reflections on projects shared by themselves and others on online platforms should be analyzed, too. Last, but not least, a further study can be conducted to develop virtual mechanisms for students to reflect their ideas, collect their individual reflections in a portfolio and refer back to their past reflections whenever necessary.

APPENDIX A: PROBABILITY ACHIEVEMENT TEST (PAT)

6th GRADE PRETEST

1. Merve, kitaplığında bulunan 7 roman ve 9 hikâye kitabından birisini okumak istemektedir. Kaç farklı seçim yapabilir?

A) 2 **B)** 9 **C)** 16 **D)** 63

2. A şehrinden B şehrine 4 farklı yoldan, B şehrinden C şehrine 2 farklı yoldan gidilebildiğine göre A şehrinden C şehrine, B şehrine uğramak koşuluyla kaç farklı yoldan gidilebilir?

A) 2 **B)** 4 **C)** 6 **D)** 8

3, 4 ve 5. soruları aşağıdaki bilgilere göre cevaplayınız.
Bir kutuda eş büyüklükte 3 mavi, 9 yeşil ve 8 kırmızı bilye vardır. Kutudan rastgele bir bilye seçiliyor. Bu bilyenin kırmızı olma olasılığı hesaplanacaktır.

3. Bu durumdaki örnek uzay aşağıdakilerden hangisidir?

A) Mavi bilyeler **B)** Yeşil bilyeler
C) Kırmızı bilyeler **D)** Mavi, yeşil ve kırmızı bilyeler

4. Bu durumdaki deney aşağıdakilerden hangisidir?

A) Kutudaki bilyeler **B)** Bir bilye seçilmesi
C) Kutudaki kırmızı bilyeler **D)** Kırmızı bilye seçilmesi

5. Bu olayın olma olasılığı kaçtır?

A) $\frac{3}{20}$ **B)** $\frac{2}{5}$ **C)** $\frac{9}{20}$ **D)** $\frac{2}{3}$

6th GRADE PRETEST

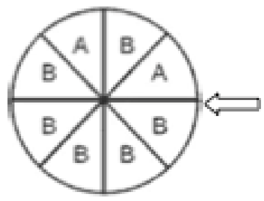
6. Yağmur 12 tane kartı 1'den 12' ye kadar numaralandırıp bakmadan bir kart seçiyor. Seçtiği kartın 8'den büyük bir sayı olma olasılığı kaçtır?

A) $\frac{1}{12}$ **B)** $\frac{1}{4}$ **C)** $\frac{1}{3}$ **D)** $\frac{1}{2}$

7. Bir sınıftaki 12 kız öğrencinin 2'si, 18 erkek öğrencinin 4'ü gözlüklüdür. Bu sınıftan rastgele bir öğrenci seçiliyor. Buna göre aşağıdakilerden hangisi yanlıştır?

A) Seçilen öğrencinin kız olma olasılığı % 40 tır.
B) Seçilen öğrencinin erkek olma olasılığı % 60 tır.
C) Seçilen öğrencinin gözlüklü olma olasılığı % 25 tir.
D) Seçilen öğrencinin gözlüksüz olma olasılığı % 80 dir.

8. Şekildeki çark saat yönünde bir kez döndürülüyor. Çark durduğunda okun A harfini gösterme olasılığı kaçtır?



A) $\frac{3}{4}$ **B)** $\frac{1}{2}$ **C)** $\frac{1}{3}$ **D)** $\frac{1}{4}$

9. Hilesiz bir madeni para atıldığında üst yüze tura gelme olasılığı kaçtır?

A) $\frac{1}{2}$ **B)** $\frac{1}{3}$ **C)** $\frac{1}{4}$ **D)** $\frac{1}{5}$

10. Aşağıdakilerden hangisi bir olayın olasılık değeri olamaz?

A) 0 **B)** $\frac{4}{5}$ **C)1** **D)** $\frac{5}{4}$

11. I. Kesin olayın olma olasılığı 1 dire.
II. İmkânsız olayın olma olasılığı -1 dir.
III. Hilesiz bir zar atıldığında üst yüze 7 gelme olasılığı hesaplanamaz.
IV. Bir olayın olma olasılığı en fazla 1 olur.

Yukarıda verilen bilgilerden hangisi ya da hangileri doğrudur?

A) I ve III **B)** I ve IV **C)** I, II ve III **D)** I, III ve IV

6th GRADE PRETEST

12. 8 tane sarı bilyenin bulunduğu bir torbadan art arda çekilen 3 bilyenin de sarı olması olayı aşağıdakilerden hangisine örnektir?

A) Kesin olay **B)** Örnek uzay **C)** İmkansız olay **D)** Örnek olay

13. Aşağıda verilen olaylardan hangisi imkansız olaydır?

A) Hilesiz bir zar atıldığında asal sayı gelmesi
B) Hilesiz bir zar atıldığında en az 6 gelmesi
C) Kırmızı ve mavi topların bulunduğu bir torbadan çekilen bir topun mavi olmaması
D) Kırmızı ve mavi topların bulunduğu bir torbadan çekilen bir topun sarı olması

14. Yandaki tabloda bir okuldaki 8. sınıf şubelerinin mevcutları verilmiştir.
Okuldan rastgele seçilecek bir 8. sınıf öğrencisinin 8/A da olmama olasılığı yüzde kaçtır?

Sınıf	Mevcut
8/A	40
8 /B	34
8/C	26

A) 26 **B)** 34 **C)** 40 **D)** 60

6th GRADE POSTTEST

1. Çağrı'nın dolabında 3 pantolonu ve 5 gömleği vardır. Çağrı, 1 pantolon ve 1 gömleği kaç değişik şekilde seçebilir?

