AN INVESTIGATION OF MODALITY, REDUNDANCY AND SIGNALING EFFECTS IN MULTIMEDIA LEARNING WITH ABSTRACT AND CONCRETE REPRESENTATION

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BOĞAZİÇİ UNIVERSITY

2016

AN INVESTIGATION OF MODALITY, REDUNDANCY AND SIGNALING EFFECTS IN MULTIMEDIA LEARNING WITH ABSTRACT AND CONCRETE REPRESENTATION

Thesis submitted to the

Institute for Graduate Studies in Social Sciences

in partial fulfillment of the requirements for the degree of

Master of Arts

in

Educational Technology

by

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Boğaziçi University

2016

An Investigation of Modality, Redundancy and Signaling Effects

in Multimedia Learning with Abstract and Concrete Representation

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June 2016

DECLARATION OF ORIGINALITY

I, Ekrem Kutbay, certify that

- I am the sole author of this thesis and that I have fully acknowledged and documented in my thesis all sources of ideas and words, including digital resources, which have been produced or published by another person or institution;
- this thesis contains no material that has been submitted or accepted for a degree or diploma in any other educational institution;
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ABSTRACT

An Investigation of Modality, Redundancy and Signaling Effects

in Multimedia Learning with Abstract and Concrete Representation

This study aimed to explore the effects of modality, redundancy, and signaling principles in multimedia learning with abstract and concrete representations of an animation on learning in real middle school settings. Based on these principles of the cognitive theory of multimedia learning, ten types of treatment conditions were tested. The study was conducted with a pre-test and post-test quasi-experimental design. Data were collected from 855 fifth and sixth graders with low prior electricity knowledge in four public middle schools. Each student, who are assigned to an experimental group with one type of intervention in each, took pre and post-test. Analyses showed that all treatments helped students to develop knowledge of the topic to some extent. However, while the modality effect holds true for middle school students' studying electricity units with a multimedia instruction in real school settings, the signaling and redundancy principles do not hold true. Analysis also showed that there were no significant two-way or three-way interactions among prior science scores, prior knowledge about the topic, and multimedia treatments on students' conceptual and procedural knowledge. However, while these three independent variables independently influenced learning of conceptual knowledge; only students' prior science scores and prior knowledge about the topic independently influenced students' learning procedural knowledge. The treatment did not significantly affect learning procedural knowledge.

ÖZET

Çoklu Öğrenme Ortamlarında Somut ve Soyut Gösterimlerle Duyu Biçimi, Artıklık ve İmleyim İlkelerinin İncelenmesi

Bu çalışmanın amacı, somut ve soyut animasyon gösterimleriyle birlikte çoklu öğrenme ortamındaki duyu biçimi, artıklık ve imleyim ilkelerinin sınıf ortamında öğrenmeye etkisini incelemektir. Çoklu Ortamla Öğrenme Bilişsel Kuramına dayanan bu ilkeler, 10 farklı çoklu öğrenme ortamı ile test edilmiştir. Çalışmada yarı-deneysel ön test-son test araştırma modeli kullanılmıştır. Veriler, dört devlet ortaokulundaki elektrik konusu ön bilgisi az olan 855 beşinci ve altıncı sınıf öğrencilerinden toplanmıştır. İlk olarak, öğrencilere elektrik konusu hakkında bir ön test uygulanmıştır. İkinci olarak, her öğrenci bireysel olarak öğrenme ortamlarından sadece biri ile çalışmışlardır. Sonrasında, öğrencilere elektrik konusundaki bilgilerini ölçmek için bir son test verilmiştir. Yapılan istatistiksel veri analizleri, bütün çoklu öğrenme ortamlarının öğrencilerin konuyu öğrenmelerine yardımcı olduğunu göstermiştir. Ortaokul öğrencileri için duyu biçimi ilkesi, çoklu ortam ile elektrik konusunu öğreniminde geçerli olsa da; artıklık ve imleyim ilkeleri geçerli olmamıştır. Ayrıca, öğrencilerin Fen ve Teknoloji dersi notları, konu hakkındaki ön bilgileri ve çoklu öğrenme ortamlarının kavramsal ve işlemsel bilgileri üzerine birlikte etkisinin olmadığı görülmüştür. Ancak, bu üç bağımsız değişkenin ayrı ayrı kavramsal bilgiyi öğrenmede etkili olduğu tespit edilmiştir. Diğer taraftan Fen ve Teknoloji dersi notları ve konu hakkındaki ön bilgi, öğrencilerin işlemsel bilgiyi öğrenmesini ayrı ayrı etkilerken, çoklu ortam öğrenme ortamı tek başına işlemsel bilgi öğrenmeyi önemli bir derecede etkilememiştir.

