THE EFFECT OF INSTRUCTIONAL SUPPORT ON LEARNING GAINS FROM TWO SIMULATED LABORATORY EXPERIMENTS ON THE RELATIONSHIP BETWEEN TWO VARIABLES

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ABSTRACT

THE EFFECT OF INSTRUCTIONAL SUPPORT ON LEARNING GAINS FROM TWO SIMULATED LABORATORY EXPERIMENTS ON THE RELATIONSHIP BETWEEN TWO VARIABLES

The present study attempts to understand the effect of additional instructional support in recognizing and recalling the relationships between two variables in two simulated laboratory experiments which include multiple representations. It was carried out with the seventh graders in a public primary school in Istanbul. Pretest-posttest group design was used in this study. 44 seventh grade students were assigned randomly into two groups each consists of 22 students but trying to match the groups according to their sixth class science and math grade means and gender. Both groups were administered a pretest called "Test on Relationships between two Variables" (TR-b2V pretest) and both made the same two simulated experiments on the computer laboratory. However, the supported group (Group S) completed a worksheet given as an additional instructional support during the simulated lab experiments whereas non-supported group (Group NS) worked only with guides included in the simulation environment. Both groups received two post measures. Firstly, Recall of Representation Test (RRT) was administered to assess the degree to which students could recall the representations in the simulation environment. Secondly TR-b2V was administered as a posttest four days after the treatment. Findings indicated a significant difference between pretest and posttest results for all participants. However, no significant difference was found between the Group S and Group NS in terms of learning gains which was calculated by differences of pretest and posttest scores. Worksheets did not result in significant improvements in the performance of Group S according to Group NS. Similarly, the Group S performed not significantly higher than the Group NS in terms of RRT scores although RRT mean of Group S was higher than RRT mean of Group NS. Therefore, the positive effect of the additional instructional support in two simulated lab experiments was inconclusive in terms of learning gains and recalling performance of the seventh graders.

ÖZET

İKİ DEĞİŞKEN ARASINDAKİ İLİŞKİ İLE İLGİLİ İKİ SİMULASYON DENEYİNDE ÖĞRETİM DESTEĞİNİN ÖĞRENİM KAZANIMLARI ÜZERİNDEKİ ETKİSİ

Bu çalışmanın amacı, ek bir öğretim desteğinin iki değişken arasındaki ilişki ile ilgili birden fazla gösterim içeren iki simülasyon laboratuar deneylerinde, bu ilişkinin farkına varmak ve bu ilişkiyi hatırlamak açısından etkisini araştırmaktır. Çalışma, İstanbul'da bir devlet okulundaki yedinci sınıf öğrencileri ile yapılmıştır. Araştırma ön test-son test desenini kullanmaktadır. Toplamda 44 yedinci sınıf öğrencisi rast gele fakat altıncı sınıf matematik ve fen dersleri not ortalamaları ile cinsiyetleri eşleştirilerek yirmi ikişer kişilik iki gruba ayrılmıştır. Her iki deney grubuna ön test olarak verilen "İki Değişken Arasındaki İlişki Testi" ve aynı iki simülasyon laboratuar deneyleri bilgisayar laboratuarında uygulanmıştır. Ancak destek alan grup (Grup S) deneyler sırasında ek olarak verilen çalışma kâğıtlarını doldurmuş, destek almayan grup ise (Grup NS) sadece simülasyon ortamında yer alan yönlendirme ile çalışmıştır. Uygulama sonrası her iki gruba da iki test uygulanmıştır. İlk olarak öğrencilerin simülasyon ortamındaki gösterimleri hatırlama düzeylerini ölçmek için Gösterim Hatırlama Testi (RRT) verilmiştir. İkinci olarak da uygulamadan dört gün sonra "İki Değişken Arasındaki İlişki Testi" son test olarak verilmiştir. Sonuçlar, çalışmaya katılan tüm öğrencilerin ön test ve son test sonuçları arasında anlamlı bir fark bulmuştur. Buna rağmen, ön test ve son test puanları arasındaki farklar hesaplanarak elde edilen öğrenim kazanımları açısından iki grup arasında anlamlı bir fark bulunamamıştır. Çalışma kâğıtları, destek alan grubun erişi düzeyinde diğer gruba göre anlamlı bir gelişme sağlamamıştır. Gösterimleri hatırlama düzeyi test sonuçlarına göre de destek alan grubun ortalaması diğer grubun ortalamasından yüksek olmasına rağmen iki grubun performansları arasında anlamlı bir fark bulunmamıştır. Sonuç olarak, iki değişken arasındaki ilişkiyi kavratma ile ilgili iki simülasyon laboratuar deneyleri esnasında verilen ek öğretim desteğinin yedinci sınıfların öğrenim kazanımlarına ve bu deneylerde bulunan gösterimleri hatırlama düzeyi üzerine olumlu bir katkı sağlamamıştır.

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LIST OF ABBREVIATIONS

CAI	Computer Assisted Instruction
d.f	Degrees of freedom
M	Mean
MBL	Microcomputer Based Labs
N	Number of subjects
NCTM	National Council of Teachers of Mathematics
NS	Non-supported
RRT	Recall of Representations Test
S	Supported
SD	Standard deviation
SE	Standard Error
Sig	Significant value
SPSS	Statistical Program for Social Sciences
TR-b2V	Test on the Relationship between two Variables

1. INTRODUCTION

In recent years, technology use in science and mathematics instructions has been increased. For instance, important technologies in mathematics and science education include physical manipulatives, calculators, computers, software, sensors and probes, and networking. In mathematics, graphing calculators, dynamic geometry tools, and multiple representations are already widely used to improve instruction. Especially graphing calculators can enable students to construct and use multiple representations, such as equations, tables, and graphs, and allow them to spend most of their time and mental energy on important mathematical concepts. Additionally, technology can combine the multi representations; for example, students can observe how a change in an equation links to a change in a graph.

In recognition of the importance of technology, the National Council of Teachers of Mathematics has established the Technology Principle as one of the six principles of High-Quality Mathematics Program outlined in *Principles and Standards for School Mathematics,* that *“Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students’ learning (NCTM, 2000, p.24)”.*

For Science Education, instructional technology also offers some opportunities such as focusing science teaching on inquiring, understanding, and seeking explanations instead of on factual knowledge, confirmatory experiments, and pre-planned investigations. For instance, electronic sensors and probes can be used in all areas of science: pH sensors in biology, pressure probes in chemistry, and motion recorders in physics. They can allow students to collect, graph, and analyze data more quickly and to focus on meaning rather than technique. Moreover, a computer can also allow students doing simulated experiments that are best investigated in a virtual environment. Computers enable repeated trials of an experiment with noticeable ease in a limited time, expose students to a wide range of experiments which may be too complicated, expensive, or dangerous to perform, provide instant feedback, allow simultaneous observation of graphical representations and offer a flexible environment.

Because of the importance of using technology in science and mathematics education as stated in the previous paragraphs, the effectiveness of computerized learning environments and how these environments can be more effective are the current research issues in these areas. Currently, computerized multimedia learning environments are highly popular that they permit students to focus on mathematical and scientific concepts, to reason, to explore ideas in a variety of modes-numeric, graphical, symbolic and to identify patterns and relationships between variables. There are many researches about the effectiveness of multimedia instructions which mostly emphasize the use of multiple representations with the help of technology. Instructional technology is particularly helpful in creating learning environments that allow for the learner to experience and coordinate multiple representations of the same procedure. However, some research also claims that multimedia instruction may actually hinder the learning and refers to Cognitive Load Theory (Sweller, 1994) to explain learner problems that students may encounter when working with multiple representations. According to the theory, multimedia learning environments consist of varied representations. This may cause heavy cognitive load in working memory because of the fact that the human mind is limited in the amount of information that it can process (Miller, 1956). Therefore, the theory suggests that the ways not to overload the mind's capacity for processing information should be considered in order to design an effective multimedia instruction. It is important to fill this limited capacity with important information not unimportant ones, and direct learner's attention to the relevant information. For this issue, Richard Mayer recommended eight principles for more effective multimedia instructions and tries to give a solution to the leading questions "How should we design multimedia instructional messages in order to promote deep understanding in learners and escape from heavy cognitive load?" with these principles (Mayer, 2002).

In addition to Mayer's Principles of multimedia learning, research also suggest using various additional instructional support mechanisms in multimedia instructional designs to overcome heavy cognitive load and to help learners select and relate relevant information included in multimedia programs. According to Berger *et al.* completely unassisted and exploratory computerized environments may cause some difficulties that students may encounter in multimedia designs (Berger *et al,* 1994). Easily accessible domain specific information (Leutner,1993), adjunct questions (Holliday and McGuire, 1992), instructional prompts (Lin.and Lehman, 1999), information sheets (Nijoo and de Jong, 1993) or assignments that guide inquiry (de Jong and van Joolingen, 1998) are some suggested additional instructional support systems in order to improve the effectiveness of multimedia learning.

The simulation environment used in the present study includes two computer lab experiments that were designed to encourage students' ability to recognize the relationship between two variables. The experiments contain multiple representations such as tabular and graphical ones, so the experimental screens may cause a heavy cognitive load in students' working memory and additional support should be used to decrease the level of this load. When all things are considered, the present study tries to understand the effects of additional instructional support in terms of learning gains of students and how much they can recall representations in two simulated experiments. The experiments are designed to make students observe relationship between two variables.

2. REVIEW OF LITERATURE

2.1. Multimedia Instruction

Nowadays, the use of multimedia instruction systems in teaching and learning has been most popular and increasing rapidly. The integration of various media enhances the quality of education so that it is essential to improvement of education. However, firstly the meaning of multimedia should be explained explicitly. According to Mayer, Multimedia refers to a technology for presenting material in both visual and verbal forms and Multimedia instruction is a presentation involving words and pictures that is intended to foster learning (Mayer, 2001). In other words, multimedia is the use of text, graphics, animation, pictures, video, and sound to present information and Multimedia instruction is to design such learning environments that combine multiple forms of representations like texts, static and animated pictures or graphs. Since, multimedia can now be integrated using a computer, there has been many practical computer-based multimedia instructional applications. As a result, multimedia is being used increasingly to provide computer-based instruction. One of the definitions of multimedia instruction also supports the idea of using computers in multimedia learning that is given in the book multimedia instruction literacy (Hofstetter, 1995):

"Multimedia Instruction is the use of a computer to present and combine text, graphics, audio and video, with links and tools that let the user navigate, interact, create and communicate. This definition contains four components essential to Multimedia Instruction. First, there must be a computer to coordinate what you see and hear and to interact with. Second, there must be links that connect the information. Third, there must be navigational tools. Finally, there must be ways for you to gather process and communicate your own information and ideas.

If one of these components is missing, you do not have multimedia instruction. For example, if you have no computer to provide interactivity, you have mixed media, not multimedia instruction. If there are no navigational tools to let you decide the course of action, you have a movie, not multimedia instruction. If you cannot create and contribute your own ideas, you have a television, not multimedia instruction."

Moreover, multimedia may be defined in multiple ways, depending upon one's perspective. Typical definitions include the following:

- Multimedia is the "use of multiple forms of media in a presentation" (Schwartz and Beichner, 1999).
- Multimedia is the "combined use of several media, such as movies, slides, music, and lighting, especially for the purpose of education or entertainment" (Brooks, 1997).
- Multimedia is "information in the form of graphics, audio, video, or movies. A multimedia document contains a media element other than plain text" (Greenlaw and Hepp, 1999).
- Multimedia comprises a computer program that includes "text along with at least one of the following: audio or sophisticated sound, music, video, photographs, 3-D graphics, animation, or high-resolution graphics" (Maddux *et al.*, 2001).

The similarities among these definitions are the use of more than one medium for communication and representing information; and most commonly the use of computer for integration of multiple forms of representations such as text, sound, graphic, static and animated pictures.

Computer simulations as an example of multimedia applications has also been in use as educational tools presently, although they have mainly been used in science fiction, high-tech industries, and computer games. Computer simulations are computer-generated versions of real-world objects (for example, a sky scraper or chemical molecules) or processes (for example, population growth or biological decay). They may be presented in 2-dimensional (text-driven formats) or, increasingly, 3-dimensional (multimedia formats). They can take many different forms, ranging from 3-dimensional geometric shapes to highly interactive computerized laboratory experiments. Computer simulations are a potentially powerful learning technology by itself, offering teachers a means to concretize abstract concepts for students and provide them with opportunities to learn by doing what they might otherwise encounter only in a textbook. This technology offers students the unique opportunity of experiencing and exploring a broad range of environments, objects, and phenomena within the walls of the classroom so that educational researchers have started to investigate the effectiveness of such technologies and their educational applications.

As multimedia environments include representation of knowledge in more than a single system, there is an increase in the popularity of the topics that deal with learning with multiple representations. Thus there has been much research in educational and cognitive science about how students learn from multiple representations. Most of these research aim to examine how different combinations of representations influence learning; to identify a set of design principles for successful multi-representational software; and to develop a model of how people learn with multiple representations. All these research share a common assumption that multimedia information helps people learn. In order to find out whether there is empirical support for this assumption, many studies from a variety of fields should be reviewed firstly to show that multimedia may be able to help people learn more information more quickly.

2.2. Effectiveness of Multimedia Instruction

The questions whether/why multimedia instruction is currently most preferred to a traditional instruction/ a classroom lecture which is most commonly used instructional method and whether there is any empirical evidence to support the statement that multimedia improves effectiveness of learning are currently discussed by educational researchers. There is a significant body of research that establishes the benefits of using multimedia and multiple representations in the learning of school knowledge (Schnotz and Kulhavy, 1994; van Sommeren *et al,* 1998).

Najjar mentioned that a number of studies have been conducted to support the effectiveness of multimedia instruction (Najjar, 1996). Meta-analyses (Bosco, 1986; Fletcher, 1989; Khalili and Shashaani, 1994; Kulik *et al.,* 1980; Kulik *et al.,* 1983; Kulik *et al.,* 1985; Kulik *et al.,* 1986; Schmidt *et al.,* 1985) examined over 200 studies that compared the effectiveness of learning information via the traditional classroom lecture versus via computer-based multimedia instruction. The study topics were biology, chemistry, foreign languages, and electronics; and participants were in K-12, higher education, industry, and the military. The control group usually learnt the information via classroom lecture or lecture combined with hands-on experiments. On the other hand, the experimental group usually learnt the information via interactive videodisc or some other kind of computer-based instruction. The achievement of learning was often measured via achievement or performance tests taken at the end of the lessons. Over this wide range of students and topics, the meta-analyses found that learning was higher when the knowledge was presented via computer-based multimedia applications than traditional classroom lectures.

Similar findings were found in six controlled primary research studies of using interactive computing and multimedia in college classrooms (Emerson and Mosteller, 1998). Their findings support the idea that computer technology could advance good teaching. Interactive computer assisted instruction was mostly more effective when the learner was more actively involved in his learning. Multimedia might have advantages due to the involvement of multiple senses so that computers could respond the diverse needs of students; and computer assisted instruction could provide effective learning. In addition, the quality of instruction was advanced when computer-based instruction, multimedia presentations, computerized laboratory work, and electronic homework with an online management systems and grade book were integrated (Smith and Stoval, 1996).