A) 15 **B)** 8 **C)** 5 **D)** 3

2. Elif, kırtasiyede beğendiği 6 defter, 5 kalem ve 2 silgiden 1 defter, 1 kalem ve 1 silgiyi kaç farklı şekilde seçebilir?

A) 10 **B)** 13 **C)** 30 **D)** 60

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3 ve 4. soruları aşağıdaki bilgilere göre cevaplayınız.
Bir kutuda eş büyüklükte 3 mavi, 9 yeşil ve 8 kırmızı bilye vardır. Kutudan rastgele bir bilye seçiliyor. Bu bilyenin kırmızı olma olasılığı hesaplanmak hesaplanacaktır.

3. Bu durumdaki olay aşağıdakilerden hangisidir?
A) Mavi bilye seçilmesi
B) Yeşil bilye seçilmesi
C) Kırmızı bilye seçilmesi
D) Bir bilye seçilmesi

4. Bu durumdaki olayın çıktıları aşağıdakilerden hangisidir?
A) Kırmızı bilyeler
B) Mavi bilyeler
C) Yeşil bilyeler
D) Mavi, yeşil ve kırmızı bilyeler

---

5. "Ali'nin kitaplığında 3 Matematik, 4 Fen Bilgisi ve 6 Türkçe kitabı vardır. Rastgele seçtiği bir kitabın Türkçe kitabı olması olasılığı kaçtır?"

Yukarıda verilen soruya göre, aşağıdakilerden kaç tanesi doğrudur?

I. Deney, kitaplıktan bir kitap seçilmesidir.
II. Örnek uzay, raftaki kitaplardır.
III. Her bir kitabın çekilme olasılıkları farklıdır.
IV. Olayın çıktıları, Türkçe kitaplarıdır.
V. Cevap $\frac{1}{3}$ tür.

A) 1 **B)** 3 **C)** 4 **D)** 5

6th GRADE POSTTEST

6. 1' den 10' a kadar numaralandırılan eş özellikteki 10 top bir torbaya konuluyor. Rastgele çekilen bir topun asal sayı olma olasılığı kaçtır?

A) $\frac{1}{10}$ **B)** $\frac{3}{10}$ **C)** $\frac{2}{5}$ **D)** $\frac{1}{2}$

7. Hilesiz bir zar atılıyor. Üst yüze gelen sayının
I. 5 olması
II. Tek sayı olması
III. Çift sayı olması
IV. 5 ten küçük bir sayı olması
olasılıklarından en büyüğü aşağıdakilerden hangisidir?
A) I **B)** II **C)** III **D)** IV

8. Bir kutuda eş büyüklükte kırmızı ve mavi kalemler vardır. Rastgele bir kalem seçildiğinde mavi gelme olasılığı $\frac{2}{5}$ dir. Kutudaki toplam kalem sayısı 20 olduğuna göre, bu kalemlerden kaç tanesi kırmızıdır?

A) 12 **B)** 8 **C)** 3 **D)** 2

9. Hilesiz bir zar atıldığında üst yüze,
I. Tek sayı gelmesi
II. Tek sayı gelmemesi
III. 7'den küçük gelmesi
IV. 6'dan büyük gelmesi
olaylarının olasılık değerlerinin doğru sıralanışı aşağıdakilerden hangisidir?

A) III < I = II < IV **B)** III < I < II < IV

C) IV < I = II < III **D)** IV < II < I < III

10. MATEMATİK kelimesinin her bir harfi eş özellikteki kartlara yazılıyor ve bakmadan bir kart seçiliyor. Bu kartta L harfi yazma olasılığı kaçtır?

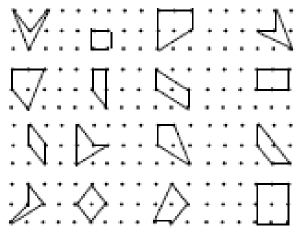
A) 1 **B)** $\frac{1}{6}$ **C)** $\frac{1}{9}$ **D)** 0

11. Aşağıdaki olaylardan hangisinin olma olasılığı en fazladır?
A) Yılın aylarından birisi rastgele seçildiğinde, L harfi ile başlayan bir harf gelmesi
B) 2 mavi, 3 kırmızı bilyeden bir tanesi rastgele seçildiğinde, mavi bilye gelmesi
C) 2 erkek 6 kızdan oluşan bir gruptan birisi rastgele seçildiğinde, seçilenin kız olması
D) Ali, Ahmet ve Ayşe'den birisi rastgele seçildiğinde, isminin A harfi ile başlaması

12. Bir olayın olma olasılığının en küçük ve en büyük değeri sırasıyla aşağıdakilerden hangisinde doğru olarak verilmiştir?

A) -1, 0 **B)** -1, 1 **C)** 0, 1 **D)** 0, sonsuz

13. Yandaki noktalı kâğıtta verilen çokgenlerden rastgele bir tanesi seçildiğinde dörtgen olması olasılığı kaçtır?



A) 1 **B)** $\frac{1}{8}$ **C)** $\frac{1}{16}$ **D)** 0

14. Bir okçunun bir atışta hedefi vurma olasılığı % 60 tır. Buna göre, bu atıcının bir atışta hedefi vurmama olasılığı kaçtır?

A) % 20 **B)** % 30 **C)** % 40 **D)** % 60

7th GRADE PRETEST

1. 4 arkadaş yan yana oturmak şartıyla kaç farklı fotoğraf çektirebilirler?

A) 4 **B)** 10 **C)** 16 **D)** 24

2. 3 kız ve 2 erkekten oluşan bir öğrenci grubu önden arkaya doğru tek sıra olacaktır. Erkekler önde, kızlar arkada olmak üzere kaç farklı şekilde dizilebilirler?