ACKNOWLEDGEMENTS

I am pleased to acknowledge the substantial contributions of those who helped me with my thesis. First and most of all, I would like to declare my deep gratitude to my thesis advisor, Prof. Yavuz Akpınar, for his conscientious and meticulous guidance during this research and the writing of the thesis. Despite his heavy workload, he made this thesis possible. This thesis would not have been completed without his unwavering dedication, expert guidance, and valuable feedback and ideas.

I am grateful to each of the other members of my thesis committee, Assist. Prof. Günizi Kartal and Assoc. Prof. Serkan Özel, for their insightful comments, feedback, and suggestions during this period.

I would like to thank my friends Metin Bilal, Şahin Taşın, Halil Polat, and Yıldırım Uludağ for helping me reach their students and to conduct the experimental studies. I would never have been able to access such a large number of participants without their diligent efforts. I am particularly grateful to my schoolmate and colleague, Burç Çeken, for helping with the statistical analysis of the data and the formatting of my thesis. I also thank my friends Gülhizar Bollu and Ali Akkaya for their support in checking the language.

I owe a very special debt of gratitude to my beloved family: to my mother, Muazzez Kutbay, to my father Faruk Kutbay, and to my brother Oytun Kutbay, all of whom were very helpful during the thesis process and throughout my academic life.

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LIST OF ABBREVIATIONS

(1) CLT: Cognitive Load Theory

(2) CTML: Cognitive Theory of Multimedia Learning

(3) ICT: Information and Communication Technology

(4) Sg-A: The multimedia condition including Signaled written text and Abstract animation

(5) Sg-C: The multimedia condition including Signaled written text and Concrete animation

(6) Sg+Sp-A: The multimedia condition including Signaled written and Spoken text, and Abstract animation

(7) Sg+Sp-C: The multimedia condition including Signaled written and Spoken text, and Concrete animation

(8) Sp-A: The multimedia condition including Spoken text and Abstract animation

(9) Sp-C: The multimedia condition including Spoken text and Concrete animation

(10) SPSS: Statistical Package for the Social Science

(11) TUIK: Turkish Statistical Institute

(12) W-A: The multimedia condition including Written text and Abstract animation

(13) W-C: The multimedia condition including Written text and Concrete animation

(14) W+Sp-A: The multimedia condition including Written and Spoken text, and Abstract animation

(15) W+Sp-C: The multimedia condition including Written and Spoken text, and Concrete animation

CHAPTER 1

INTRODUCTION

The increasing availability of high-speed Internet and more capable personal computers, smartphones, and multimedia devices have enabled people to access and to participate in online learning environments more easily and comfortably. A 2015 information and communication technology (ICT) usage survey on households and individuals conducted by the Turkish Statistical Institute (TUIK) indicated that 54.8% of Turkish people aged 16-74 use a computer and 55.9% of them use the Internet. The ICT usage survey showed that 69.5% of households have Internet access. The same survey announced that 96.8% of households have at least one mobile or smartphone. It is expected that these percentages will increase in the coming years. On the other hand, although technological improvements and changes in online learning environments are more predictable, educational improvements and changes of online learning environments are not. This issue seems to have a more complex status.

The developers, instructors, and educational technologists of online learning environments should develop appealing, meaningful, and useful online content, interfaces, and materials in order to achieve effective learning. For this reason, the research about e-learning should be examined in detail and if there are contradictory findings, new research should be conducted.