Apart from general using of multimedia applications in math and science lectures, it is recently more used in laboratory sessions of these lessons. Leonard (1989) explained the benefits of using a microcomputer in the laboratory. These are simplifying data analysis, making experimental results more meaningful by permitting students to observe relationship between independent and dependent variables as the experiment is completed , allowing students to more effectively understand abstract concepts, and providing opportunity for developing problem solving skills. Similarly, Kirschner and Humisman (1998) indicated that non-laboratory practicals (“dry labs”), especially multimedia practicals, were very useful instructional applications to encourage students achieve specific cognitive skills (such as analysis, synthesis and evaluation) that are required to practice science and to develop scientific inquiry. Moreover, Waugh (1987) randomly assigned two groups of chemistry students to study equilibrium with either a traditional laboratory activity or simulation with an interactive videodisc system and resulted that the score of latter group were significantly better on both laboratory quizzes and on their laboratory reports.

A further advantage of microcomputer based laboratories is the support to the development of students' science process skills. It enables repeated trials of an experiment, immediate feedback and simultaneous observation of graphical representations so that students can carry out with their own plans when doing an experiment. With the help of the flexibility of the learning environment provided by computers, students can think hypothetically and test their hypothesis by identifying and controlling variables (Mokros and Tinker, 1987). Similarly, a computerized environment helps students to investigate and analyze patterns and relationships between variables, since they encourage the use of "what if" questions and foster them to generate and test their hypothesis (Lin and Lehman, 1999; Swaak *et al,* 1998; Swaak and de Jong, 1996). Additionally, Students could connect mathematics and science to real issues by using the benefits of computer based labs and data analysis .The use of interactive software for geometry, algebra and calculus enabled students to use fundamental ideas, multiple representations to reason about applied problems and mathematical ideas.

Besides that, students can observe and manipulate normally inaccessible objects, variables, and processes in real-time with the help of computer simulations. These technologies can make learning more straightforward and intuitive for many students and supports a constructivist approach to learning by concretizing of objects such as atoms, molecules, and bacteria. Therefore, there are many researches in the literature about the effectiveness of these technologies especially for mathematics and science which require students to develop understandings based on textual descriptions and 2-D representations.

Computer simulations have the ability of scaffolding student learning potentially in an individualized way (Jiang and Potter, 1994). For example, simulation programs records data and translates between notation systems for the students, so that they can concentrate on the targeted skills of learning probability (Jiang and Potter, 1994). Students can control their learning by the ability of revisiting aspects of the environment repeatedly. Moreover, the multi sensory nature of these technologies can be especially helpful to students who are less visual learners and those who are better at comprehending symbols than text. With virtual environments, students can encounter abstract concepts directly, without the barrier of language or symbols. According to Sykes and Reid (1999), "There is simply no other way to engage students as virtual reality can". Song et al (2000) reported that middle school students who spent part of their geometry class time exploring 3-D solids were significantly more successful at solving geometry problems that required visualization than were peers taught geometry by verbal explanation.

Zietsman and Hewson (1986) investigated the effects of a microcomputer simulation on students' misconceptions about the relationship between velocity and distance, fundamental concepts in physics. The computer simulation program was designed based on the conceptual change model of learning and was applied to 74 students in high school and freshmen year of college. The author found significant differences in pre to post scores for students receiving the simulations. These students had more accurate conceptions of the construct of velocity and they conclude that science instruction that employs conceptual change strategies is effective especially when provided by the computer simulation.

The use of computer simulations in skill development also more widely investigated in literature. The majority of these simulations involved mathematical or scientific scenarios (for example, a simulation of chemical molecules and a simulation of dice and spinner probability experiments), but a few incorporated other topic areas such as history (a digital text that simulated historical events and permitted students to make decisions that influenced outcomes) and creativity (a simulation of Lego block building). Skills reported to be improved include reading (Willing, 1988), problem solving (Jiang and Potter, 1994; Rivers and Vockell, 1987), science process skills (e.g. measurement, data interpretation, etc.; (Geban *et al.*, 1992; Huppert *et al.*, 2002), 3D visualization (Barnea and Dori, 1999), abstract thinking (Berlin and White, 1986), creativity (Michael, 2001), and algebra skills involving the ability to relate equations and real-life situations (Verzoni, 1995).

Another educational application for computer simulations is the development of content area knowledge. According to the research literature, computer programs simulating topics as far ranging as frog dissection, a lake's food chain, microorganismal growth, and chemical molecules, can be effectively used to develop knowledge in relevant areas of the curriculum. Students who worked with computer simulations significantly improved their performance on content-area tests (Akpan and Andre, 2000; Barnea and Dori, 1999; Geban *et al.*,1992; Yildiz and Atkins, 1996) and working with computer simulations was in nearly every case as effective (Choi and Gennaro, 1987; Sherwood and Hasselbring, 1986) or more effective (Akpan and Andre, 2000; Barnea and Dori, 1999; Geban *et al.*,1992; Huppert *et al.*, 2002; Lewis *et al.*, 1993; Woodward *et al.*,1988) than traditional, hands-on materials for developing content knowledge. The content area knowledge for these studies were frog anatomy and morphology, thermodynamics, chemical structure and bonding, volume displacement, and health and disease.

Learning also takes less time when multimedia instruction used instead of classroom lectures. In one study, Kulik, Bangert, and Williams (1983) found that computerized instruction (90 minutes) saved 88 per cent in learning time compared to classroom instruction (745 minutes). In another study they recorded a 39 per cent savings in learning time (135 minutes for computerized instruction versus 220 minutes for classroom instruction). Kulik, Kulik, and Schwalb (1986) identified 13 studies in which students in traditional classroom instruction learned in 71 per cent more time than students using computers for tutoring. After they compared 8 studies, Kulik, Kulik, and Cohen (1980) found that computer-based instruction had a 36 per cent savings in learning time (2.25 hours per week) than traditional classroom instruction (3.5 hours per week).

To summarize, some of the benefits of learning in multimedia environments include requiring the student to respond actively; reinforcing to correct responses immediately; helping students form and test their hypothesis, working at the student’s own pace; and following a systematic plan of instruction (Kulik and Bangert, 1984). According to Kulik and Bangert (1984), technology is supposed to bring learners better, more comfortable and faster learning. Thus, technology enables students to learn at their own pace and at their own convenience by providing opportunities to work with richer materials and more sophisticated problems; unlimited study time and immediate feedback.

2.3. Learner Difficulties Encountered in Multimedia Instruction

Much research evidence signifies the effectiveness of using multiple representations of information to enhance learning. Dual coding theory (Paivio, 1986) which provides a basis for using multiple representational systems in instruction suggests that information presented by verbal and imagery channels are processed separately and established two independent codes in the long term memory (imagery and semantic) and it supposed that information is more easily remembered and recalled when it is coded by both verbal and non-verbal systems than when only coded by one of them. The theory has been tested in several studies (Mayer, 1996; Mayer and Anderson, 1991; Mayer and Anderson, 1992; Mayer and Sims, 1994; Moreno and Mayer, 1999; Rieber, 1990) and it is a greater improvement observed among students who learn in a multiple representation environment than those who learn in a single representation environment. One of the reasons for this improvement is that multiple representations provide complementary information when a single representation would be insufficient to carry all the information about the domain (Ainsworth, 1999). In other words, multiple representations may complement each other with regard to their content. For example, complex information is often distributed over multiple representations in order to avoid overloading a single representation. Therefore, multiple representations also support deeper understanding when the level of abstraction of a concept increases (Ainsworth, 1999).

However, the usage of multiple representations has not always given good results. There are also studies that report inconclusive or even negative results. Research indicates that students experience difficulties when interpret and integrate information coming multiple representations of the same or related phenomena (Ainsworth *et.al,* 2002). For example, in a laboratory study, Samuels (1967) presented words alone or words with identifying pictures to kindergarten children who were learning to read four words. After the children saw each word or word and picture, the experimenter read the word to the children. When the experimenter tested learning using only words, the children who saw only words performed better than the children who saw words with pictures. For this latter test, it appears that the pictures distracted the children.

According to the cognitive theory of multimedia learning, when learners are required to attend to several representations simultaneously, the portion of working memory that needs to be used mentally integrating multiple sources of information may be unavailable for the learning process (Mayer, 1997). One representation may constrain the interpretation of another representation (Ainsworth, 1999). Therefore, students may need to learn how to read and use information from the representations. They may use one preferred representation and avoid others thus they limit their own potential in order to learn the information in a knowledge domain. Simply providing multiple representations is not always enough for students in understanding and integrating different representational modes in learning science concepts and methods. The studies (Ainsworth, 1999; Dolin, 2001; Russell and McGuigan, 2001; Stenning, 1998) argue that in order to learn science effectively students must understand different representations of science concepts and processes, be able to translate these into one another, and co-ordinate their use in representing scientific knowledge. Similarly, Russell and McGuigan (2001) argued that learners need opportunities to generate various representations of a concept, and to recode these representations in different modes, as they refined and made more explicit their understanding.

Research explain learner difficulties experienced when working with multiple representations with the help of the Cognitive Load Theory (Sweller, 1994). Cognitive Load Theory (Chandler and Sweller, 1991; Sweller, 1988, Sweller, 1994) states that working memory is limited in its capacity to selectively attend to and process incoming sensory data. For an effective instructional design, the theory suggest that it should be avoided from overloading the working memory capacity for processing information by requiring learners to engage in unnecessary cognitive activities. The theory is concerned with the limitations of working memory capacity and instructional conditions that are probably support learning by imposing adequate levels of cognitive load. Mayer (2001) recommends a framework supported by the cognitive load theory to identify conditions for effective multimedia instruction. According to Mayer, active processing which leads to meaningful learning is that people understand the presented material when they pay attention to the relevant material, organize it into a coherent mental structure, and integrate it with their prior knowledge. He claims that instructional practices should try to reduce the excessive memory load to help the learners actively process the new information.

Therefore, Mayer (2002) described eight principles for an effective multimedia design in his article to try to give solution to the leading question “How should we design multimedia instructional messages in order to promote deep understanding in learners?”

2.4. Cognitive Theory and Multimedia Processing

Three theory-based assumptions about how people learn from words and pictures contributed by cognitive theory: the dual channel assumption, the limited capacity assumption, and the active processing assumption (Mayer, 2002).

2.4.1 The Dual Channel Assumption

The human cognitive system consists of two distinct channels for representing and manipulating knowledge: a visual-pictorial channel and an auditory-verbal channel (Baddeley, 1986, Baddeley, 1999; Paivio, 1986). Pictures enter the cognitive system through the eyes and may be processed as pictorial representations in the visual-pictorial channel. Spoken words, sentences enter the cognitive system through the ears and may be processed as verbal representations in the auditory verbal channel (Mayer, 2002). The verbal and visual systems can be activated independently, but there are interconnections between the two systems that allow dual coding of information. The interconnectedness of the two systems permits cueing from one system to the other, which in turn facilitates the interpretation of our environment (Rieber, 1994).

2.4.2. The Limited Capacity Assumption

Working memory, one of the components of the human cognitive system, manipulates verbal and pictorial representations in the auditory–verbal and visual–pictorial channels. However, each channel in the human cognitive system has a limited capacity for holding and manipulating knowledge (Baddeley, 1986; Baddeley, 1999; Sweller, 1999). Therefore, the visual-pictorial can be overloaded when a lot of pictures (or other visual materials) are displayed at one time. Likewise, the auditory-verbal channel can become overloaded when a lot of spoken words (and other sounds) are presented at one time. Only a few items or elements of information can be handled in working memory at one time (Baddley, 1992).

2.4.3. The Active Processing Assumption

Meaningful learning occurs when a learner engage actively in three cognitive process: selecting relevant words and pictures, mentally organizing them into coherent pictorial and verbal models, and integrating them with each other and appropriate prior knowledge (Mayer, 1999, Mayer, 2001; Wittrock, 1989). When corresponding verbal and pictorial representations comes together in working memory at the same time, these active learning processes are more likely to occur (Mayer, 2002).

2.4.4. The Cognitive Theory of Multimedia Learning

A cognitive theory of multimedia learning based on these three basic theory-based assumptions about how people processed the information explained in Figure 2.1. The right column of the figure represents the auditory-verbal channel and the left column the visual-pictorial channel.

According to the theory, pictures enter the cognitive system through the eyes and words (if the words are spoken) enter through the ears. In the cognitive process of selecting pictures, the learner pays attention to some of the pictures that leads to the construction of some images in working memory. In the cognitive process of organizing these images in the working memory, the learner mentally arranges the selected images into a coherent mental representation called a pictorial model. This process of constructing knowledge by selecting, organizing, and integrating images is called *visuospatial thinking.* Comparatively, in the cognitive process of selecting spoken words, the learner attends to some of the words, leading to construction of word sounds in working memory. While organizing words, the learner arranges the selected words into a coherent mental representation called a verbal model. The process of selecting, organizing, and integrating words is called *verbal thinking.* In the cognitive process of integrating, the learner mentally connects both pictures and words that means connect the verbal and pictorial models and appropriate prior knowledge from long-term memory. According to the cognitive theory of multimedia learning, appropriate verbal and visuospatial thinking leads to meaningful learning.

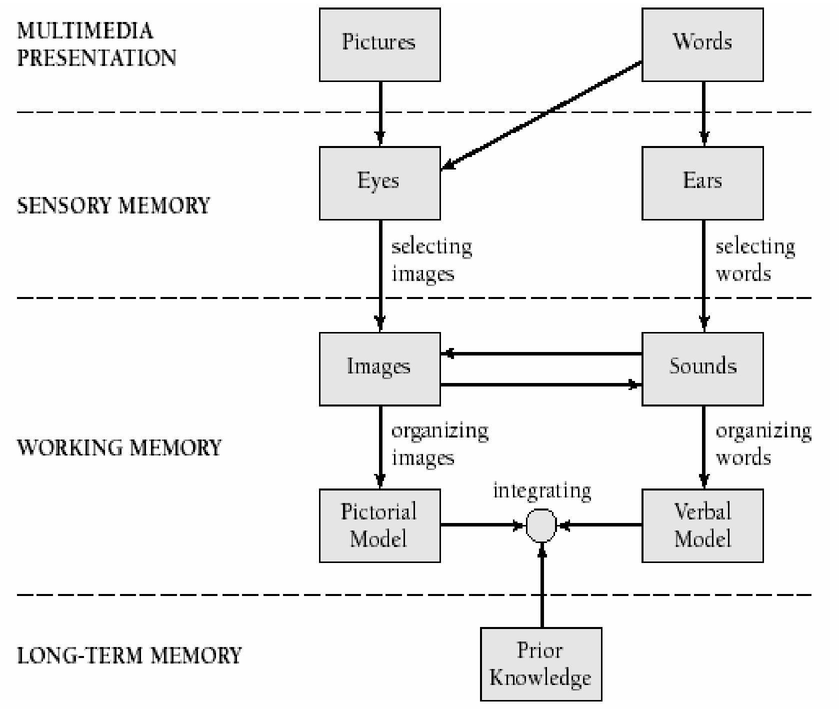


Figure 2.1. Cognitive Theory and Multiple Learning (Mayer, 2001)

To sum up, Mayer and Moreno (2002) propose that multimedia learning involves three important cognitive processes,

- Selecting: applied to incoming verbal information to yield a text base and visual information to yield an image base.