A) 6 **B)** 12 **C)** 24 **D)** 120

3. 10 kişinin katıldığı bir yarışta ilk üç sıralama kaç değişik şekilde gerçekleşebilir?

A)10 **B)** 30 **C)** 90 **D)**720

4. 20 kişilik bir sınıfta bir başkan ve bir başkan yardımcısı kaç farklı şekilde seçilebilir?

A) 20 **B)** 40 **C)** 380 **D)** 400

5. K, İ, T, A, P harflerinden her biri yalnız bir kez kullanılarak beş harfli anlamlı ya da anlamsız kaç farklı kelime oluşturulabilir?

A) 5 **B)** 25 **C)** 120 **D)** 5^5

6. 1, 3, 5, 7, 9 sayılarını birer kez kullanarak 2 basamaklı kaç farklı sayı oluşturulabilir?

A) 20 **B)** 24 **C)** 60 **D)** 120

7. 0, 3, 6, 9 rakamlarını birer kez kullanarak dört basamaklı kaç farklı sayı oluşturulabilir?

A) 6 **B)** 18 **C)** 24 **D)** 30

8. “OLASILIK kelimesinin her bir harfi eş büyüklükteki kağıtlara yazılarak bir torbaya konuluyor. Rastgele bir kağıt çekildiğinde, üzerinde L veya sesli harf yazılı olması olasılığı nedir? ”

Yukarıda verilen sorunun örnek uzayı aşağıdakilerden hangisidir?

A) {O, L, A, I}
B) {O, L, A, S, I, K}
C) {O, L, A, I, L, I}
D) {O, L, A, S, I, L, I, K}

9. “1 den 12 ye kadar (1 ve 12 dahil) olan doğal sayılar aynı özelliklere sahip kartlara yazılarak bir torbaya atlıyor. Rastgele çekilen bir kağıdın üzerinde asal ve tek sayı yazma olasılığı nedir?”

Yukarıdaki sorudaki olaylar aşağıdakilerden hangisinde doğru verilmiştir?

A) {2, 3, 5, 7, 11} ile {1, 3, 5, 7, 9, 11}
B) {1, 2, 3, 5, 7, 11} ile {1, 3, 5, 7, 9, 11}
C) {2, 3, 5, 7, 11} ile {1, 9}
D) {1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11} ile {3, 5, 7, 11}

10. Aşağıda olaylar ve çeşitleri verilmiştir. Buna göre verilenlerden hangisi yanlıştır?

A) Bir zar atıldığında tek ve 4 ten büyük gelmesi - Ayrık olmayan olaylar
B) Bir madeni para atıldığında yazı veya tura gelmesi - Ayrık olaylar
C) Bir ay seçildiğinde yaz veya 30 çeken bir ay olması - Ayrık olmayan olaylar
D) Bir zar atıldığında çift ve asal gelmesi - Ayrık olaylar

11. A ile B ayrık olaylar olmak üzere, P(A) = $\frac{1}{5}$ ve P(AUB) = $\frac{3}{4}$ olduğuna göre P(B) kaçtır?

A) $\frac{4}{15}$ **B)** $\frac{3}{20}$ **C)** $\frac{11}{20}$ **D)** $\frac{19}{20}$

12. A ile B ayrık olmayan iki olay olmak üzere, P(A\B) = $\frac{1}{6}$, P(B\A) = $\frac{1}{4}$ ve P(A∩B) = $\frac{3}{8}$ olduğuna göre P(AUB) kaçtır?

A) $\frac{1}{24}$ **B)** $\frac{7}{24}$ **C)** $\frac{11}{24}$ **D)** $\frac{19}{24}$

7th GRADE PRETEST

13. Büşra ile Ezgi'nin ellerinde eş büyüklükte mavi ve kırmızı kağıtlar vardır. Büşra 5 mavi ve 6 kırmızı kağıda B, Ezgi ise 10 mavi ve 3 kırmızı kağıda E yazıp bir torbaya atıyorlar. Bu torbadan rastgele çekilen bir kağıdın kırmızı veya üzerinde B yazılı olması olasılığı kaçtır?

A) $\frac{3}{8}$ **B)** $\frac{11}{24}$ **C)** $\frac{7}{12}$ **D)** $\frac{5}{6}$

14. Yeni bir işe başlayacak olan Mustafa, haftada kendi belirleyeceği 1 gün izin kullanabilecektir. İzin kullanacağı günün P harfi ile başlaması veya hafta sonuna denk gelmesi olasılığı kaçtır?

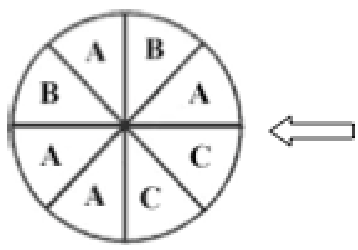
A) $\frac{5}{7}$ **B)** $\frac{4}{7}$ **C)** $\frac{3}{7}$ **D)** $\frac{2}{7}$

15. Yandaki tabloda 8. sınıflar arasında düzenlenen proje yarışmasına katılan bir ilköğretim okulundaki şubelerin hazırladıkları proje sayıları verilmiştir. Okuldan bir proje seçileceğine göre, bu projenin 8-A'nın hazırladığı bir Matematik veya 8-B'nin hazırladığı bir Fen projesi olma olasılıgı kaçtır?

Sınıf / Proje Alanı	8-A	8-B	8-C
MATEMATİK	5	4	3
FEN BİLİMLERİ	4	3	5

A) $\frac{1}{3}$ **B)** $\frac{1}{2}$ **C)** $\frac{2}{3}$ **D)** $\frac{62}{63}$

16.



Yukarıdaki çark saat yönünde bir kez çevrildiğinde, okun A veya C harfinde durması olasılığı kaçtır?