A significant number of studies on multimedia learning materials and their effects on learning have been conducted by Mayer and his colleagues (e.g., Harskamp, Mayer, & Suhre, 2007; Mautone & Mayer, 2001; Mayer & Johnson, 2008; Moreno & Mayer, 1999). According to Mayer et al. (2000), some important assumptions and principles should be adhered to when presenting information in a learning environment. They found that providing multimedia instruction resulted in better learning outcomes as opposed to single media instruction. Textual information in multimedia materials is not the only important medium for learning; pictorial information is also critical.

Multimedia is a term that relates to the presentation of words and pictures. Words can be presented as printed or spoken, and pictures can be presented as photos, graphics, illustrations, videos, or animations in multimedia. Mayer and Moreno (2003) defined multimedia learning as learning through words and pictures, and multimedia instruction as introducing words and pictures that are aimed to support learning. According to Mayer (2009), presenting text and pictures in multimedia instruction should not be applied in unsystematic ways; they should take the cognitive processes of learners into account. In particular, multimedia instructional designers must be aware of the cognitive processes of learners and the impact of cognitive load on the learning process. When they design multimedia instruction, they should manipulate learning content, arrange multimedia materials, and choose media types correctly to meet the needs of learners.

Mayer introduced a cognitive theory of multimedia learning (CTML) that may play an important role in the improvement of multimedia instruction. The theory focuses on how the human mind works and how learners process information and construct knowledge. The CTML is based on three main assumptions: dual channels, limited capacity, and active learning. Firstly, the dual channel assumption claims that people have two separate channels, auditory and visual, for processing information. The theory addresses how learners select and process information through these two channels. The theory is actually based on the dual-coding theory from Paivio (1971).

Secondly, the limited capacity assumption asserts that each channel has a finite capacity (Sweller, 1988). The theory comes from Alan Baddeley and Graham Hitch's working memory model (1974). Thirdly, the active learning assumption declares that meaningful learning is a process that requires actively selecting, organizing, and integrating information based upon prior knowledge.

There are some principles of multimedia learning that are derived from experimental studies on CTML. They may be helpful in designing multimedia instruction. These principles were also based on Chandler and Sweller's (1991) three types of cognitive load: (a) intrinsic, (b) extraneous, and (c) germane. Intrinsic cognitive load refers to the fact that instructional issues have inherent difficulties. This load is not directly dependent on instructional designers' interventions but it can be managed partially with segmenting, pre-training, and modality principles (Mayer, 2011). Extraneous cognitive load results from incorrect multimedia design which ignores the limitation and capacity of human memory. This load is directly dependent on instructional designers' decisions, and principles of coherence, redundancy, temporal contiguity, signaling, and spatial contiguity can provide guidance to reduce extraneous cognitive load (Mayer, 2011). Germane cognitive load depends on the construction and automation of learning schemas of a learner. Unlike the former two types of cognitive load, germane load is needs to be maximized. Mayer (2011) suggested that multimedia, generation, personalization, and voice principles may be useful in promoting germane cognitive load.

According to Mayer (2005), visual materials for multimedia instruction should take the limitations of the cognitive structure of the human mind into account. Information can be presented visually with different types of representation in multimedia instruction such as abstract, concrete, or pictorial. Some multimedia design studies propose that different representation types may result in different degrees of cognitive load for different learners (e.g., Mayer, 2005; Moreno & Mayer, 1999; Moreno, Ozogul, & Reisslein, 2011). On the other hand, beyond the relationship between a visual type of material representation and cognitive load, there is still a hot debate on which representation is more beneficial for learning and teaching abstract concepts.

Using a concrete representation in visual material is very common in teaching in schools. According to some researchers' findings (e.g., Dori et al., 2003), concrete representation for abstract concepts in science learning enables learners to understand these concepts more easily. However, Jaakkola and Veermans (2015) stated that additional relevant materials for concrete representations may distract a learner from the important parts of the instruction. Similarly, some experimental findings show that high-quality concrete visual images require more time to be processed, and this situation, in turn, may result in an increase in cognitive load (Stanney, 2002). Similarly, although there are few studies with young students, there are conflicting results. Some researchers (e.g., Moyer, 2003) claim that children under twelve years of age are more receptive to concrete operations, but others assert that younger children do not need concrete representation to understand abstract concepts in the way that older ones do (Kaminski, Sloutsky, & Heckler, 2006).