- Organizing: applied to the word base to create a verbally-based model of the to-be-explained system and is applied to the image base to create a visually-based model of the to-be-explained system.

- Integrating: occurs when the learner builds connections between corresponding events (or states or parts) in the verbally-based model and the visually-based model.

2.4.5. Eight Principles of Multimedia Learning

Mayer (2002) presents eight research-based principles for the most effective design of multimedia by using the assumptions of the cognitive theory of multimedia learning.

1. **Multimedia Principle**: Deeper learning occurs from words and pictures than from words alone.
2. **Contiguity Principle:** Deeper learning results from presenting words and pictures simultaneously rather than successively in time and space.
3. **Coherence Principle**: Deeper learning occurs when extraneous words, sounds, or pictures are excluded rather than included.
4. **Modality Principle**: Deeper learning occurs when words are presented as narration rather than as on-screen text.
5. **Redundancy Principle**: Deeper learning occurs when words are presented as narration rather than as both narration and on-screen text.
6. **Personalization Principle**: Deeper learning occurs when words are presented in conversational style rather than formal style.
7. **Interactivity Principle**: Deeper learning occurs when learners are allowed to control the presentation rate than when they are not.
8. **Signaling Principle**: Deeper learning occurs when key steps in the narration are signaled rather than nonsignaled.

In summary, Mayer's eight principles of multimedia design, each based on cognitive theory and supported by the findings of empirical research points out a way to prepare an effective multimedia in order to avoid heavy cognitive load (Mayer and Anderson, 1991, Mayer and Anderson, 1992; Mayer and Sims, 1994; Mayer *et al.,* 1999; Mayer *et al.,* 2001; Moreno and Mayer, 1999, Moreno and Mayer, 2000). Although these eight principles applied in many multimedia instructions, many researches have shown that learners often do not use multiple representations effectively (van Someren *et al.,* 1998). Learners must interconnect the external representations and actively construct a coherent mental representation to benefit from complementing function of multiple representations, but especially learners with low prior knowledge often have problems with the co-ordination and integration of multiple representations (Kozma and Russell, 1997; Yerushalmly, 1991;

Ainsworth, 1999). They do not use different representations but rather concentrate only on one representation, often the more familiar or concrete one (Cox and Brna, 1995; Scanlon, 1998; Tabachnek and Simon, 1998). These findings indicate that learners should get instructional additional support in their coherence formation process in order to benefit from multiple representations. Mayer also claims that instructional support that directs attentional resources can facilitate active processing because it helps selection, organization and integration of relevant information.

2.5. Additional Instructional Support in Multimedia Learning

The role of additional instructional support in multimedia learning in order to help learners select and relate relevant information included in multimedia applications has been examined in several studies. Reed (1985) analyzed the role of additional instructional support on student achievement from animated displays and resulted that higher levels of performance was seen when animated displays were paired with an externally provided lesson strategy that required learners to make estimations. According to Reed, additional activities were functional in directing learners' attention to the relevant features in the animated displays.

Lowe (2003) found similar results in an experimental study that analyzes the learner benefits from animations where the learners are given high degree of freedom. It supports the view that if animations simply display processes without providing further instructional enrichment, their educational potential may be compromised and suggest that learners could be helped by animations designed to provide a more directed learning environment incorporating specific visual and temporal guidance (such as graphic cues and pre-set interrogation pathways) to direct their attention to the domain-relevant information in animations. Similarly, Lewalter (2003) investigated the cognitive strategies for learning from static and dynamic visuals and concluded that students may need additional support to use suitable learning strategies in order to learn effectively with animated visuals. According to Goldman (2003), different forms of help encourage different kinds of processing, and care needs to be taken to make sure that the kind of processing being supported is consisted with the demands of the outcome task performance. For example, with respect to the task, Seufert (2003) analyzed the effects of different kind of instructional help (directive help, non-directive help and no help) depending on whether learners had to recall material or answer comprehension questions. Results indicated that directive help especially supports recall performance due to the its summarizing and repeating function and it is also more effective for comprehension than non-directive help, but non-directive help was found to be more cognitively demanding.

Research also indicate increased effectiveness of additional support mechanisms such as easily accessible domain specific information (Leutner, 1993), adjunct questions (Holliday and McGuire, 1992), instructional prompts (Lin and Lehman, 1999), information sheets (Nijoo & de Jong, 1993) or assignments that guide inquiry (deJong and van Joolingen, 1998) to improve the effectiveness of computer-based learning that relies on discovery rather than expository instruction.

Alessi and Trollip (1991) cited that a computer lesson requires extensive adjunct materials such as practice sheets, maps, and other large diagrams, videotapes or photographic slides or scoring sheets for games. Gardner *et al.* (1992) conducted a study to determine whether combining computer assisted instruction (CAI) with hands-on activities could significantly increase students' outcomes on the cognitive and affective assessments and resulted that both achievement assessment and attitudes toward math scores were significantly higher when combining hands-on activities and CAI. Similarly, Akaygün (2000) conducted a research to investigate the effect of multimedia based instruction on learning chemicals in science and use worksheets during the instruction in order to follow the changes in students' views and ideas about chemical reactions. The author concludes that the use of worksheets were functional in guiding the students to be aware of what they were doing. Sezen (2000) compared the effect of with and without teacher guidance on CAI in an experimental study and resulted that students in computer assisted individualized instructions frequently failed to understand the material so that the instructional support was necessary.

Although studies in previous paragraphs suggest the additional instructional support to design an effective multimedia instructions, indecisive or even negative results observed in a number of studies (Reid *et al.,* 2003; Zhang *et al.,* 2000; Zhang *et al.,* 2004).

According to these studies, learners with different level of reasoning ability and achievement may show different reactions when instructional support is given. For instance Zhang, Chen, and Reid (2000) observed a positive effect of experimental support for low ability learners whereas they found a negative effect for middle and no effect for high ability learners. They explained the negative effect of additional support for middle ability learners with cognitive load theory and stated that support mechanisms might cause extra cognitive load and interrupt the thinking process of these learners who can discover the relevant aspects of the learning material on their own. These findings indicate that considering the differential effect of instructional support, whether help is given or not should be decided carefully according to the personal characteristics of the learning groups.

The present study also tries to understand the differential effect of instructional support for students by comparing their performance gains and the degree of recall of representations included in the simulation environment. The simulation environment included two experiments that were designed to encourage students' ability to recognize the relationship between two variables.

The following paragraphs outline an understanding of the relationship between two variables and the value of this topic in mathematics and science lessons.

What do we mean when we talk about a "relationship" between variables? In general, we are referring to a connection between two or more factors that we can measure or systematically vary. The ability to recognize the relationship between two variables and to represent it using tables and graphs is an important skill for mathematics and science.The skill to relate two variables is included in a number of content specified by the Principles and Standards for School Mathematics (NCTM, 2000). Principles and Standards for School Mathematics documents describe five content standards of mathematics: (1) Number and Operations; (2) Algebra ;(3) Geometry; (4) Measurement; (5) Data Analysis and Probability and in all five content standards emphasized highly the understanding relationships. The mathematics topic of ratio and proportion might be seen as one of the very difficult subject in math lesson by students. However, this topic is highly important for students to gain them proportional reasoning ability. According to Van de Walle (2000) proportional reasoning requires the ability to make comparisons, not just of the quantities involved but of the relationships between quantities as well. Therefore, understanding relationships between two variables requires proportional reasoning ability. Proportional reasoning is the ability to compare ratios or make a statement of equality between two ratios (Bar, 1987, Tourniaire and Pulos, 1985). This ability plays a central role in the development of mathematical thinking and is often presented as the capstone of the elementary curriculum and the cornerstone of the algebra and higher mathematics as well as the most important of the basic mathematical concepts (Lesh *et al.,* 1987). Proportional reasoning is taught primarily in mathematics courses, but student success in science is highly dependent on proportional reasoning ability. Moreover, this ability helps students solving problems involving proportional relations in a variety of knowledge areas, such as mathematics, physics, chemistry, economics, statistics, and probability.

According to Inhelder and Piaget (1958), there are three stages in the development of the proportional scheme ,as it is used in proportional reasoning : (1) the intuitive stage (age 3-7) during which the child is unable to coordinate between two variables and relies on intuitive considerations; (2) the concrete stage (age 8-12) when the child manifests an ability to coordinate between two variables in concrete situations, and reveals a grasp of their proportional relationship, but without being able to generalize this to a formal-mathematical rule, and (3) the formal stage (age 12-15) during which the proportional scheme reaches maturity and the child understands the rules underlying proportional relationships. Therefore, Piaget's concept of formal operational thought is often associated with one's ability to reason proportionally (Bar, 1987; Tourniaire and Pulos, 1985) so that the middle school years are critical in the development of students' proportional reasoning which is a required ability in order to understand the relations between variables.

The quickest way to see if two variables are related is to depict their relationship graphically so that using multimedia instruction techniques is a very effective way to make students realize whether two variable is related or not. Recognizing the relationship between mass, force, and acceleration is one of science topics that strength the importance of understanding relationships between variables. Therefore, the ability to understand relationships between variables which require proportional reasoning is both important for science and mathematics.

3. STATEMENT OF THE PROBLEM

When developing the skill to recognize the relationship between two variables we need to use a number of representations such as graphics, tables, lab experiments etc. Therefore an effective way to construct an accurate understanding on the relationships between two variables can be achieved by helping the students to deal with multiple representations. Multimedia environments provide an effective medium for using multiple representations.

The multimedia environment in the present study includes two simulated experiments which uses multiple representations such as tabular and / or graphic ones to show the relationship between two variables. The simulations used in the study enables students to do experiments about identifying relationships between variables in multiple representational computerized environments, to repeat trials of an experiment, to get immediate feedback and to simultaneously observe graphical representations. The experimental screens may impose heavy cognitive load so that in order to decrease the degree of cognitive demanding of the simulations and to call students’ attention to the relevant information, additional support might be required. The present study questions the role of additional instructional support in terms of learning gains of students and in the degree to which students recall representations included in the simulation environment.

3.1. Research Questions

The research addresses the following specific questions about the role of additional instructional support in understanding relationships between two variables from two simulated experiments:

1. Do all participants indicate significant learning gains (difference between the pre and posttest scores) following the multimedia instruction?

2. Is there a significant difference in learning gains between the supported group (Group S) and the non-supported group (Group NS)?
3. Is there a significant difference between the Group S and Group NS in terms of the Recall of Representations Test (RRT) scores?

Statement of the Research Hypotheses

- Both groups who received support (Group S) and the group who did not receive support (Group NS) will show significant learning gains. The mean of post test scores will be higher than the mean of pretest scores for each group.
- The group who received support (Group S) will perform significantly higher than the group who did not receive support (Group NS) in terms of pre-posttest differences.
- The group who received support (Group S) will perform significantly higher than the group who did not receive support (Group NS) in terms of Recall of Representations Test (RRT) scores.

3.3. Variables and Operational Definitions

The study questions the role of additional instructional support in learning relationships between two variables from two simulated experiments which include multiple representations (such as graphs, tables etc.) Whether additional support may decrease the degree of cognitive load in students' working memory that might be caused by the multiple representational computerized environments will be addressed.

The dependent variables of the study are performance on relationships between two variables and the degree of recall representations following the simulated lab experiments.

The independent variable of the research is type of instruction specified as taking additional instructional support or not during two simulated lab experiments.

- Performance on relationships between two variables is assessed through the test called “Test on the Relationship between two Variables” (TR-b2V) given as a pre and post test. Detailed description of the test is explained in the “Instruments” section.

- The degree of recall representations is assessed by the Recall of Representations Tests (RRT) which measure how much a student can remember what he sees on the experimental screens. Detailed description of the test is explained in the “Instruments” section.

- The simulated lab experiment (multimedia instruction) is the independent variable of the study. The instruction is carried out in two ways, giving additional support or not. The group that receives support (Group S) fills a worksheet during the lab experiment which direct participants to the relevant information about what they are doing. The group that does not receive support (Group NS) does not fill such a worksheet as an additional support during the experiments.

4. METHOD

4.1. Subjects

Subjects in this study consist of 44 seventh grade students from a state school, in Istanbul, in Turkey. There are two groups each consists of 22 students from different achievement levels in the study. The Supported Group (Group S) took additional support during the multimedia lab session where as The Group Non-Supported (Group NS) did not. Each group had similar mathematics and science backgrounds. The math and science grades are the students' sixth grade scores.

All seven grades students (N=239) in this school are considered as the target population, since the ability to reason proportionally which is required to understand the relationships between two variables is gained by students around age of 12 according to Piaget's cognitive stages of development. However, in order to increase the chances that the participants were in the formal operational stage, the sample consisted of students whose sixth class math and science grade mean is three, four and five. Therefore, students were classified according to their mean of sixth class math and science grades which was obtained from the administration of the school so that grade mean of the students were one of the important criteria for sample selection.

The space limitation of the computer lab was also considered in the decisions about the number of participants. There are 23 computers in the school computer laboratory so that the groups are firstly designed to consist of 23 students in different grade means. By using the list of sixth class math and science grades obtained from administration, 8 students were randomly selected by the researcher out of 61 sixth class science and math grade-mean-3 students; 14 students out of 42 sixth class science and math grade-mean-4 students and 24 students out of 42 sixth class science and math grade-mean-5 students. Each group was intended to compose of four students with grade-mean-3, seven students with grade-mean-4 and 12 students with grade-mean-5. In the randomly assignment process, the researcher took into consideration gender and tried to match each group equal number of female and male. However, due to some practical reasons the desired numbers of students from each science and math grade mean could not been provided equally for each group. But the gender equality criterion for the groups was supplied. Table 4.1 and Table 4.2 shows the distribution of total 44 seventh grade students according to their sixth grade mean of science and math and gender and Figure 4.1 summarize the sample selection procedure.