A) $\frac{1}{8}$ **B)** $\frac{5}{8}$ **C)** $\frac{6}{8}$ **D)** $\frac{7}{8}$

17. Aşağıdakilerden hangisinde olasılık değeri, verilen olayların olasılık değerlerinin toplamınaeşittir?

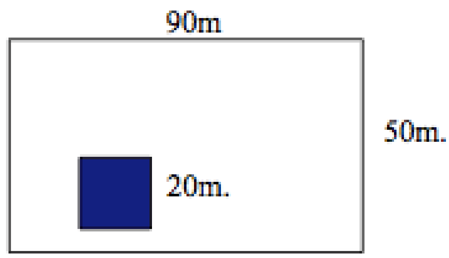
A) Bir torbadaki 1 den 20 ye kadar numaralandırılmış toplardan rastgele bir tanesi çekildiğinde 3 ün veya 4 ün katı gelmesi

B) 250 sayfalık bir kitabın rastgele bir sayfası açıldığında sayfa numarasının asal ve 15 in katı olması

C) İki basamaklı sayılardan rastgele bir tanesi seçildiğinde onlar basamağının 3 veya rakamlarının aynı olması

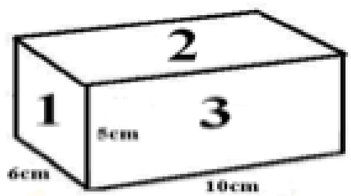
D) Bir kutudaki 5 mavi, 7 sarı ve 4 yeşil bilyeden rastgele bir tanesi çekildiğinde mavi veya sarı gelmesi

18. Bir helikopter, yanda verilen dikdörtgen şeklindeki bir alana iniş yapacaktır. Bu helikopterin içerideki kare alana inme olasılığı kaçtır?



A) $\frac{2}{5}$ **B)** $\frac{2}{9}$ **C)** $\frac{2}{14}$ **D)** $\frac{4}{45}$

19.

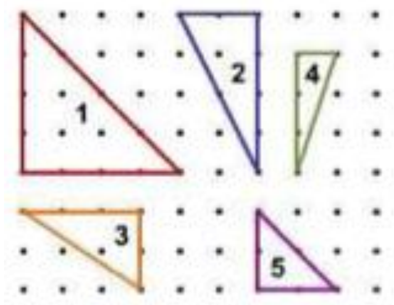


Ayrıtları 5, 6 ve 10cm. olan dikdörtgenler prizması şeklindeki kutunun tüm yüzleri 1'den 6'ya kadar numaralandırılmıştır. Kutu atıldığında 2 numaralı yüzün üste gelme olasılığı kaçtır?

A) $\frac{3}{7}$ **B)** $\frac{3}{14}$ **C)** $\frac{3}{28}$ **D)** $\frac{5}{28}$

7th GRADE PRETEST

20.



Kerem şekildeki gibi bir kağıda yukarıdan küçük cisim bırakıyor. Buna göre verilen beş bölgeyle ilgili olarak aşağıdakilerden hangisi yanlıştır?

A) Cismin 1 numaralı bölgeye düşme olasılığı en büyüktür.
B) Cismin 4 numaralı bölgeye düşme olasılığı en küçüktür.
C) Cismin 3 veya 4 numaralı bölgeye düşme olasılığı 9/37 dir.
D) Cismin 2 numaralı bölgeye düşme olasılığı, 5 numaralı bölgeye düşme olasılığının 2 katıdır.

7th GRADE POSTTEST

1. Yandaki kare, köşelerinde K,L,M ve N harfleri kullanılarak kaç farklı şekilde adlandırılabilir?

A) 4 **B)** 12 **C)** 16 **D)** 24

2. 5, 6, 7, 8, 9 rakamlarını birer kez kullanarak 9 ile başlayıp 7 ile biten beş basamaklı kaç farklı sayı yazılabilir?

A) 6 **B)** 12 **C)** 24 **D)** 120

3. P(5, 2) ifadesinin değeri kaçtır?

A) 10 **B)** 20 **C)** 25 **D)** 60

4. Aşağıda verilen permütasyonlardan hangisinin değeri en büyüktür?

A) P(8, 7) **B)** P(4, 2) **C)** P(10, 2) **D)** P(6, 4)

5. I. P(9,0) = 0 II. P(9,9) = 1
III. P(12,11) = P(12,12) IV. P(20,1) = 20
Yukarıdaki ifadelerden kaç tanesi doğrudur?

A) 4 **B)** 3 **C)** 2 **D)** 1

6. Asal rakamlar kullanılarak yazılabilecek, rakamları farklı ve üç basamaklı sayılardan kaç tanesi çift sayıdır?

A) 4 **B)** 6 **C)** 12 **D)** 24

7. Furkan dolabındaki 3 farklı pantolon ve 4 farklı gömleği, aynı tür kıyafetler yan yana olmak şartıyla kaç değişik şekilde dizebilir?

A) 144 **B)** 288 **C)** 720 **D)** 5040

7^{th} GRADE POSTTEST

8. "Ahmet'in 2 Matematik, 4 Fen Bilgisi, 3 Türkçe kitabı ve Selim'in 4 Matematik, 5 Türkçe kitabı aynı rafta dizilidir. Rastgele seçilen bir kitabın Selim'in kitabı veya Matematik kitabı olması olasılığı kaçtır?"

Yukarıda verilen soruya göre,

I. Deney, raftan kitap seçilmesidir.
II. Örnek uzay, raftaki kitaplardır.
III. Verilen olaylar ayrık olaylardır.
IV. Cevap $\frac{5}{6}$ dır.

ifadelerinden kaç tanesi doğrudur?