To test the quality of different types of visual representations and multimedia instruction, retention and transfer tests have generally been used. These tests assess students' conceptual knowledge and procedural knowledge in a learning unit. Additionally, traditional courses in schools convey these types of knowledge. Conceptual knowledge can be defined as the knowledge of the subject matter such as ideas, terminology, formulas, facts, vocabulary, concepts, models, definitions, and theories. On the other hand, procedural knowledge can be defined as the application of conceptual knowledge, such as applying ideas, using terminology, thinking about facts, using vocabulary, applying concepts, practicing theories, solving problems, and testing ideas in a variety of contexts.

1.1 Statement of the problem

Although many experimental studies have been conducted on the principles of multimedia learning and type of visual representation, and there are many promotive empirical findings about them, there are still some crucial criticisms of weaknesses in those studies.

Firstly, principles of multimedia learning have most often been tested with unrealistic and narrow settings (Ballantyne, 2008; Harskamp, Mayer, & Suhre, 2007). According to Ginns (2005), real school settings can be explained as class-based experiment in authentic classroom settings and they are significantly different from laboratory experiments using one-on-one testing. There is a lack of experimental studies about the principles of multimedia learning based on authentic classroom settings and on entire learning units. Most of the existing research has attempted cause-and-effect systems such as the formation of lightning, the nitrogen cycle, animal behavior, physical and mechanical systems and so on (Gall, 2004; Moreno & Mayer, 2000; Renkl, 2005). There is limited research on multimedia learning in the field of social sciences (Westelinck et al., 2005). Few studies have investigated multimedia principles with science subjects in real school contexts (Segers, Verhoeven, & Hulstijn-Hendrikse, 2008).

Secondly, over 90 research studies on multimedia principle studies by Mayer and his colleagues reported in Ginns's meta-analysis studies (2005, 2006) revealed that the principles were usually respected. These studies were usually conducted with adults; there are only a few studies carried out with young students. For this reason, these principles cannot be generalized to the whole learner population. Studies with younger children should be conducted. Similarly, Mayer (2011) points out the need for more research on the principles in realistic learning environments with children to clarify the boundary conditions of the principles and to test these principles in computer-based environments, using simulations, animations, and games.

Thirdly, in the literature, there are many investigations about static and graphical representations in a science context. However, there is a lack of experimental research on how abstract and concrete representations in science influence younger students’ conceptual and procedural knowledge. Some research has yielded contradictory results; some studies have claimed that concrete representation should be used because children are more receptive to concrete operations (Moyer, 2001), and others declared that children do not need concrete representation to understand science concepts (Kaminski, Sloutsky & Heckler, 2006).

Fourthly, most of the research about the principles, especially modality, redundancy, and signaling tested with learning material has been done in English. Although there are a few experimental studies with children using other languages such as Dutch and German (Harskamps, Mayer, & Sugre, 2007; Witteman & Seger, 2010), there are not any studies examining the principles with science content in Turkish.

To sum up, when the literature is taken into account, the multimedia principles—particularly with respect to modality, redundancy, and signaling—has not been tested sufficiently with whole learning units, including abstract components for young children in a real school setting.

1.2 Purpose of the study

With all prior known research and requirements about the multimedia learning considered, the main purpose of the current study is to explore the effects of modality, redundancy, and signaling principles on abstract and concrete representations of an animation of electricity unit in real middle school settings in Turkey.

1.3 Research questions

This study was designed to answer the following research questions:

1. Do abstract and concrete representation of animations with the following five different text representations affect differently middle school students' learning of an electricity unit?
    - written text representations
    - signaled written text representations
    - spoken text representations
    - written and spoken text representations
    - signaled written and spoken text representations
2. Does the modality effect in a multimedia setting with abstract or concrete representation of animation hold true for middle school students' learning of an electricity unit?

3. Do the effects of spoken text modality and signaled written text modality on an electricity unit achievement differ in a multimedia setting with abstract or concrete representation of animation?
4. Does the redundancy effect in a multimedia setting with abstract or concrete representation of animation hold true for middle school students' learning of an electricity unit?
5. Do the effects of spoken text modality, and signaled written text and spoken text modality on an electricity unit achievement differ in a multimedia setting with abstract or concrete representation of animation?
6. Does the signaling effect in a multimedia setting with abstract or concrete representation of animation hold true for middle school students' learning of an electricity unit?
7. Do the effects of written text and spoken text modality, and signaled written text and spoken text modality on an electricity unit achievement differ in a multimedia setting with abstract or concrete representation of animation?