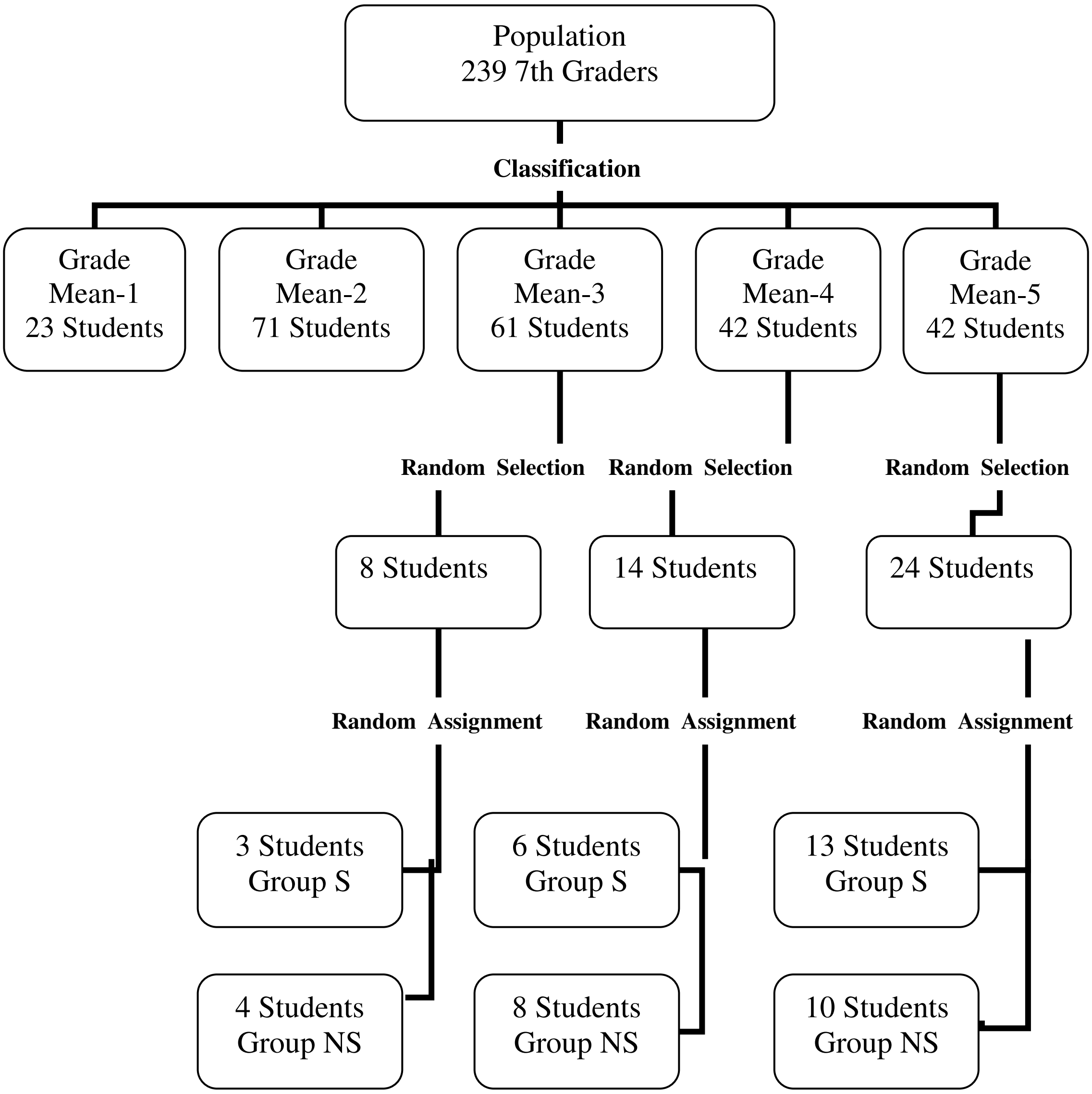


Figure 4.1. Procedure for selecting the sample

Table 4.1. Distribution of the 44 seventh grade students

Gender	The Number of Students in Group S	The Number of Students in Group NS	Total
Female	13	13	26
Male	9	9	18
Total	22	22	44

Table 4.2. Distribution of the students in terms of sixth class science and math grade mean

Grade mean*	The Number of Students in Group S	The Number of Students in Group NS	Total
5	13	10	23
4	6	8	14
3	3	4	7
Total	22	22	44

* grade mean is calculated by taking the mean of science and mathematics grades

Table 4.3. Distribution of the study groups in terms of sixth class math and science grade mean

Groups	The Mean of Sixth Class Math Grades	The Mean of Sixth Class Science Grades	The Average of Sixth Class Math and Science Grades
Group S	4.18	4.36	4.27
Group NS	4.14	4.18	4.16

Table 4.3 explains the average of sixth class math and science grades (M= 4.27 for Group S; M=4.16 for Group NS). Two independent samples t-tests were conducted in order to prove that there is not significant difference between the Group S and Group NS in

terms of students' sixth class science and math grade mean and pretest scores of "Test on the Relationship between two Variables (TR-b2V)". For sixth class science and math grade mean, it is found that the two groups are no statistically different from each other (t= .461, p= .647). Similarly, it is found out that there is no significant difference between pretest scores of the two groups (t= 1.68, p= .102)

4.2. Instruments

4.2.1. Test on Relationships between two Variables (TR-b2V Pre-and-Post Tests)

The test items based on the following objectives:

- To be able to identify the nature of changes in variables in a picture and develop inferences that describes the relationships between two variables. (Related to first question)
- To be able to investigate how a change in one variable relates to a change in a second variable. (Related to all questions)
- To be able distinguish inversely and directly proportional relationships. (Related to all questions)
- To be able to interpret rates of change from graphical, numerical and pictorial data and develop inferences that are based on data. (Related to all questions)
- To be able to use mathematical models such as graphs, tables to represent, understand and analyze relationships between two variables. (Related to second-third-fourth questions)
- To be able to describe situations with constant or varying rates of change by using concrete pictorial and verbal representations to show an understanding of relationships between two variables. (Related to fifth question)
- To be able to explain and generalize the relationships between two variables such as volume-force, math study time-math grade, solubility-heat. etc. (Related to all questions)

Test on Relationships between Two Variables (TR-b2V) is both used as a pretest and posttest in the study. The test is composed of five questions prepared by Ardaç (Ardaç and

Muğaloğlu, 2002). The first four items are convergent nature. These items are designed to assess how students represent the relationship between variables using verbal statements, tables and graphics. In the first question, students investigate how a change in one variable relates to a change in a second variable in pictures. By analyzing the example given at the top of the first question, students firstly state the decreased and increased variables in the pictures. And then develop inferences based on the pictorial data about the relationships between two variables.

In the second question, students read a table that describes the relationships between math study time and math grade and then graph the data in the table. According to the graph, they generalize the relationships between study time for math and math grade. In the third question, students interpret a picture which explains the relationship between force applied to a unit area and volume. Firstly, they write the numbers on the picture in a table and draw a graph according to the data in the table. Similarly, in the part c of the third question, they make an inferences based on their interpretations of graphical, numerical and pictorial data. In contrast to the second question, in the forth one students firstly interpret a graph that show the relationships between heat and the number of soluted sugar, and then they make a table using the data in the graph. In the last part, they again explain the relationships between heat and the number of soluted sugar in a sentence. The last item is designed to assess divergent thinking. In this item the students are expected to illustrate similar situations which show relationships between two variables and if they can not draw an idea comes on their mind, they will write it.

The test is scored as two independent parts. In the first part the students receive partial or full credits (changing between 6 - 18) for each item. A total maximum point for the first part of the test is 39. Reliability analysis carried out for the first part (convergent items) of TR-b2V revealed high item-total correlations for all the items and high alpha level coefficient with a= .7770 and a= .8647 for the pretest and post-test items respectively Ardaç and Muğaloğlu, 2002). Content validity was established through matching the items with the objectives that are previously explained. The medium but significant (at .01 level) correlation (r = .485) observed between the pre-test scores and the mean of science and math grades of the students was also considered to provide evidence for the concurrent validity of the test.

The second part of the item includes student generated pictorial or verbal expressions showing the relationship between two variables. The items are scored in terms of relevance, fluency and originality. For the present study the representations are scored only for their relevance. The total score changes according to the number of accurate drawings and/or verbal statements representing the relationship between two variables.

In terms of relevance, for each series of pictures or statements the students received:

a) 3 points if it contained related variables changing with respect to each other,
b) 2 points if it contained two changing but unrelated variables,
c) 1 points if it contained one changing variable(increasing, decreasing, getting bigger or smaller, getting closer),
d) No points if it contained no change in variable or totally irrelevant information.

The inter-rater reliability of the second part was analyzed by calculating the correlation between the scores obtained from two different scorers. The divergent part in posttest papers of Group S were scored by both the researcher and the thesis supervisor. A high and significant (at .000 level) correlation (r = .908) was observed between the two sets of scores.

4.2.2. Recall of Representations Test (RRT)

The Recall of Representations Test includes two questions that are asked to the students at the end of the two simulated experiments. These questions are developed by the researchers and try to measure students' level of recall representations included in the two simulated experiments. Each question includes a picture of each experiment to remind students of the experiments. Students are expected to draw and illustrate what they recall from the experimental screen and if they can not draw, they are expected to write what they remember from the simulated experiments. The students are scored in terms of how much they recall from the experiment screens. Both experiment screens included (1) the experimental setup showing the variables and relation between them, and (2) the tabular/or graphical representation of the variables and the relation between them. The students could receive 3 points from each component (experimental setup and tabular/graphical representation) with a total of 6 points. The scores changed between 0-3 for each component depending on how many the students could recall and draw the variables in the experiment and the relation between them.

In terms of experimental set up, students received:

a) 3 points if it contained two variables and relationships between them.
b) 2 points if it contained change in one variable.
c) 1 points if it contained one or two unchanging/unrelated variable or incomplete drawings.
d) no points if it contained no information about the experimental set up.

In terms of the tabular representation, students received:

a) 3 points if it contained two variables and relationships between them and the details in the table.
b) 2 points if it contained two variables and relationships between them but no detailed information.
c) 1 points if it contained one variable and incomplete table.
d) no points if it contained no information about the tabular representation.

In terms of the graphical representation, students received:

a) 3 points if it contained two variables and the points in the graphic.
b) 2 points if it contained points in the graphic but unclear variables.
c) 1 points if it contained incomplete graphic.
d) no points if it contained no information about graphical representation.

The content validity of the items can be supported because both items were based on the content used (the screens included in the simulated experiments) during instruction. Therefore there was a direct match between the content of the instruction and the item content. Support for inter-rater reliability was based on the correlation between two judges who independently scored the two items for the entire sample and the significant (at .000

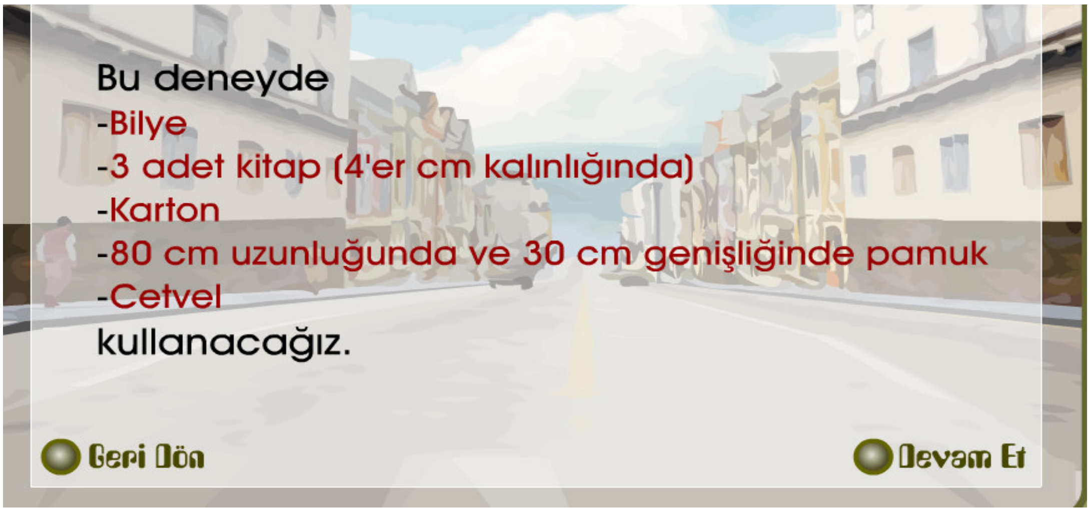
level) correlation(r = .711) was observed between the two sets of scores. Therefore, the scoring is based on the mean of two scores given by two separate scorers.

4.3. Instructional Materials

4.3.1 The Simulated Experiments

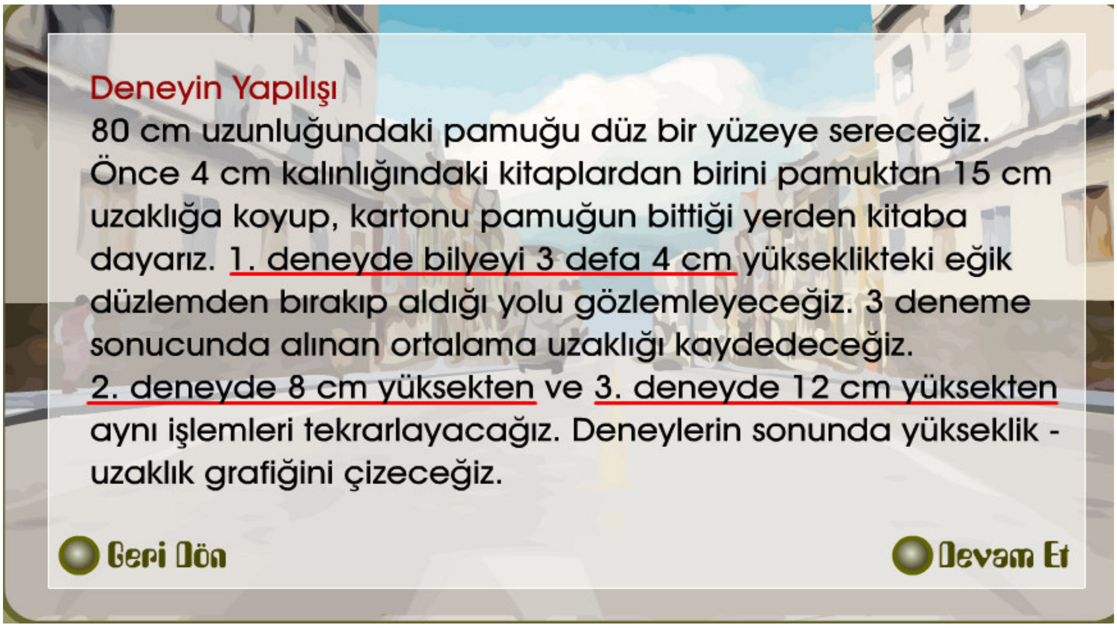
The study used two simulated lab experiments in Macromedia Flash Platform were developed by a graduate student (Öztürk, 2002) in an elective course (Sced 480) as a partial requirement for his graduate studies. The major objective of the lab experiments is to prepare students to collect, question, and organize data through experimentation and to arrive at a reasonable conclusion about the relationships between two variables.

The first experiment which is called "Rolling Marbles (Yuvarlanan Bilyeler)" is designed to make students understand the relationships between the slope of a surface and distance which marbles take. Like confirmatory science laboratory sessions, the purpose, the materials and the method of the activity are clearly explained to the students at the beginning of the experiment. (Figure 4.2 and Figure 4.3). Apart from conventional lab experiences, students will use virtual materials and virtual platform in this experiment occurs in a computerized laboratory environment not in a real one.



Bu deneyde
-Bilye
-3 adet kitap (4'er cm kalınlığında)
-Karton
-80 cm uzunluğunda ve 30 cm genişliğinde pamuk
-Cetvel
kullanacağız.