A) 1 **B)** 2 **C)** 3 **D)** 4

9. "Hilesiz bir zar havaya atıldığında üst yüze gelen sayının 5'ten küçük ve tek sayı gelmesi"

Yukarıdaki olayın deneyi, örnek uzayı ve çeşidi aşağıdakilerden hangisinde doğru olarak verilmiştir?

DENEY	ÖRNEK UZAY	OLAY ÇEŞİDİ
A) Zarın havaya atılması	{1,2,3,4,5,6}	Ayrık olmayan
B) Zarın 5'ten küçük ve tek sayı gelmesi	{1,2,3,4,5,6}	Ayrık
C) Zarın 5'ten küçük ve tek sayı gelmesi	{1,3}	Ayrık olmayan
D) Zarın havaya atılması	{1,3}	Ayrık

10. Bir kutuda 1 den 10 a kadar numaralandırılmış eş büyüklükte 10 top bulunmaktadır.

Rastgele çekilen bir topun,
Asal veya tek sayı gelmesi olayları ………. olaylardır.
Tek veya çift sayı gelmesi olayları ………. olaylardır.
Çift veya 3 ün katı gelmesi olayları ………. olaylardır.

Yukarıda noktalı yerlere yazılması gereken sözcüklerin doğru sıralanışı aşağıdakilerden hangisidir?

A) ayrık - ayrık - ayrık olmayan
B) ayrık olmayan - ayrık - ayrık olmayan
C) ayrık - ayrık olmayan - ayrık olmayan
D) ayrık olmayan - ayrık – ayrık

7th GRADE POSTTEST

11. I. Hilesiz bir zar atıldığında tek ve asal gelmesi
II. Hilesiz bir zar atıldığında tek veya asal gelmesi
III. Hilesiz bir zar atıldığında çift veya tek gelmesi
IV. Hilesiz bir zar atıldığında çift ve tek gelmesi

Yukarıdaki olayların olasılık değerlerinin büyükten küçüğe doğru sıralanışı aşağıdakilerden hangisinde doğru olarak verilmiştir?

A) IV, I, II, III **B)** III, II, I, IV **C)** III, I, IV, II **D)** II, IV, I, III

12. Yandaki tabloda Ferdi'nin kitaplığındaki kitap sayıları verilmiştir. Buna göre, Ferdi kitaplıktan rastgele bir kitap seçtiğinde, bu kitabın 2007 baskılı veya masal olma olasılığı kaçtır?

Basım Yılı / Kitap Türü	2005	2006	2007
Roman	2	5	2
Hikaye	1	2	1
Masal	1	0	2
Şiir	3	1	4

A) $\frac{1}{8}$ **B)** $\frac{3}{8}$ **C)** $\frac{5}{12}$ **D)** $\frac{1}{2}$

13. Bir düzgün sekizyüzlünün her bir yüzüne 1 den 8 e kadar tüm rakamlar yazılmıştır. Bu düzgün sekizyüzlü atıldığında üst yüze 3'ten büyük veya asal sayı gelme olasılığı ile olay çeşidi aşağıdakilerden hangisinde doğru olarak verilmiştir?

A) $\frac{1}{4}$, Ayrık olmayan **B)** $\frac{1}{4}$, Ayrık

C) $\frac{7}{8}$, Ayrık **D)** $\frac{7}{8}$, Ayrık olmayan

14. MATEMATİK kelimesinin her bir harfi eş özellikteki kartlara yazılıp bir torbaya atılıyor. Torbadan rastgele seçilen bir kartın üzerinde sessiz harf veya A harfi yazılı olması olasılığı kaçtır?

A) $\frac{2}{9}$ **B)** $\frac{4}{9}$ **C)** $\frac{5}{9}$ **D)** $\frac{7}{9}$

15.

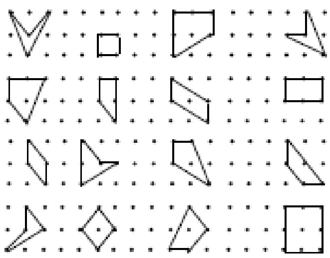
Şekildeki gibi bir düzgün onikiyüzlünün her bir yüzü 1 den 12 ye kadar numaralandırılmıştır. Düzgün onikiyüzlü atıldığında üst yüze 10 dan küçük ve 3 ile tam bölünebilen bir sayı gelme olasılığı kaçtır?

A) $\frac{1}{4}$ **B)** $\frac{1}{3}$ **C)** $\frac{3}{4}$ **D)** $\frac{5}{6}$

16. Koltukların yan yana 10 ar tane ve arka arkaya 15 er tane sıralandığı bir sinema salonunda, rastgele alınan bir biletin önden 4. veya soldan 2. sıraya denk gelmesi olasılığı kaçtır?

A) $\frac{1}{150}$ **B)** $\frac{4}{25}$ **C)** $\frac{1}{6}$ **D)** $\frac{1}{2}$

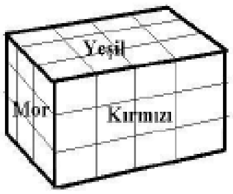
17. Yandaki noktalı kâğıtta verilen dörtgenlerden herhangi birisi rastgele seçildiğinde, bu dörtgenin yamuk veya en az bir iç açısının 90º olması olasılığı kaçtır?



A) $\frac{3}{16}$ **B)** $\frac{1}{2}$ **C)** $\frac{9}{16}$ **D)** $\frac{11}{16}$

7th GRADE POSTTEST

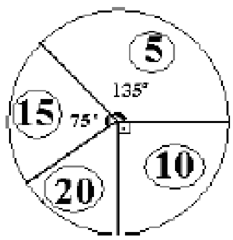
18.