1.4 Significance of the study

Some researchers (e.g., Mayer, 2005; Sweller, 2005) have pointed out that multimedia instructions usually take form by the multimedia designers' perceptions, but they must be based on empirical studies. A review of the literature shows that the majority of research in this area is centered on higher education for adults. There are a few relevant research studies on multimedia learning for children, and a multimedia designer shapes a multimedia instruction unit by using her or his perception. The current study aims to contribute to the research of multimedia learning with real middle school settings. The goal of the study is to provide practical direction and knowledge for multimedia instruction designers, content developers, and educators. With this knowledge, multimedia instructions can be designed in a way that better addresses the human cognitive architecture.

1.5 Organization of the study

In this study, Chapter 2 introduces a literature review of multimedia learning and its underlying theories, along with findings of related experimental studies. Chapter 3 includes the research methodology: the design, participants, sampling, treatment, instruments, and data collection procedures of the current study. Chapter 4 presents the data analysis procedure in detail. Chapter 5 contains the results of the data analyses. Finally, Chapter 6 focuses on outcomes of the findings, the limitations of the study, and recommendations and suggestions for further research.

CHAPTER 2

LITERATURE REVIEW

2.1 Multimedia learning

Multimedia learning refers to constructed representation of knowledge in the minds of people with the help of words and pictures. It simply means learning from pictures and words. On one hand, words can be presented as written or spoken text; on the other, pictures might be presented in multimedia learning as animation, illustrations, photos, graphics or video. Multimedia learning derives from the dual coding theory, which states that people have two segregated channels, auditory and visual, for processing information (Clark & Paivio, 1991). However, the cognitive theory of multimedia learning (CTML) maintains that when people learn something, they have a limited cognitive capacity during the learning process. Their channels only employ a small quantity of cognitive procedure at each time (Mayer, 2011).

The aim of presenting pictures and words is to promote learning with the help of building mental representations, namely multimedia instruction (Mayer, 2014). It is important that when a multimedia instruction is authored, three types of cognitive processing should be taken into account (Mayer & Moreno, 2003): (a) extraneous processing, (b) essential processing and (c) generative processing.

Firstly, extraneous processing is usually caused by inappropriate instructional learning materials. When extraneous or unnecessarily difficult material in an instruction is laborious, a learner’s cognitive processing serves in that way (Sweller, 2011). Secondly, essential processing is related to the complexity of a learning unit. In this process, learners’ background knowledge or prior knowledge of the learning unit is an influencing factor. Essential processing is directly related to the intrinsic cognitive load introduced by Sweller (2011). Thirdly, generative processing refers to activities of mental organization, representation, and integration of new information in working memory of the learners. The organization and integration are accomplished by the construction of schemas by applying prior knowledge to a new situation. This process can take place successfully only if learners really understand this new phenomenon and organize and integrate it into their schemas. Generative processing is directly related to Sweller's germane cognitive load (2011). The generative process and the essential process are the most essential cognitive processes for meaningful learning.

Learning can be defined in education as changes in behavior, thought or attitude with the introduction of new knowledge. There are two types of learning: remembering and understanding (Mayer, 2014). Remembering is the capability to reproduce or retain the demonstrated material. Understanding is the capability to use the presented material in novel situations. At the end of the multimedia learning process, three different learning outcomes may be expected: no learning, rote learning, and meaningful learning (Mayer, 2014). In the literature on multimedia learning, many researchers have used retention and transfer tests to measure learning performances (see for example, Chandler & Sweller, 1992; Craig et al., 2002; Kalyuga et al., 1999; Mousavi et al., 1995). A retention test is used for measuring learners' remembering ability in a learning context, while the transfer test is used for measuring learners' understanding in a learning context. According to Mayer (2005), the results of these tests are handled with regard to learning outcome and cognitive description, leading to the following three possible conclusions: the first possibility – if a learner's retention and transfer test scores are poor, there is no meaningful learning and there is no knowledge construction; the second possibility – if one's retention test score is good, but the transfer test score is poor, there is rote learning and fragmented knowledge construction. That is to say, a learner can remember learning content but cannot use it in a new situation. The third possibility – if one's retention and transfer test scores are good, there is meaningful learning and integrated knowledge construction.