Figure 4.2. The screen representing the materials of the experiment "Rolling marbles"

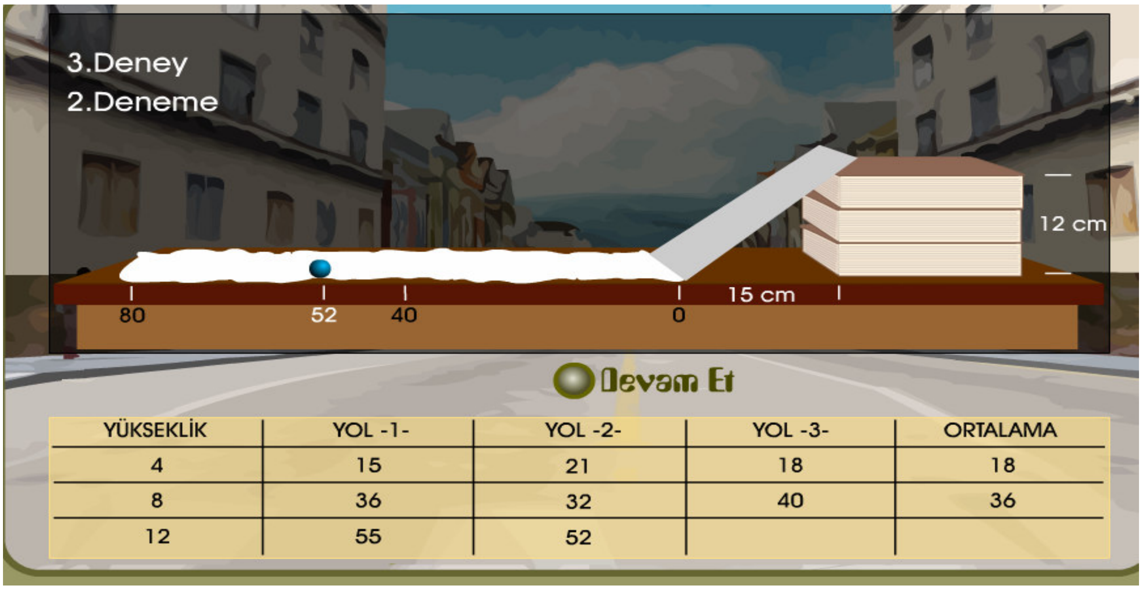


Deneyin Yapılışı

80 cm uzunluğundaki pamuğu düz bir yüzeye sereceğiz. Önce 4 cm kalınlığındaki kitaplardan birini pamuktan 15 cm uzaklığa koyup, kartonu pamuğun bittiği yerden kitaba dayarız. 1. deneyde bilyeyi 3 defa 4 cm yükseklikteki eğik düzlemden bırakıp aldığı yolu gözlemleyeceğiz. 3 deneme sonucunda alınan ortalama uzaklığı kaydedeceğiz. 2. deneyde 8 cm yüksekten ve 3. deneyde 12 cm yüksekten aynı işlemleri tekrarlayacağız. Deneylerin sonunda yükseklik - uzaklık grafiğini çizeceğiz.

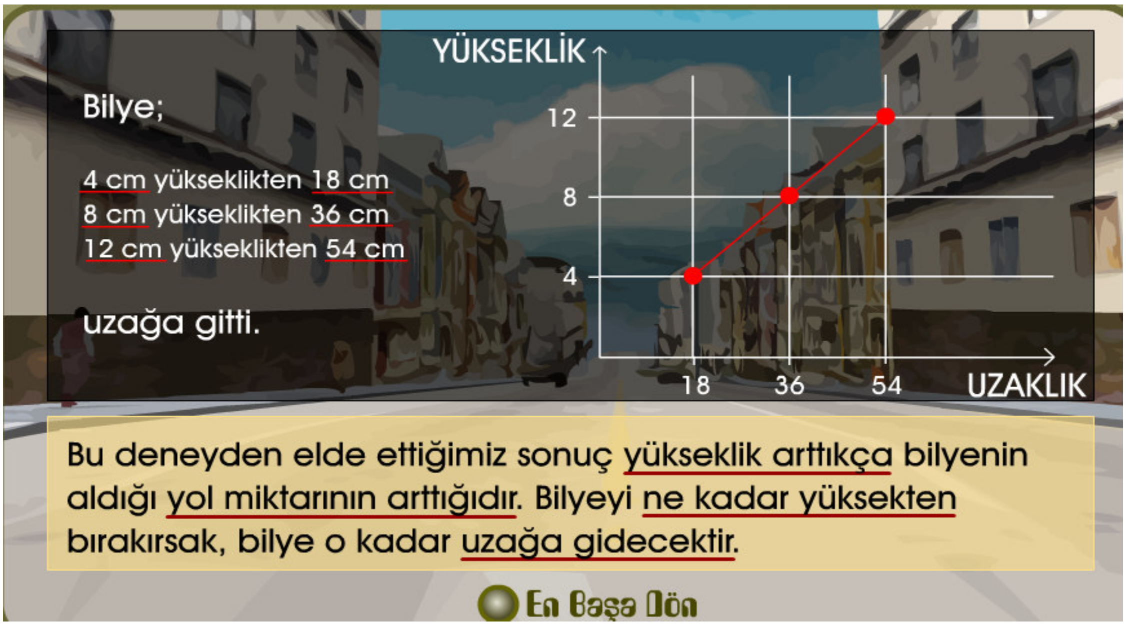
Figure 4.3. The screen representing the methods of the experiment “Rolling marbles”

It is composed of three parts. In each part, students will roll a marble from a height of 4 cm, 8 cm, and 12 cm and will observe the distances that marbles take. For each height, they will carry out three trials and then they will register the mean distance of trials on the table (Figure 4.4).



YÜKSEKLİK	YOL -1-	YOL -2-	YOL -3-	ORTALAMA
4	15	21	18	18
8	36	32	40	36
12	55	52		

Figure 4.4. The screen representing the second trial of the third part of the experiment “Rolling marbles”



Bilye;

4 cm yükseklikten 18 cm
8 cm yükseklikten 36 cm
12 cm yükseklikten 54 cm

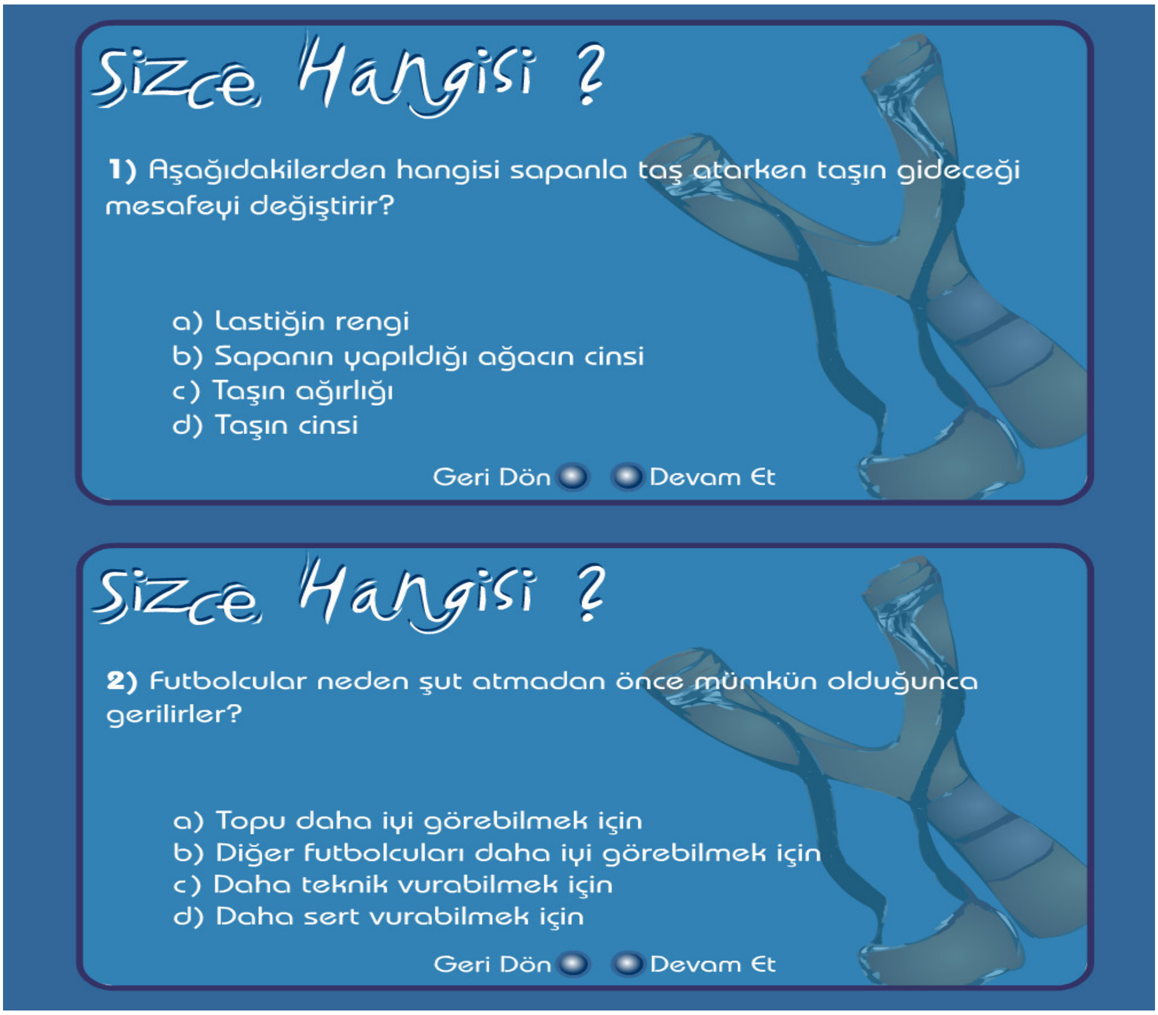
uzağa gitti.

Bu deneyden elde ettiğimiz sonuç yükseklik arttıkça bilyenin aldığı yol miktarının arttığıdır. Bilyeyi ne kadar yüksekten bırakırsak, bilye o kadar uzağa gidecektir.

Figure 4.5. The screen representing the distance-and -height graph and the result of the experiment “Rolling marbles”

At the end of the experiment, students in the Group NS will directly encounter a distance-and -height graph and the result of the experiment which explain the relationships between the slope of surface and distance which marbles take (Figure 4.5) whereas the Group S will firstly fill the table in their worksheet given as an additional support during the experiment and then they will try to develop inferences based on their tabular data (Appendix B). After writing their conclusion with their own words on the worksheet, they will pass the next step screen which shows the graph and result of the experiment.

The second simulated lab experiment called “Elastic Band (Lastik Bant)” is designed to investigate the factors which affect the distance of a ball stretched by an elastic band. Students will try to understand the relationships between the amount stretching of an elastic bant and the amount of distance a thrown ball takes. Before starting to the experiment, students will take a quiz about the factors affect the distance of a thrown ball stretched by a elastic bant (Figure 4.6).This mini pretest tries to understand students’ prior knowledge, their misconceptions and their hypothesis about this issue based on their experiences.



Sizce Hangisi ?

1) Aşağıdakilerden hangisi sapanla taş atarken taşın gideceği mesafeyi değiştirir?

a) Lastiğin rengi
b) Sapanın yapıldığı ağacın cinsi
c) Taşın ağırlığı
d) Taşın cinsi

Sizce Hangisi ?

2) Futbolcular neden şut atmadan önce mümkün olduğunca gerilirler?

a) Topu daha iyi görebilmek için
b) Diğer futbolcuları daha iyi görebilmek için
c) Daha teknik vurabilmek için
d) Daha sert vurabilmek için

Figure 4.6. Sample screen representing the pretest questions for the experiment “Elastic band”

Similar to the first experiment, it starts with presenting the aim, the materials and the method of the experiment. (Figure 4.7. and Figure 4.8.). It is composed of two parts. In the first part, students will throw 10gr.ball that is stretched 2cm, 4cm, 6cm, 8cm, and 10cm by an elastic bant and observe the distance covered by the ball. The same procedure with a 20gr. ball will be followed in the second part. (Figure 4.9 and Figure 4.10.). While students make their trials, the amount of distance a thrown ball taken and the amount stretching of an elastic band graph will be drawn at the upper right corner of the screen so that students may comprehend whether there is a directly or inversely proportional relationship between two variables.

Deneye Başlayalım

Bu deneyde farklı ağırlıktaki iki küçük topu, lastiği farklı ölçülerde çekerek fırlatacağız. Topların düştükleri noktaları tespit edip, en sonda topun gittiği mesafe ve lastiği çekme miktarı grafiğini çizeceğiz.

Malzemeler

- 2 adet çivi
- tahta blok
- 15-20 cm. uzunluğunda lastik
- Farklı ağırlıkta iki küçük top
- Cetvel

Figure 4.7. The screen representing the materials of the experiment “Elastic band”

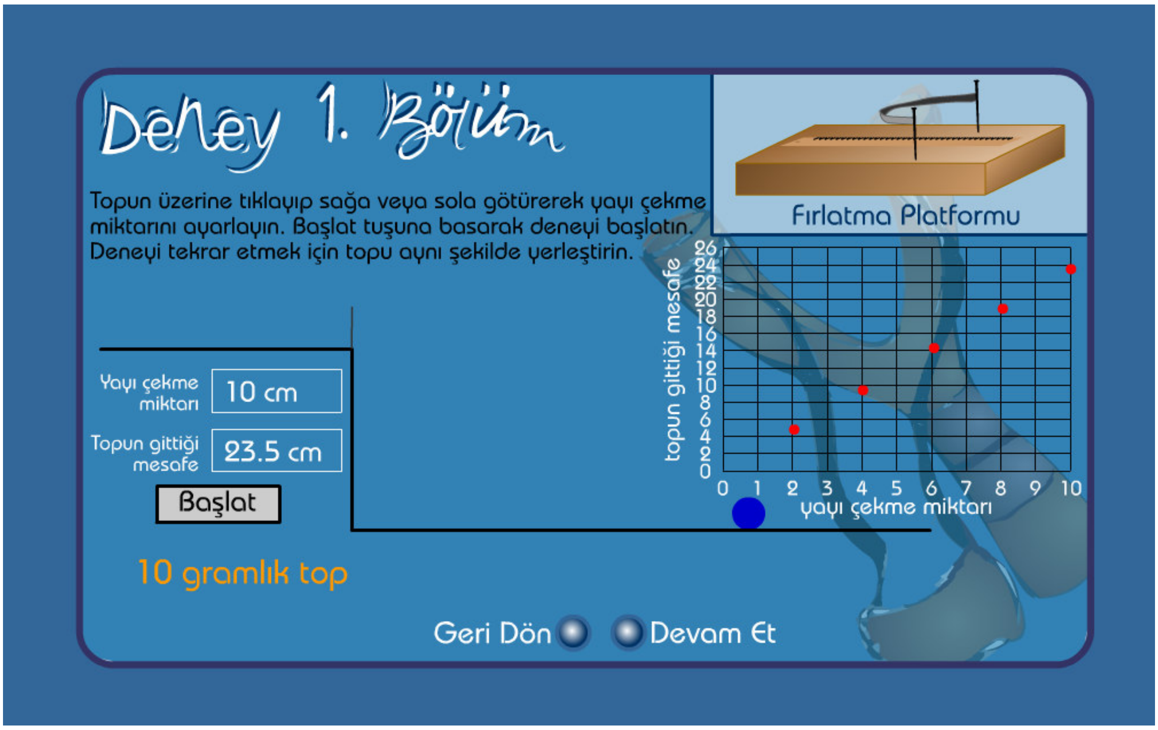
Deneyin Yapılışı

Deneyin birinci bölümünde 10 gr. olan hafif topu kullanacağız. Topu atış platformumuzdaki lastiği önce 2 cm çekerek fırlatacağız ve düştüğü noktayı işaretleyeceğiz. Aynı işlemi, yine hafif topumuzu kullanarak 4 cm, 6 cm, 8 cm ve 10 cm için yapacağız. Topun gittiği mesafe - yayı çekme miktarı grafiğini çizeceğiz.