Yukarıdaki şekilde verilen dikdörtgenler prizmasının eş karelere ayrılmış olan yüzlerinden karşılıklı olanları aynı renge boyanmıştır. Bu prizma atıldığında kırmızı yüzün altta kalması olasılığı kaçtır?

A) $\frac{1}{6}$ **B)** $\frac{1}{3}$ **C)** $\frac{4}{11}$ **D)** $\frac{8}{11}$

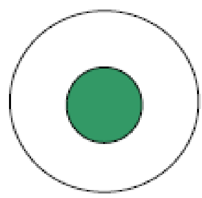
19.



Yukarıdaki gibi bir daireyle oynanan oyunda, oyuncunun attığı ok ile 20 puan alması olasılığı kaçtır?

A) $\frac{1}{6}$ **B)** $\frac{1}{5}$ **C)** $\frac{1}{4}$ **D)** $\frac{2}{5}$

20. Melih yandaki platforma atış yapacaktır. Büyük dairenin çapı küçük dairenin çapının 3 katı olduğuna göre Melih'in beyaz bölgeyi vurma olasılığı kaçtır?



A) $\frac{1}{3}$ **B)** $\frac{1}{2}$ **C)** $\frac{3}{4}$ **D)** $\frac{8}{9}$

APPENDIX B: REFLECTIVE THINKING TOWARDS PROBLEM SOLVING SCALE (RTPSS)

Bu ölçekte doğru ya da yanlış cevap söz konusu değildir. Her soru için size uygun olan seçeneği işaretleyiniz.

	Her zaman	**Çoğu zaman**	**Bazen**	**Nadiren**	**Hiçbir zaman**
1) Bir problemi çözemediğimde, neden çözemediğimi anlamak için kendime sorular sorarım.					
2) Problemi çözdükten sonra daha iyi bir çözüm yolu bulabilir miyim diye düşünürüm.					
3) Arkadaşlarımın çözüm yollarını sorgulayarak daha iyi bir yol bulmaya çalışırım.					
4) Çözüm yollarımı tekrar tekrar değerlendirip bir sonraki problemi daha iyi çözmeye çalışırım.					
5) Problem çözerken, hangi işlemi neden yaptığımı düşünerek yaparım.					
6) Bir problemi çözdüğümde, yaptığım işlemleri tekrar inceler, değerlendiririm.					
7) Problem çözerken, farklı çözüm yolları bulmak için kendime sorular sorarım.					
8) Problem çözerken, yaptığım işlemlerin nedenini düşünerek, bulduğum sonuçla ilişkisini kurmaya çalışırım.					
9) Bir problemi okuduğumda, çözüm için hangi bilgiye ihtiyacım olduğunu düşünürüm.					
10) Problemi çözüp sonucunu bulduktan sonra yaptığım işlemleri kontrol ederim.					
11) Bir problemi okuduğumda, daha önce çözdüğüm problemleri düşünerek benzerlik ve farklılıklarına göre aralarında ilişki kurarım.					
12) Problem çözerken, her işlemimi önceki ve sonraki adımlarımı düşünerek yaparım.					
13) Problemi okuduğumda verilen ve istenenleri belirlemek için kendime sorular sorarım.					
14) Problemi çözdükten sonra arkadaşlarımın çözümleri ile karşılaştırır, sonucumu değerlendiririm.					

APPENDIX C: STUDENT WORKSHEETS USED IN THE MAIN STUDY

Activity:	**Aquarium Animation**
Week:	1
Content:	In this activity, we will learn how to use Scratch: • to create new characters • to change the background image • to use programming blocks • to move characters programmatically And also we will use Scratch to study some geometry concepts: • Angles • Lines • Circles
Description:	 We are going to develop an aquarium animation. We will add an aquarium background to our project and at least 3 fishes. You can also add crabs, divers, starfishes etc. You can even add fantastic characters like a swimming cow or a banana eating fish. In the second part of this activity, your teacher will conduct a discussion about the relation between an aquarium and mathematics.

Figure C.1. Student worksheet of the 1st activity of the main study.

Activity:	Loves me, Loves me Not
Week:	2
Content:	In this activity, we will learn how to: • create costumes for our characters • change costumes and backgrounds programmatically • use keyboard buttons in our projects in Scratch. In addition, we will use Scratch to study fractions.
Description:	 We are going to develop a "loves me, loves me not" game. When the user presses a button, such as space, tab, or simply A or B, a leaf will decrease from our flower. Also, a text will change continuously showing "loves me" or "loves me not". In the second part of this activity, your teacher will conduct a discussion about the relation between our game and fractions in mathematics.

Figure C.2. Student worksheet of the 2nd activity of the main study.

Activity:	Milli Piyango Simulation
Week:	3
Content:	In this activity, we will learn how to: • create and use variables • use loops • make logical decisions in Scratch. Also, we will use Scratch to study sample spaces.
Description:	 We are going to develop a lottery (a.k.a. "Milli Piyango") simulation. There will be variables to change the number of digits in the simulation and the max number. User will press a button to generate a random number. In the second part of this activity, your teacher will conduct a discussion about the relation between our simulation and sample spaces.

Figure C.3. Student worksheet of the 3rd activity of the main study.

Activity:	Pet Feeding
Week:	4
Content:	In this activity, we will learn how to: • understand if one character touches another • create lists and manipulate variables • use broadcasting blocks in Scratch. Also, we will use Scratch to study ratios.
Description:	 We are going to develop a pet feeding game. You can choose any animal you like. We will control our animal by pressing arrow key on keyboard. Foods will appear randomly on the screen. The user will have 60 seconds to finish the game. Our pet will grow after eating a food. If user can't grow the animal enough, they will fail. In the second part of this activity, your teacher will conduct a discussion about the relation between our game and ratio concept.