2.2 Theories of multimedia learning

2.2.1 The cognitive theory of multimedia learning

Meaningful learning is provided when learners pay necessary attention to learning visual and verbal instructional material and integrate it with their existing knowledge by engaging in active cognitive processing (Mayer, 2009). CTML deals with how learning cognitive strategies relate to multimedia instructional practices. It claims that students can acquire knowledge more effectively when information is presented both auditorily and visually (Mayer & Anderson, 1992).

CTML is built on three main assumptions: (a) dual-channel assumption, (b) limited capacity assumption, and (c) active processing assumption. The dual-channel assumption asserts that human beings have separate channels for processing auditory-verbal represented materials and visual-pictorial represented materials. Verbal and visual representations are processed separately but simultaneously in working memory (Paivio, 1971). While the dual-channel assumption indicates that the human information-processing system consists of an auditory channel and a visual channel, the limited capacity assumption indicates that each of these channels is limited to processing information at one time (Baddeley & Hitch, 1974). The last assumption, active processing, asserts that meaningful learning may be observed under the following conditions (Mayer, 2005): if the learner is keenly engaged with the cognitive process of selecting words and images, organizing words into a verbal model and images into a pictorial model, and integrating the representation of new information with prior knowledge.

It is critical to figure out the relationship between learning and memory for multimedia learning. CTML aims to clarify the human information processing system. While doing this, the human memory comprises three memory stores; (a) sensory memory, (b) working memory (short-term memory), and (c) long-term memory. This representation originates from the assumption of the Atkinson-Shiffrin model, also known as the multi-store model (Atkinson & Shiffrin, 1968). The information from words and pictures of multimedia presentation enter the sensory memory with the help of the ears or eyes. Sensory memory briefly holds sensory copies of incoming words and pictures. Its capacity is unlimited but the duration is very brief (Mayer, 2014). After that, according to Mayer (2014, p. 54), "learners must engage in the following five cognitive processes:

- Selecting relevant words for processing in verbal working memory
- Selecting relevant images for processing in visual working memory
- Organizing selected words into a verbal model
- Organizing selected images into a pictorial model
- Integrating the verbal and pictorial representations with each other and with relevant prior knowledge activated from long-term memory."

Working memory allows for manipulating selected incoming information. Its capacity is limited and its duration is short (Mayer, 2014). It is entirely related to verbal and pictorial representations in learners' mind. Later, these representations are integrated with the prior knowledge of a learner, and they are converted into permanent organized knowledge in long-term memory; its capacity is unlimited and the duration is permanent (Mayer, 2014, p. 53). Figure 1 demonstrates a cognitive model of multimedia learning aimed to symbolize the human information-processing system.

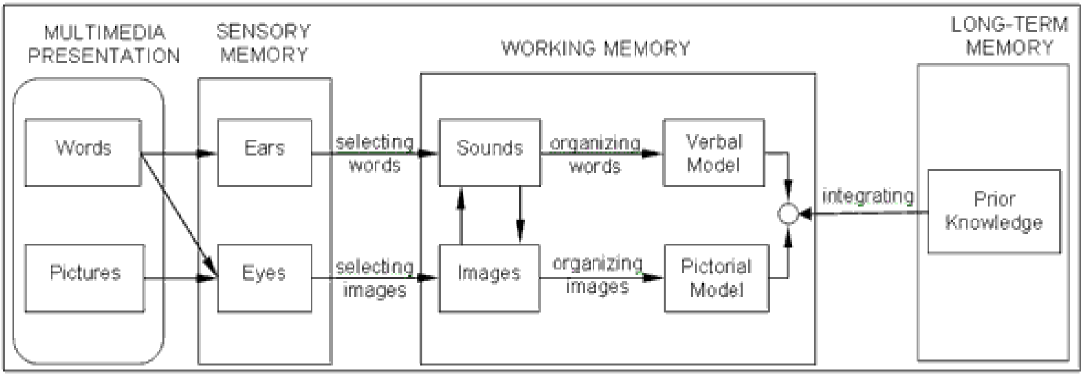

Figure 1 Cognitive theory of multimedia learning (Mayer, 2014, p. 52)