İkinci bölümde ağır olan 20 gramlık topu kullanacağız. Birinci bölümde yaptığımız ölçme işlemlerini bu sefer de ağır top için yapacağız. Ağır top için de topun gittiği mesafe - yayı çekme miktarı grafiğini çizeceğiz.

Figure 4.8. The screen representing the methods of the experiment “Elastic band”

After the completion of the experiment, students will again answer the same questions but this time they will use the knowledge learned from the experiment so that they will realize the reasons for their misunderstandings if there are and will get immediate feedback (Figure 4.11.)



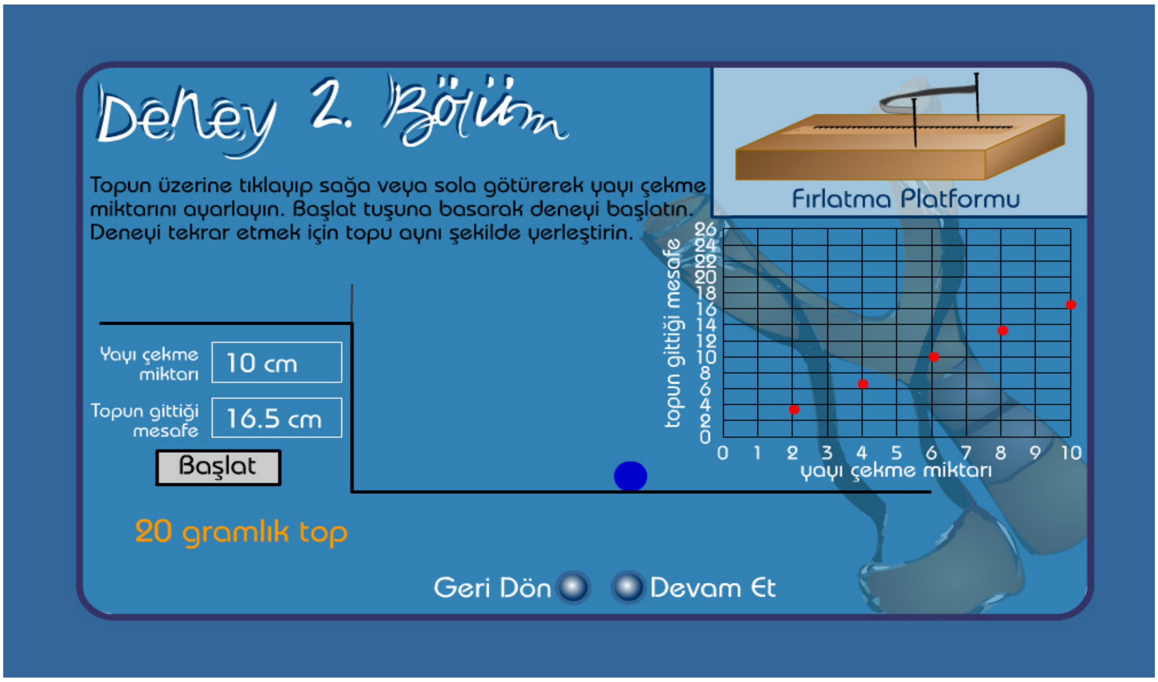
Deney 1. Bölüm

Topun üzerine tıklayıp sağa veya sola götürerek yayı çekme miktarını ayarlayın. Başlat tuşuna basarak deneyi başlatın. Deneyi tekrar etmek için topu aynı şekilde yerleştirin.

Yayı çekme miktarı: 10 cm

Topun gittiği mesafe: 23.5 cm

Figure 4.9. The screen representing the first part of the experiment “Elastic band”



Deney 2. Bölüm

Topun üzerine tıklayıp sağa veya sola götürerek yayı çekme miktarını ayarlayın. Başlat tuşuna basarak deneyi başlatın. Deneyi tekrar etmek için topu aynı şekilde yerleştirin.

Yayı çekme miktarı: 10 cm

Topun gittiği mesafe: 16.5 cm

Figure 4.10. The screen representing the second part of the experiment “Elastic band”

Tekrar Edelim

Deneye başlamadan önce Ali cevabını vermiştin. Deneyden sonra Mehmet cevabını verdin. Doğru cevap Mehmet idi. ünkü en hafif top Mehmet'in ve lastiği en fazla Mehmet gerebiliyor.

Figure 4.11. The screen representing the review of the pretest questions of the experiment "Elastic band"

4.3.2. Worksheet Given as an Additional Support

The worksheet was designed by the researcher for the Group S students to attract their attention to the relevant information; to decrease the degree of cognitive load due to the multiple representations on the experimental screens, and to repeat the important knowledge gained from the simulated lab experiments. It is delivered for an instructional additional support which is believed to make learning easier and permanent.

In the first part of the worksheet, the Group S students will firstly fill a table during the experiment and then they will try to develop inferences based on their tabular data. For the second experiment, they will firstly fill a table and then they will both draw two graphs and develop two inferences based on the tabular data.

For example, when carrying out the "Elastic Band" experiment, although the students in Group NS were given specific measures for stretching the band only in the introduction section of the experiment, these measures were specifically indicated in the worksheet for

Group S students. Additionally they were expected to fill in a table using these measures and draw the graphics based on the table. A complete copy of the worksheet is included in Appendix B.

5. DESIGN AND PROCEDURE

The pretest-posttest design was used in this study. There were two matched groups-Group Supported (Group S) and Group Non-supported (Group NS) which are formed by the method of stratified random sampling. Both groups were administered a pretest and both made the same two simulated experiments on the computer laboratory of the state school. The Group S fills a worksheet given as an additional instructional support when they were studying the experiments on their own whereas the Group NS only made the experiment on their own. Finally, both groups were administered Recall of Representation Test (RRT) and posttest following the multimedia lab session.

Before the two simulated experiments, total 44 seventh grade students were administered a test called “Test on the Relationships between two Variables” (TR-b2V) as a pretest which continues one lesson hour (40 minutes). The test was conducted by the researcher in the science laboratory class of the school. After pretest, two groups each included 22 seventh grade students are formed randomly but trying to match the groups according to their sixth class science and math grade means and gender.

One day later, the two simulated experiments were loaded to 22 computers in the computer lab and in the same day each group made the experiments in different computer lab sessions. The Group S firstly carried out the experiments and the lab session continued 50 minutes (40 minutes class hour + 10 minutes break time). Secondly, the Group NS tried experiments in 40 minutes. Extra 10 minutes for the Group S grows out of filling a worksheet given as an additional support. Each computer lab lessons were conducted by the researcher so the same directions were given to the students. As soon as the completion of two experiments, Recall of Representation Test (RRT) was delivered and 20 minutes given to each group to fill up.

The same TR-b2V was used again as a posttest in the study, but it was applied four days later then the lab sessions. All participants took the test at the same time in the science laboratory of the school and it continued 40 minutes again.

6. RESULTS

6.1. Normality Tests for the Pretest, Posttest and Recall of Representations Test Scores of the Two Groups

The number of subjects in each group is 22, lower than 30. In order to apply parametric tests, firstly normality test was conducted to the TR-b2V pretest, TR-b2V posttest and recall of representations test (RRT) scores of the students in the two groups will be given in the first part of this section.

The skewness and kurtosis of pretest and posttest for both Group S and Group NS were examined firstly for the allowance of the parametric tests.

Table 6.1. Skewness and kurtosis statistics for pretest scores of Group S

TR-b2V Pretest		
Group S	N	22
Skewness		-,031
Std. Error of Skewness		,491
Kurtosis		-1,267
Std. Error of Kurtosis		,953
Kurtosis / Std. Error of Kurtosis		-1,329

Table 6.2. Skewness and kurtosis statistics for posttest scores of Group S

TR-b2V Posttest		
Group S	N	22
Skewness		-,078
Std. Error of Skewness		,491
Kurtosis		-1,177
Std. Error of Kurtosis		,953
Kurtosis / Std. Error of Kurtosis		-1,235

The distribution is normal because X/Y ratio for both skewness and kurtosis is between -2 and +2 in pretest and posttest scores for Group S so that parametric tests can be used (SPSS 14.0 User's Guide). Paired sample t-test will be used to check whether there is a significant difference between the pre and post test scores.

The same descriptive also found for the Group NS in order to apply parametric tests. The Tables 6.3 and Table 6.4 shows the skewness and kurtosis of pretest and posttest for Group NS. It is seen that X/Y ratio for both skewness and kurtosis is also between -2 and +2 in pretest and posttest scores for this group so that paired sample t-test will be used to check whether there is a significant difference between the pre and post test scores for this group.

Table 6.3. Skewness and kurtosis statistics for pretest scores of the Group NS

TR-b2V Pretest		
Group NS	N	22
Skewness		-,039
Std. Error of Skewness		,491
Kurtosis		-,750
Std. Error of Kurtosis		,953
Kurtosis / Std. Error of Kurtosis		-,786

Table 6.4. Skewness and kurtosis statistics for posttest scores of the Group NS

TR-b2V Posttest		
Group NS	N	22
Skewness		,936
Std. Error of Skewness		,491
Kurtosis		,761
Std. Error of Kurtosis		,953
Kurtosis / Std. Error of Kurtosis		,798

Normality tests of Kolmogorov-Smirnov and Shapiro-Wilk were also conducted for both pretest and posttest scores for both Group S and Group NS. The results of these tests (Table 6.5) show that these scores are not significantly different than the scores which have normal distribution.

Table 6.5. Kolmogorov-Smirnov and Shapiro-Wilk Normality tests' results for the pretest and posttest scores of Group S and Group NS

TR-b2V	Groups	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Pretest	S	.129	22	.200(*)	.943	22	.232
	NS	.118	22	.200(*)	.948	22	.291
Posttest	S	.133	22	.200(*)	.956	22	.413
	NS	.174	22	.080	.926	22	.102

Similar statistical analysis were carried out for Recall of Representations Test. Firstly, the skewness and kurtosis of RRT scores for both Group S and Group NS is examined for the allowance of the parametric tests.

Table 6.6. Skewness and kurtosis statistics for RRT scores of Group S

RRT		
Group S	N	22
Skewness		.009
Std. Error of Skewness		.491
Kurtosis		.354
Std. Error of Kurtosis		,953
Kurtosis / Std. Error of Kurtosis		,371

Table 6.7. Skewness and kurtosis statistics for RRT scores of Group NS

RRT		
Group NS	N	22
Skewness		.864
Std. Error of Skewness		,491
Kurtosis		.341
Std. Error of Kurtosis		,953
Kurtosis / Std. Error of Kurtosis		,358

It is seen that X/Y ratio for both skewness and kurtosis is also between -2 and +2 in RRT scores so that the distributions are normal for both groups.

Similarly, normality tests of Kolmogorov-Smirnov and Shapiro-Wilk were also carried for RRT scores for both Group S and Group NS. According to these test results, Shapiro-Wilk test of normality indicated that distribution was normal for each groups (p = .569 for Group S and p = .100 for Group NS), while Kolmogorov-Smirnov test of normality indicated distribution was normal for Group S (p> .05) and not normal for the Group NS (p< .05). However, since the skewness coefficients (skewness =. 864, kurtosis = .341) are in the acceptable range, it is also accepted distribution as normal for the Group NS. Therefore, independent sample t-test will be used to check whether there is a significant difference between the RRT scores of Group S and Group NS. Furthermore, a non-parametric test of Mann-Whitney U was also carried out between RRT scores of each group because of the small sample size.

Table 6.8. Kolmogorov-Smirnov and Shapiro-Wilk Normality tests' results for the RRT of Group S and Group NS

Groups	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
S	.184	22	.052	.964	22	.569
NS	.197	22	.026	.926	22	.100

6.2. Analysis of Variance Results

In this part, the mean differences between the groups in terms of TR-b2V pretest, TR-b2V posttest and RRT mean scores will be analyzed.

Research Question 1: *Do all participants show significant learning gains (difference between the pretest and posttest) following the multimedia instruction?*

It is expected that both groups who received support (Group S) and the group who did not receive support (Group NS) will show a significant difference between pre and posttest results. The mean of post test scores will be higher than the mean of pretest scores for each group.

The mean of scores in both pretest and posttest is calculated for each group, and it is found to be M = 26, 23 in pretest and M = 30, 36 in posttest for Group S and M = 21, 86 in pretest and M = 27, 50 in posttest for Group NS. Table 6.9 shows descriptive statistics related to pretest and posttest scores of the two groups.

Table 6.9. Descriptive statistics related to pret and posttest scores of Group S and Group NS

Groups	TR-b2V	N	Mean	Std. Deviation
S	Pretest	22	26.23	10.71
	Posttest	22	30.36	10.71
NS	Pretest	22	21.86	5.81
	Posttest	22	27.50	7.74

There is an increase in means of posttest scores of students when compared with their pretest scores. Since the assumption of a normal distribution was checked for the pre and post test scores in previous part and found a normal distribution for each test, Paired-sample t-test was carried out between the pretest and posttest scores of students in order to determine whether this increase is statistically significant or not (see Table 6.10 and Table 6.11.).

Table 6.10. Paired-Sample t-test results on pretest and posttest scores of Group S

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
			Lower	Upper			
-4.136	4.257	.908	-6.024	-2.249	-4.557	21	.000

Table 6.11. Paired-Sample t-test results on pretest and posttest scores of Group NS

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
			Lower	Upper			
-5.636	5.745	1.225	-8.184	-3.089	-4.602	21	.000

It is found out that there is a statistically significant difference between pretest and posttest scores of Group S students: t (21) =-4.56, p=.000. Similarly, there is a statistically significant difference between pretest and posttest scores of Group NS: t (21) = -4.60, p=.000. This means that the two lab experiments about the relationships between variables affect positively the post test scores of all participants. The results indicate significant learning gains for all participants.

Because of the sample size of each group which is 22 lower than 30, a non-parametric test ofWilcoxon Signed Ranks Test was also carried out between the pre and post test scores of the students. Results of this analysis are shown in Table 6.12 and Table 6.13.

Table 6.12. Ranks of pretest and posttest scores for Group S and Group NS

Groups	TR-B2V		N	Mean Rank	Sum of Ranks
S	POSTTEST - PRETEST	Negative Ranks	3(a)	8.83	26.50
		Positive Ranks	19(b)	11.92	226.50
		Ties	0(c)		
		Total	22		
NS	POSTTEST - PRETEST	Negative Ranks	3(a)	5.67	17.00
		Positive Ranks	19(b)	12.42	236.00
		Ties	0(c)		
		Total	22		

a POSTTEST < PRETEST
b POSTTEST > PRETEST
c POSTTEST = PRETEST

Table 6.13. Wilcoxon Signed Ranks test results on pretest and posttest scores of Group S and Group NS

Groups	Z	Asymp. Sig. (2-tailed)
S	-3,258	,001
NS	-3,561	,000

It is found out that there is a statistically significant difference between pretest and posttest scores of Group S students, Wilcoxon Signed Ranks test, z = -3.26, p=.001. Similarly, there is a statistically significant difference between pretest and posttest scores of Group NS, Wilcoxon Signed Ranks test, z = -3.56, p=.000. As with the parametric tests the non-parametric test results also indicate significant gains for all participants, supporting the first hypothesis.