Figure C.4. Student worksheet of the 4th activity of the main study.

Activity:	Coin Flipping
Week:	5
Content:	In this activity, we will develop a coin flipping game in order to study randomness.
Description:	 We are going to develop a coin flipping game. We will create a coin character with two costumes: heads and tails. The user will press a button and coin will flip randomly. In the second part of this activity, your teacher will conduct a discussion about the relation between our game and probability concepts.

Figure C.5. Student worksheet of the 5th activity of the main study.

Activity:	**Lucky 100**
Week:	6
Content:	In this activity, we will develop a dice game in order to study probability.
Description:	 We will develop a dice game. The game will consist a dice and two buttons for two users. The users will press their buttons in turns and the dice will roll. The first to collect 100 points will win the game. After developing the games, your teacher will conduct a discussion about the relation between our game and probability concepts.

Figure C.6. Student worksheet of the 6th activity of the main study.

<table>
<tr><td>Activity:</td><td>Problem Solving with Scratch</td></tr>
<tr><td>Week:</td><td>7</td></tr>
<tr><td>Content:</td><td>In this activity, we will solve a mathematics problem using Scratch.</td></tr>
<tr><td>Description:</td><td>

The question is:

There are 4 different roads from City A to City B, and 2 different roads from City B to City C. A driver wants to go to City C by visiting City B. How many different roads can he use?

In the second part of this activity, your teacher will conduct a discussion about basic principles of counting and will ask you to make some changes in your projects.
</td></tr>
</table>

Figure C.7. Student worksheet of the 7th activity of the main study.

Activity:	100 Meters Sprint
Week:	8
Content:	In this activity, we will develop a 100 meters running game in order to study probability.
Description:	 There will be 6 runners and a RUN button in our games. When the RUN button clicked, a dice will roll and the corresponding runner will advance 10 meters. For example, if 6 comes, 6th runner will go one step. In the second part of this activity, your teacher will conduct a discussion about randomness and will ask you to make some changes in your projects.

Figure C.8. Student worksheet of the 8th activity of the main study.

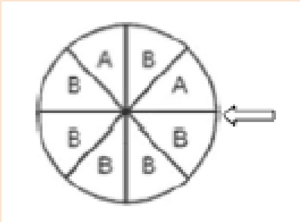
Activity:	Wheel of Fortune
Week:	9
Content:	In this activity, we will solve a wheel of fortune problem using Scratch.
Description:	The question is as follows: *What is the probability of getting A, when the wheel is spun clockwise one time?*  In the second part of this activity, your teacher will conduct a discussion about probability and will ask you to make some changes in your projects.

Figure C.9. Student worksheet of the 9th activity of the main study.

APPENDIX D: TEACHER GUIDELINES USED IN MAIN STUDY

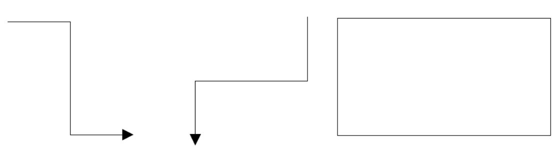
Activity:	**Aquarium Animation**
Week:	1
Content:	This is an introductory activity for kids to learn Scratch. At the end of this lesson, students should be able to learn the interface of Scratch, character settings and its programming blocks system. The order of instruction is as follows: 1. Opening www.scratch.mit.edu webpage and showing how to use it. a. It's the Youtube of Scratch. b. Creating a new user. c. Creating a new project d. Saving and sharing the project 2. Motion Blocks a. Move 10 steps b. Turn 15 degrees c. Point in direction 90 d. If on the edge, bounce 3. Control Blocks a. Forever b. Wait 1 seconds 4. Adding characters and background a. Choosing from library b. Drawing by hand c. Resizing d. Removing e. Giving names to the characters 5. Events a. When green flag clicked
Description:	In the beginning, students will use the cat while learning motion blocks and forever block. After that, they will start creating an aquarium. They will change the background, remove the cat, add fishes and use block to make the fishes swim.
Mathematics Discussion	The teacher will start a discussion about the mathematics content of the animation: 1. Did we need mathematics knowledge to make this game? If yes, explain. 2. Which mathematical concepts did we use? 3. Can you make your fish move on paths like these drawings:  4. Can you calculate the distance your fishes travel?

Figure D.1. Teacher guidlines of the 1st activity of the main study.

Activity:	**Loves me, Loves me Not**
Week:	2
Content:	1. Events a. When space key pressed 2. Character Costumes a. Adding costumes b. Giving names to costumes c. Changing order of costumes 3. Looks blocks a. Say hello b. Switch costume c. Next costume
Description:	In the beginning, students will make the cat move by pressing arrow keys like pressing → for right and ← for left. Then they will learn how to change costumes by making a dancer animation. Then they will be asked to develop a "loves me, loves me not" game.
Mathematics Discussion	The teacher will start a discussion about the mathematics content of the animation: 1. Do you see any usage of fractions in our projects? 2. What fraction of your flower is left after pressing space for 6 times? 3. After how many spaces your flower loses ½ of its leafs? 4. Now change your projects according to the following fractions. a. Whe the space key pressed, it should lose 1/6th of its leafs. b. When the space key pressed, it should lose 1/3rd of its leafs.

Figure D.2. Teacher guidlines of the 2nd activity of the main study.