2.2.2 The cognitive load theory

Cognitive load theory (CLT) is one of the theories that accounts for how instructional design principles should be handled to construct the human cognitive architecture in a useful way (Sweller, 2011). In the context of this theory, human cognitive architecture may be explained by the relationship between working memory and long-term memory. According to Kalyuga, Ayres, Chandler, and Sweller (2003), long-term memory involves knowledge structures which have been organized by schemas to understand various problems or situations and to decide most proper solution acts. For the preparation of these schemas, working memory sources are needed. Automatic processing of schemas needs less working memory resources, namely, less effort, in problem solving situations with respect to controlled use of schemas (Kalyuga et al., 2003). These schemas can be built with automatic processing of schemas with the help of sufficient practice (Kotovsky, Hayes, &

Simon, 1985). CLT emphasizes mainly the function of working memory in the learning. Because the capacity and duration of working memory are very limited, when designing multimedia presentations for learners to practice, it may be helpful to consider Sweller's (2011) three types of cognitive load which are (1) intrinsic cognitive load, (3) extraneous cognitive load, and (3) germane cognitive load.

Firstly, intrinsic cognitive load refers to that all instructional topics have inherent complexities and difficulties (Chandler & Sweller, 1991). In addition to this, the complexity of a learning task specifies the intrinsic cognitive load (Corbalan, Kester, & van Merrienboer, 2008; Moreno & Mayer, 2010). This inherent difficulty cannot be eliminated by instructors or multimedia instruction developers, but if tasks of instruction are broken down into meaningful small parts, the cognitive load may decrease. On the other hand, extraneous cognitive load may result from improper multimedia instructions, if they are prepared by ignoring the limitation and capability of working memory on schema construction and automation of learner (Sweller, 2005). Extraneous cognitive load is under the wings of instructional designers and should be low during the learning process (Pollock et al., 2002). Unnecessary elements, procedures or applications of instruction should be eliminated by taking into account extraneous cognitive load. To reduce the effects of this load, many instructional techniques have been designed, such as the goal-free effect (Sweller, Mawer, & Ward, 1983) and the worked example effect (Renkl, 2005). Finally, while previous two types of cognitive load are concerned with characteristic of learning material and instruction, germane cognitive load is related only to characteristics of learners. This load is dedicated to construct and automate of learner's schemas. Meaningful learning is possible with effective schema construction and automation (Ayres & van Gog, 2009; Paas et al., 2003; Sweller, 2010). The determination of the proportion of working memory sources related to learning subject will be provided with the help of maximized germane cognitive load (Sweller, 2010).

2.3 Principles of multimedia learning

Powerful multimedia presentation should be designed by considering the principles of multimedia learning (Butcher, 2006). Empirical studies provide guidance for reducing extraneous processing in multimedia learning with the help of five principles of multimedia learning: coherence, redundancy, temporal contiguity, signaling, and spatial contiguity (Mayer, 2011). Intrinsic processing cannot be dependent on instructional designers' decision of including or excluding materials in designing a multimedia instruction, but it is necessary to manage with some multimedia learning principles, such as segmenting, pre-training, and modality (Mayer, 2011). To promote generative processing, Mayer (2011) suggested implementing four multimedia principles: generation, multimedia, personalization, and voice.

The coherence principle holds that learning is more effective when additional irrelevant and unneeded animations, pictures, words, and sounds are omitted rather than inserted into multimedia material. According to Mayer (2005) extraneous material, unrelated pictures, sounds, or words ought to be used minimally in multimedia presentations, because humankind has two types of information processing channels, visual and auditory, and each both channels have a limited capacity. “Interesting but irrelevant adjuncts,” namely pictures, words, animations and sounds, use working memory and divert resources away from relevant learning material (Harp & Mayer, 1998). Based on these assumptions, the elimination of irrelevant materials can reduce extraneous cognitive load.