Research Question 2: *Is there a significant difference in learning gains between the Group S and the Group NS?*

It is hypothesized that the group who received support (Group S) will perform significantly higher than the group who did not receive support (Group NS) in terms of pre-posttest result differences. In order to test the second hypothesis, the learning gains of the two groups were analyzed by using independent samples t-test. Results of this analysis are shown in Table 6.14.

Table 6.14. Results of the independent samples t-test in learning gains between the Group S and Group NS

t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	95% Confidence Interval of the Difference	
					Lower	Upper
-.984	42	.331	-1.500	1.52446	-4.57649	1.57649

It is found that there is no significant difference in learning gains between the Group S and Group NS, t (42) =-.98 , p=.331.

Similarly, a non-parametric test of Mann-Whitney U test is carried out because of the small sample size. Non-significant difference was found in learning gains between the Group S and the Group NS, (Mann-Whitney *U*-test, Z = -.67, p = .50).Results are shown in Table 6.15 and Table 6.16.

Table 6.15. Ranks of learning gain scores for Group S and Group NS

Groups	N	Mean Rank	Sum of Ranks
S	22	21,20	466,50
NS	22	23,80	523,50

Table 6.16. Results of Mann-Whitney U test in learning gains between the Group S and Group NS

Learning Gain	
Mann-Whitney U	213,500
Wilcoxon W	466,500
Z	-,671
Asymp. Sig. (2-tailed)	,502

Research Question 3: *Is there a significant difference between the Group S and Group NS in terms of the Recall of Representations Test (RRT) scores?*

It is expected that the group who received support (Group S) will perform significantly higher than the group who did not receive support (Group NS) in terms of Recall of Representations Test (RRT) scores. As previously explained in the first section, RRT scored by two scorers and the averages of these two scores was used as RRT actual scores. According to the normality test results of RRT scores, both group normally distributed. Therefore, independent-samples t-test was carried out between the RRT scores of the two groups to determine whether there is a significant difference between the groups. Table 6.17 shows descriptive statistics related to RRT scores of the two groups and Table 6.18 shows the results of this analysis.

Table 6.17. Descriptive statistics related to RRT scores of the Group S and Group NS

Groups	N	Mean	Std. Deviation	Std. Error Mean
S	22	5,9318	1,99132	,42455
NS	22	5,4091	1,51686	,32340

As it was seen, there is not a significant difference between the RRT scores of the two groups, t (42) =-.98, p=.333. Although the mean of RRT scores M= 5.93 (SD= 1.99) for Group S is higher than the mean of RRT scores M= 5.41 (SD= 1.52) for Group NS, The Group S performed not significantly higher than the Group NS in terms of RRT scores. This result indicated that whether receiving additional support or not during the two lab experiments do not have different effects on recalling performance of the students.

Table 6.18. Results of the independent samples t-test between the RRT scores of the Group S and Group NS

t-test for Equality of RRT Means						
t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	95% Confidence Interval of the Difference	
					Lower	Upper
,979	42	,333	,52273	,53369	-,55431	1,59976

In the same way, Mann-Whitney U test is also carried out between the RRT scores of the two groups and no significant difference was found the Group S and the Group NS, (Mann-Whitney *U*-test, Z = -1.25, p = .212). Table 6.19 and Table 6.20 show the results of this analysis.

Table 6.19. Ranks of RRT scores for Group S and Group NS

Groups	N	Mean Rank	Sum of Ranks
S	22	24,89	547,50
NS	22	20,11	442,50

Table 6.20. Results of Mann-Whitney U test between RRT scores of the Group S and Group NS

RRT	
Mann-Whitney U	189,500
Wilcoxon W	442,500
Z	-1,247
Asymp. Sig. (2-tailed)	,212

When the results are considered as a whole they showed that two of the three hypotheses could not be confirmed. Although the students in both groups seemed to benefit from multimedia instruction that used simulated experiments on the relationship between variables, additional instructional help did not seem to provide improvements in what students learned and remembered from the simulated environments. These results are further discussed in the following section.

7. DISCUSSION AND CONCLUSION

This study aims to understand the role of additional instructional support in terms of learning gains of students and how much they can recall representations in two simulated lab experiments which include multiple representations (such as graphs, tables etc.). The experiments are designed to make students observe relationship between two variables. Whether additional support may decrease the degree of cognitive load in students' working memory was addressed. 44 seventh grade students were used in this study and they were assigned into two groups in equal number (22 students for each group). Supported group (Group S) received additional instructional support during the simulated lab experiments whereas non-supported group (Group NS) did not receive.

The method of the research in this study was pretest-posttest group design. Both groups were administered a TR-b2V pretest and both made the same two simulated experiments on the computer laboratory of the state school. However, the Group S fills a worksheet given as an additional instructional support when they were studying the experiments on their own whereas the Group NS only made the experiment on their own. Finally, both groups were administered Recall of Representation Test (RRT) at the end of the simulated lab experiments and TR-b2V posttest four days later than the multimedia lab session.

First of all, whether all participants show a learning gain about relationships between two variables was addressed in this study. The mean of scores in both pretest and posttest are found to be M = 26, 23 in pretest and M = 30, 36 in posttest for Group S and M = 21,86 in pretest and M = 27,50 in posttest for Group NS. The mean of posttest scores is higher than the mean of pretest scores for both groups. Analysis of pretest and posttest results of both groups who received support (Group S) and the group who did not receive support (Group NS) shows that there is a significant difference between pre and posttest results (t (21) =-4.56, and p=.000. for Group S; t (21) = -4.60, p=.000. for Group NS). The results of the analysis revealed that the two simulated lab experiments about relationships between two variables affect positively the posttest scores of all participants regardless of whether receiving additional support or not. Hence the first hypothesis was verified. In other words, a single class period of a computer lab session seemed to be sufficient for most of the students to improve their understanding of relationships between two variables which is a required ability for proportional reasoning. There were only three students in each Group S whose TR-b2V posttest results were lower than their TR-b2V pretest results.

The results of the present study were also parallel with some research findings in literature. A number of studies indicate increases in performance gains following simulated lab experiments. (Kinzie *et al.,* 1993; Baird and Koballa, 1988; Fortner and Schar, 1986; Akpan and Andre, 2000; Barnea and Dori, 1999; Geban *et al.,* 1992; Yildiz and Atkins, 1996). Moreover, there are many science educators who focus on the use of microcomputer-based labs to enhance the learning of science concepts, graphing skills and problem solving skills (e.g., Nakhleh and Krajcik, 1993; Edelson, 1998; Linn and Hsi, 2000). Mokros and Tinker (1987) also found a significant change in students' ability to interpret and use graphs. In line with the results observed in the above mentioned studies, the present study also indicated the effectiveness of computerized environments in improving students' science process skills. This can be considered as an important gain because process skills such as the one used in the present study (i.e. understanding the relationship between two variables) are highly generic and applicable in several different domains.

The study further questioned differences in learning gain about relationships between two variables between the supported and non-supported groups was addressed. Although the posttest scores of Group S were higher than the Group NS, the results of the analysis showed that there is no significant difference between the Group S and Group NS in terms of learning gains which was calculated by differences of pretest and posttest scores, $t(42)=-.98$, $p=.331$. In other words, there is no significantly higher or lower learning gains between the two groups. That is to say that the second hypothesis which stated Group S will perform significantly higher than the Group NS in terms of pre-posttest result differences was not verified. As a result, a positive effect of additional instructional support given as a worksheet in order to keep students' attention to the relevant and important information on the two simulated lab experiments was not found. Worksheets did not result in significant improvements of the Group S performance according to Group NS. Therefore, effects of the additional instructional support were not conclusive. This conclusion has also been supported by Reid *et al.*'s (2003) findings that there was no significant effect for experimental support on the post-tests. In this study, experimental support included explanations about experimental design, the prompts for identifying the objective of each experiment, the prompts for predicting and observing outcomes, and drawing conclusions. However, this result disagreed by Rivers and Vockell's (1987) finding that providing learners with general experimentation hints before their exploration could promote their experimentation abilities, as well as Swaak *et al.*'s (1998) conclusion that the experimental support in the form of assignments had a clear effect on scientific discovery learning.

One possible reason behind this result might be the way how students completed worksheets. There were incomplete, inattentive and carelessly filled out worksheets. It was investigated that three worksheet papers were incomplete in terms of open-ended questions which ask the results of the experiments; two papers were unfinished in terms of graphic drawings and one worksheet paper was incomplete concerning filling the table part of the worksheets. The study was applied in the last days of the first semester, so they did not learn the unit of Ratio and Proportion in mathematic lesson. Therefore, participants were also deficient about how to draw and interpret a graphic and also how to express the relationships between variables. Their expressions about the relationship between two variables were insufficient in worksheets although they might understand the type of relationship between variables whether it was directly or inversely proportional. It is also stated in the literature that insufficient prior knowledge might be the cause that learners do not know which hypothesis to state, can not make a good interpretation of data, and move to unsystematic experimentation behavior (Glaser *et al.,* 1992)

Furthermore, it was observed that Group S students appeared to be less motivated and less actively engaged to fill the worksheets while they were doing the simulated lab experiments because they got bored with writing and filling worksheets in these last days of the semester. Therefore, the worksheet might have a distracted role in this lab session for the Group S. However, most of the students appeared to be motivated and actively engaged in order to do the simulated lab experiments.

Finally, the role of additional instructional support on the recalling performance of the students was explored. It was hypothesized that the group who received support (Group S) will perform significantly higher than the group who did not receive support (Group NS) in terms of Recall of Representations Test (RRT) scores. However, analysis of RRT scores showed that there was not a significant difference between the RRT scores of the two groups (Mann-Whitney *U*-test, Z = -1.25, p = .212). The groups did not differ significantly in the rate of recalling performance. Although RRT mean of Group S, M= 5.93 (SD= 1.99) is higher than RRT mean of Group NS, M= 5.41 (SD= 1.52), the Group S performed not significantly higher than the Group NS in terms of RRT scores. Accordingly, the third hypothesis also was not verified. This result indicated that receiving additional support or not during the two lab experiments do not have different effects on recalling performance of the students. The reasons for this result might be poor drawing performance of the Group S students according to Group NS ones. The Group NS students' drawings were generally much more obvious, apparent, noticeable, and successful. Maybe for this reason, their RRT scores approached to the Group S ones. Another possible explanation might be that Group S students, who had already reported the experimental setup and tabular/graphical representations on their worksheets, might have considered it unnecessary to report the same things during RRT drawings, and give emphasis on other information included in the screens. Yet another possible explanation could be that the worksheets had no effect on recalling performance.

Apart from additional support, there might be other factors such as memory capacity, visual memory capacity, metacognitive or cognitive and learning styles as well as the drawing performance of the students which may affect the recalling performance of the students. Therefore, these dimensions also should be investigated by additional research.

7.1. Limitations of the Study

The study was implemented in the last days of the first semester so that some of the participants were appeared to be less motivated and less actively engaged to do pre and post tests, and two simulated lab experiments. The grades were given to the administration so they were anxious about their marks and these damaged their concentrations and motivations towards the study. This might have decreased the effectiveness of the two simulated laboratory experiments about relationship between two variables and of the worksheets given as an additional instructional support. Therefore, the time of application was a limitation of the study.

Only one laboratory session includes two short simulated experiments was used in the study to decide on the role of additional instructional support in multimedia learning and the effectiveness of this virtual laboratory applications. Ideally, subjects should be exposed to the such kind of simulated lab applications and additional instructional support mechanisms for a longer period of time in other related topics of mathematics and science in order to accurately asses its effectiveness. Using only one computer laboratory session was another limitation of the study.

Group S students also studied extra 10 minutes break time to complete the both lab experiments and the worksheets given as an additional support. However, this break time damaged students' concentrations because they did not use this playtime while other students were using and making a lot of noise. Hence, using break time for the application of the study was only a limitation for the supported group students.

Most of the participants were deficient about how to draw and to interpret a graphic and also express the relationship between variables, because they did not learn the unit of "Ratio and Proportion" in mathematics lesson. Therefore, they had a difficulty in expressing the relationship between two variables in a graph and drawing a graph. Similarly, they encountered some problems in using a computer because they were new learners in this issue, too. Most of them required help from the researcher such as opening a Flash program and this damaged also the flow of the lab sessions and concentrations of the students. Therefore, unfamiliarity with the use of computers was also considered as a limitation.

7.2. Suggestions for Further Research

This study investigated the effects of additional instructional support on students' performance on a test of relationship between two variables (TR-b2V) and on a test of recall of representations (RRT) in two simulated lab experiments which include multiple representations (such as graphs, tables etc.). There are some suggestions for further research.

First of all, only one laboratory session includes two short simulated experiments was used in the study to decide the role of additional instructional support. This may not be satisfactory to decide that using worksheets as an additional instructional support has no effect on decreasing heavy cognitive load in the working memory due to the multiple representations in the simulated experiments. In order to understand more clearly the role of additional instructional support, more than one lab sessions integrated into a semester can be used. In addition to these, nearly all students seems liked to do an experiment in a virtual environment, so in the future students' attitudes toward simulated laboratory experiments versus conventional ones should be compared after a longer period of implementation time.

Secondly, the worksheet used as an additional instructional support in this study is designed to decrease the level of heavy cognitive load on students' working memory which might be occurred because of the multiple representations (such as tabular and graphical) on experimental screens. It has both repeating and attracting functions of relevant and important information in the simulated lab experiments. It tried to make learning easier and permanent. However, no effect of worksheets was found. It may especially help the students' cognitive process of selecting relevant pictures and organizing them, but not much more for the cognitive process of integrating. Therefore, it should be improved and redesigned to emphasize higher-order thinking skills such as synthesizing and evaluating for further research.

Thirdly, apart from delivering worksheets for an additional instructional support, other instructional support mechanisms such as adjunct questions (Holliday and McGuire, 1992), instructional prompts (Lin and Lehman, 1999), information sheets (Nijoo and de

Jong, 1993) or assignments that guide inquiry (deJong and van Joolingen, 1998) in order to improve the effectiveness of multimedia learning may be investigated. For instance, many teachers spend last five or ten minutes of their lessons to discuss and summarize what they have learned from the lesson and they believe the effectiveness of this short discussion hours on students' learning. Therefore, a brief discussion session can be done after each experiment in order to emphasize the important information and make easier to integrate the new knowledge with the prior one for the learners. There may be one or two group more in a further study to investigate also the role of discussion sessions on students' performance on TR-b2V and RRT.

As previously stated that most of the participants were deficient about how to draw and to interpret a graphic and also express the relationships between variables, because they did not learn the unit of "Ratio and Proportion" in mathematics lesson. Therefore, the learning gains should be compared between the ones who did not learn this unit and the ones who had learnt for further research.