Activity:	Milli Piyango
Week:	3
Content:	1. Variables a. Make variable b. Set variable to 0 c. Change variable by 1 d. Change the look of the variable by double clicking 2. Control a. Repeat 10 b. If-then-else 3. Operators a. +, -, *, / b. Pick random 4. Looks a. Show, hide
Description:	In the beginning, students will learn how to use variables by making a basic simulation, which changes the size of the cat according to a variable. They will also make the cat bigger when up arrow key pressed and make it smaller when down arrow pressed. Then they will develop a lottery game which has max 6 characters. There will be two variables: digit count and max value. If digit count is 4, 4 characters will be shown and other two will be hidden. Max value will contain sample spaces. Random numbers will be chosen between 0 and this max number.
Mathematics Discussion	1. Can you tell me what numbers did you get? 2. What is the highest number? 3. Let's assume that we set MAX_NUMBER to 6, what numbers can we get? 4. Can we get 8? 5. Do you know what sample space is? 6. Can you develop an application, in which 100 numbers are drawn automatically? Can we collect statistics of these numbers? 7. Which numbers do you think we will get most?

Figure D.3. Teacher guidlines of the 3rd activity of the main study.

Activity:	Pet Feeding
Week:	4
Content:	1. Sensing a. Touching to a character? b. Touching to a color? c. Timer 2. Events a. Broadcast message b. When I receive a message
Description:	In the beginning, students will learn how to check if one character touches each other. They will create their pets and foods. Then, they will learn how to broadcast messages to other objects. They will use it to make animal growth after touching a good food or to make it shrink after touching a bad food.
Mathematics Discussion	1. Do you see any use of ratio in our projects? 2. Which block should we use to grow our animal in the ratio ½? 3. Can you change your game mechanics as follows: Put three different types of food: a. First food increases the size by ¼ b. Second food increases the size by 1/10 c. Third food decreases the size by ½ d. There are 3 good foods for every 1 bad food.

Figure D.4. Teacher guidlines of the 4^{th} activity of the main study.

Activity:	Coin Flipping
Week:	5
Content:	Randomness
Description:	Students will develop a coin flipping game which consists a button to flip the coin, and a coin image which consists heads image and tails image as costumes. When the flip button clicked, the game will pick a random number as FLIP_COUNT and costumes will change FLIP_COUNT times.
Mathematics Discussion	1. What is the event here? 2. What is the sample space of this event? 3. Which one has higher probability: getting heads or getting tails? Why do you think so? 4. Use your friend's game and conduct 20 experiments. Count the results and share with us. 5. Can we make the computer run tests for us? For example, can we make it run 1000 experiments and report the data? Let's do it, and share our results together! 6. How can we convert these results to fractions and percentages?

Figure D.5. Teacher guidlines of the 5th activity of the main study.

Activity:	**Lucky 100**
Week:	6
Content:	Probability
Description:	Students will develop a dice game. The game will consist a dice and two buttons for two users. The users will press their buttons in turns and the dice will roll. The first to collect 100 points will win the game.
Mathematics Discussion	1. What is the event here? 2. What is the sample space of this event? 3. What can be an impossible event in this situation? 4. What can be a certain event for situation? 5. Which number has highest probability? Explain why. 6. Which player has higher probability to win? Explain why. 7. Like last week's activity, can we automate this process? Can we make the computer play the game for us 100 times, for example? Let's do that, and share results. 8. How can we convert these results to fractions and percentages?

Figure D.6. Teacher guidlines of the 6th activity of the main study.

Activity:	Problem Solving with Scratch
Week:	7
Content:	Basic principles of counting
Description:	In this activity, students will try to solve a question by developing a Scratch project. The question is: *There are 4 different roads from City A to City B, and 2 different roads from City B to City C. A driver wants to go to City C by visiting City B. How many different roads can he use?* They will need to create a car and icons for cities A, B and C. They will draw roads between these cities. Then they will create the animation of the question by hand.
Mathematics Discussion	1. How many different paths did you need to create? 2. Add another road between City B and City C. What changes? 3. Do you think there is a formula of this? 4. Remove two roads between City A and City B. Now calculate the paths. Does it fit our formula?

Figure D.7. Teacher guidlines of the 7^{th} activity of the main study.

Activity:	100 Meters Sprint
Week:	8
Content:	Randomness
Description:	Students will develop a dice game. There will be 6 runners and a RUN button in the games. When the RUN button clicked, a dice will roll and the corresponding runner will advance 10 meters. For example, if 6 comes, 6^{th} runner will go one step. They will create the dice by adding costumes to a character and roll it by choosing a random number, just like coin flipping activity.
Mathematics Discussion	1. What is the event here? 2. What is the sample space of this event? 3. Which runner has higher probability to win? Explain why. 4. Can we automate this process, like lucky 100 game? Can we make the computer play the game for us 100 times and collect data? Let's do that, and share results. 5. How can we convert these results to fractions and percentages?

Figure D.8. Teacher guidlines of the 8^{th} activity of the main study.

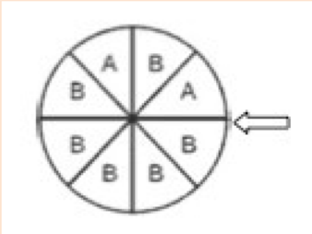
Activity:	Wheel of Fortune
Week:	9
Content:	Probability
Description:	Students will try to solve following question: *What is the probability of getting A, when the wheel is spun clockwise one time?*  They will be given the wheel of fortune because it is very hard to draw a precise one with Scratch. They will be asked to paint pieces of the wheel to different colors accordingly. Students will check the result by using "Touching color?" block.
Mathematics Discussion	1. What is the event here? 2. What is the sample space of this event? 3. Which letter has highest probability? Explain why. 4. Can we automate this process? Can we make the computer turn the wheel for us 100 times, for example? Let's do that, and share results. 5. How can we convert these results to fractions and percentages? 6. What if we change one B to A? How will this effect the results? Chan you do that?

Figure D.9. Teacher guidlines of the 9th activity of the main study.

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