Additionally, students' memory capacities especially visual memory capacities and their learning styles can be a factor on the recalling performance of students on RRT. For further research, the effect of memory capacity and learning styles should be examined. Whether the ones who have high visual memory capacity or have visual learning style recall much more or not should be investigated. What students remember, as induced by the RRT test seems to show some variance. These differences might also further be analyzed to understand the role of individual differences in the degree of recall.

The state school which the study was applied has only one computer laboratory composed of 22 working computers. Therefore, 22 students were chosen for each group in the study and each student used a computer on their own. However, most of the state schools in Istanbul have a student number of 40-60 in a class. Therefore the conditions applied in the present study had limited generalizability. In order to improve generalizability and increase the usability of such simulated laboratory experiments in science and math lessons in state schools, collaborative and cooperative learning techniques should also be analyzed. Hence, the efficiency of collaborative working should be studied.

The lab sessions was implemented by one teacher (by the researcher) so that it was hard to apply it in this state school because the participants have started to learn using computer at this semester, one hours a week and sharing a computer with their classmates. Most of them encountered technical problems during the lab sessions and required help from the researcher such as opening a Flash program. This damaged to the flow of the lab sessions and concentrations of the students. While an extra technical support might increase the internal validity of the study, this would decrease the external validity. Another possibility is that this study could be replicated in private schools where most of the students have no problem in using a computer effectively or there should be more than one lab assistants to help students in their computer usage and observe students to fill their worksheets eagerly.

This study was an attempt to overcome certain learning difficulties encountered in multimedia instructions. However, with the developing technologies teachers and researchers need to discover better ways in this issue in order to meet the desires and demands of the students to provide high quality of education.

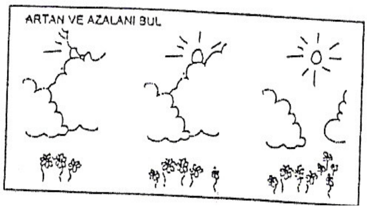
APPENDIX A: TEST ON THE RELATIONSHIP BETWEEN TWO VARIABLES (TR-B2V)

Adı Soyadı ____________________ Matematik notu _________
Sınıfı ____________________ Fen Notu _________

Sevgili öğrenciler
Bu test bir ön hazırlık testidir. Sorulari iyi düşünerek yanıtlamaya çalışın.

1. Aşağıdaki resimlerde artan ve azalan nesnelere göre sıralayın. Artan ve azalan nesneleri bulun. Aralarındaki ilişkiyi belirlemeye çalışın.

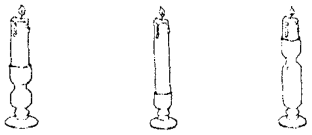
Örnek



Güneş ışığı artıyor, Bulutlar azalıyor
Çiçekler artıyor

Artan: Güneş ışığı, çiçekler
Azalan: Bulutlar

Aralarındaki ilişki: Güneş ışığı arttıkça çiçekler artıyor. Bulutlar azaldıkça çiçekler artıyor



Aşağıdaki soruları (a-c) örnekteki gibi cevaplayın.

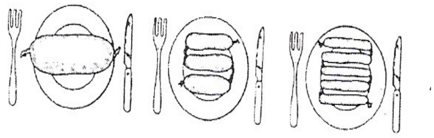
a)

Artan ___________________

Azalan __________________

Aralarında nasıl bir ilişki var? ____

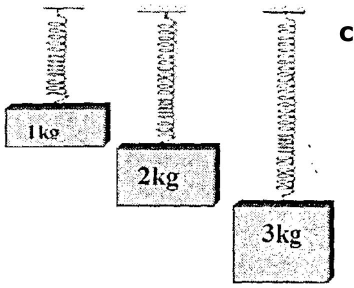
b)



Artan ___________________

Azalan __________________

Aralarında nasıl bir ilişki var?____



c)

Artan ___________________

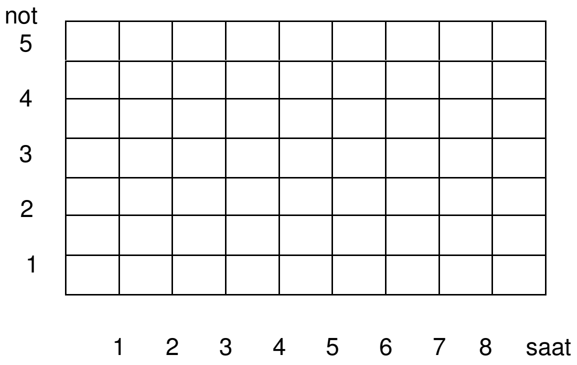
Azalan __________________

Aralarında nasıl bir ilişki var?____

2. Aşağıdaki tabloda üç arkadaşın matematik dersi için kaç saat çalıştıkları ve aldıkları notlar yazılı

	Matematik çalışmaya ayrılan zaman	Matematik notu
Ayşe	2 saat	2
Ali	5 saat	3
Deniz	7 saat	5

a) Tablodaki sayıları kullanarak çalışma saatleri ve matematik notunun grafiğini çizmeye çalışın.

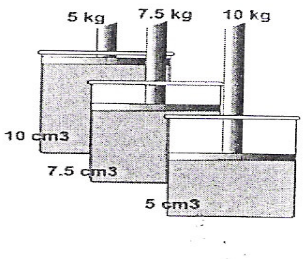


b) Öğrencilerin çalışma saatleri ve notları arasında nasıl bir ilişki vardır?

---

3. Birim alana uygulanan kuvvet ve hacim ilşkisi: Aşağıdaki resmi inceleyin ve soruları cevaplandırın.

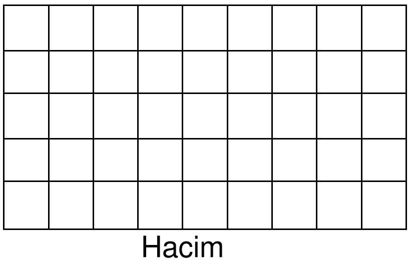
a) Resimdeki rakamları tabloya aktarın.
b) Tablodaki rakamları kullanarak ilişkinin grafiğini çizin.
c) İlişkiyi genel bir kural olarak belirtin. (örneğin: ağırlık arttıkça kuvvet artar.)



Tablo: Kuvvet ve hacim

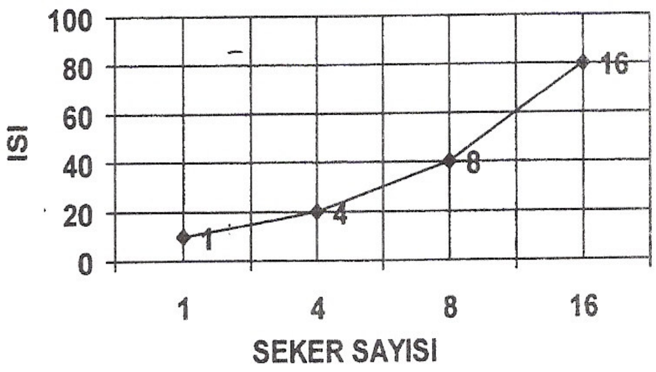
Kuvvet	Hacim

Grafik : Kuvvet ve hacim



4. Aşağıdaki grafik ısı ve çözünürlük arasındaki ilşkiyi göstermektedir. Grafikte gördüğünüz değerleri tabloya yazınız.

Grafik: ISI VE COZUNURLUK



Tablo : ISI VE ÇÖZÜNÜRLÜK

Isı	Çözünen şeker sayısı

Isı ile çözünen seker sayısı arasında nasıl bir ilişki vardır?

____

____

5. Aşağıdaki boş kutuları iki olay arasındaki ilişkiyi gösterecek şekilde doldurun.

Aklınıza gelen ve çizemediğiniz ilişkileri buraya yazabilirsiniz.

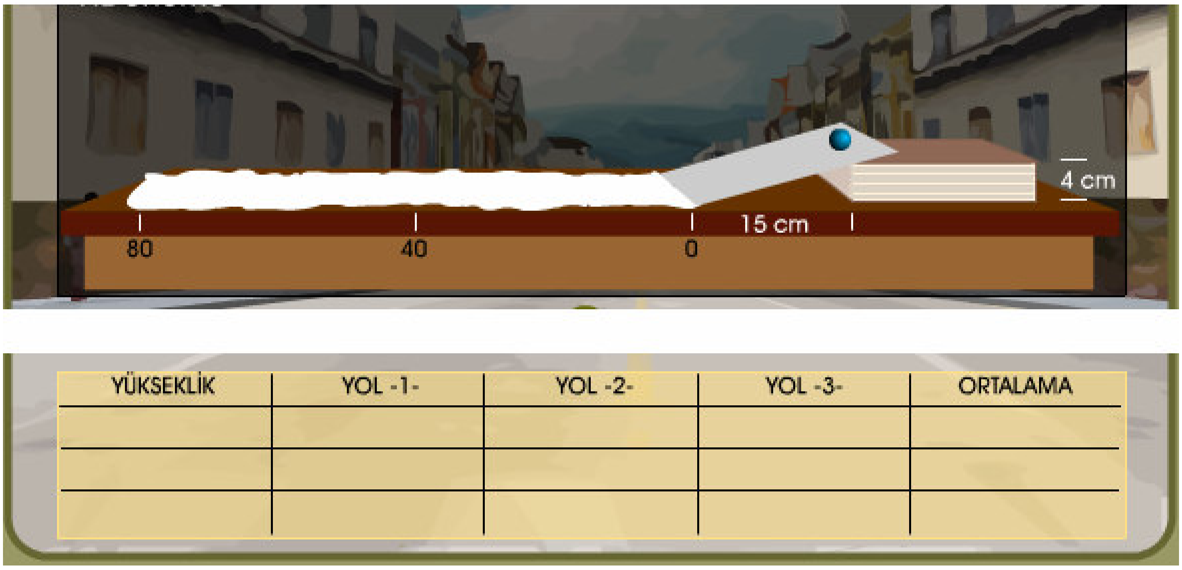
APPENDIX B: THE WORKSHEET

Adı Soyadı _____________ Sınıfı ______

YUVARLANAN BİLYELER

Bilye Deneyi: Bu deneyde eğik düzlemde "yüzey eğimi" ve "bilyelerin gittiği mesafe" arasındaki ilişkiyi anlamaya çalışıyoruz.

Deneyi yaparken deneyle ilgili aşağıdaki tabloyu doldurun.



YÜKSEKLİK	YOL -1-	YOL -2-	YOL -3-	ORTALAMA

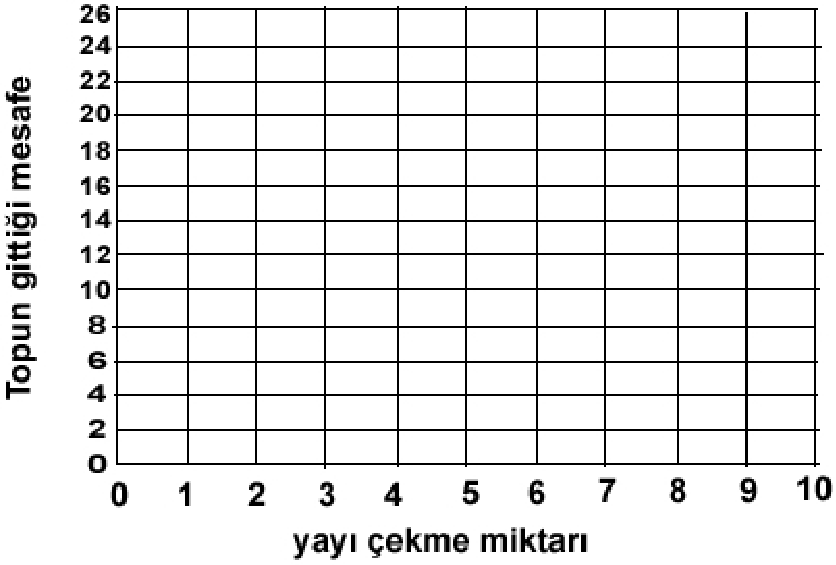
Yüzey eğimi ile bilyelerin gittikleri mesafe arasında nasıl bir ilişki var?

LASTİK BANT

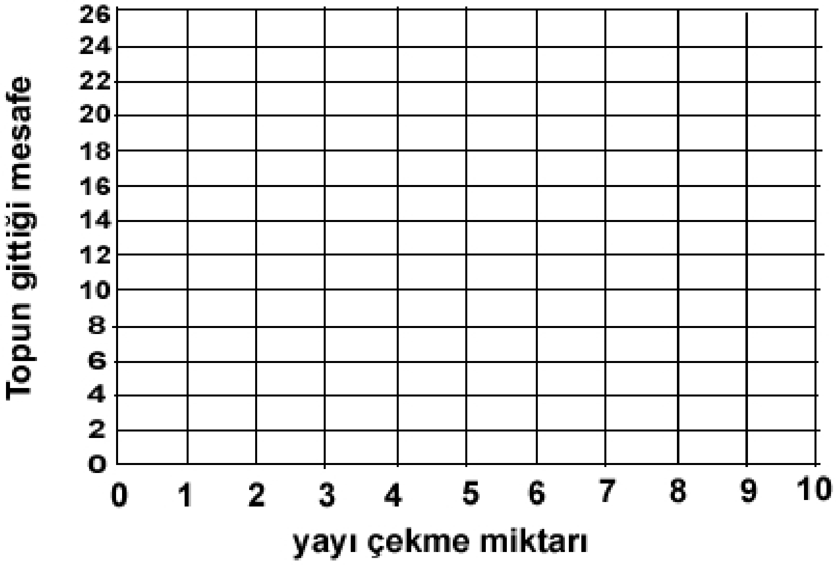
Yay Deneyi: Bu deneyde farklı ağırlıktaki toplar için "yayın gerilme miktarı" ve "topun gittiği mesafe" arasındaki ilişkiyi anlamaya çalışıyoruz.

Deneyi yaparken aşağıdaki tabloyu doldurun ve ilişkili grafiği çizin. Yay 2 cm, 4 cm, 6 cm, 8 cm ve 10 cm gerildiğinde 10 gr. ve 20 gr. ağırlığındaki toplar ne kadar yol alır? Deneyin ve aşağıdaki tabloda belirtin.

YAYI ÇEKME MİKTARI	10 gr. TOP	20 gr. TOP
	TOPUN GİTTİĞİ MESAFE	TOPUN GİTTİĞİ MESAFE
2cm		
4cm		
6cm		
8cm		
10cm		



10 gr. TOP



20 gr. TOP

Aynı ağırlıktaki toplar için yayın gerilme miktarı ile topun gittiği mesafe arasında nasıl bir ilişki var?

____

____

Farklı ağırlıktaki toplar için yayın gerilme miktarı ile topun gittiği mesafe arasında nasıl bir ilişki var?

____

____

APPENDIX C: RECALL OF REPRESENTATION TEST(RRT)

Adı Soyadı ______________ Sınıfı _______

Yokuştan yuvarladım bir bilye
Ölçtüm, gitmiş kaç metre
Yükselttim yokuşun boyunu
Gözlemledim yolunu

Deney ekranında gördüklerinizi aşağıya çizin.

Adı Soyadı ______________ Sınıfı _______

LASTİK BANT

Deney ekranında gördüklerinizi aşağıya çizin.

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