According to the spatial contiguity principle, Learning is more effective when visual materials and written text are physically integrated rather than separated. It can be said that this principle originates from a split attention effect. Split-attention theory claims that learners may split their attention if learning materials such as text, diagrams, audio and pictures are physically or synchronically separated from each other. Chandler and Sweller (1992) claim that if diagrams are used in instructional materials with integrated form, learning will improve with respect to split form. On the other hand, meaningful physical or synchronic integration of these related learning material can reduce the load on working memory and facilitate learning possible. Spatial contiguity is related to only the physical integration of learning materials in multimedia learning. Mayer (2005) used the term “spatial contiguity” to distinguish it from temporal continuity.

The temporal contiguity principle indicates that when visual material and audial material such as spoken text are temporally synchronized rather than successively, people learn better. Mayer (2009) claimed that when learning materials are separated in time, learners have difficulty connecting words and pictures. For better learning, learners can connect audial and visual information in the learning process. These connections can be provided more easily in the case of processing visual and audial materials in working memory concurrently. According to Mayer’s CTML, referential connection between audial and visual information can be ensured more efficiently when audial and visual materials are temporally processed in working memory, after which they are taken into long-term memory (Mayer & Anderson, 1991). Some research (e.g., Mayer & Anderson, 1992; Mayer & Sims, 1994) has also showed that learners who study learning units with simultaneous presentations perform better on transfer tests than learners who study learning units with successive presentations.

The segmenting principle proposes that people are able to acquire information more effectively and easily from a learning material with the help of user-paced segments rather than system-paced segments. The main idea in this principle is to break down segments of the large learning unit into the smallest segments. Thus, the learners can probably manage crucial and essential processing of learning and avoid cognitively overloaded situations (Clark & Mayer, 2011). In the literature, a common way for applying the segmenting principle is that the learning material is broken down and pieced together by clicking the “CONTINUE” button in the frame of each small segment. This opportunity allows learners to study learning units at their own speed, neither too fast nor too slow. According to Ayres and Sweller (2005), this principle is very useful especially for less experienced learners, and when the learning subject is very complex.

The multimedia principle states that learning materials consisting of combined words and pictures rather than those consisting of words alone lead to better learning. Words and pictures in instructional materials may enable learners to integrate verbal and pictorial representation in their working memory. After that, learners can transform them to knowledge in long-term memory. If just words are used in an instructional material, learners may create their own images related to words. This may result in rote learning, especially for low-experienced learners (Mayer, 2011). When integrated related words and pictures are used in instructional material, Mayer (2005) claims that “students learn better through mentally organizing the material into a cognitive representation and mentally integrating the material with their existing knowledge” (p. 128). Many experimental studies were conducted using mechanical, physical, or biological systems in this context (e.g., Mayer, 1989; Mayer & Anderson, 1991; Mayer, 2002). They have usually shown that learners who study learning materials with meaningfully integrated words and pictures about learning subjects have better performance scores on transfer tests than those who study with learning materials which contained only words. On the other hand, when pictures are used in multimedia material, if words are presented in the form of written text, it may cause learners to split their attention on the visual process channel, and that result in cognitive overload (Chandler & Sweller, 1991).

Pre-training principle indicates that people learn better from a multimedia instruction when they are familiar to the names and characteristic of the main concepts. When learners' prior knowledge is absent from long-term memory, they have to distribute limited working memory to search for such information (Sweller, 2005). Thus, pre-training relevant knowledge to build coherent models will enable learners to effectively select and organize information for new learning (Mayer 2005). For this reason, key concepts of number sense are introduced first and then the exercises are presented.

Personalization principle claims that people learn better from multimedia instruction when words are in conversational style rather than formal style. The theoretical rational for this principle as presented by Mayer (2009) asserts that "when learners feel that the author is talking to them, they are more likely to see the author as a conversational partner, and therefore will try harder to make sense of what the author is saying" (p. 242). Kartal (2010) also states that "according to the personalization principle, people learn better from computerized multimedia materials when information is presented informal (personalized), rather than formal (non-personalized), style of language" (p. 616).

Generation principle asserts that people learn better from multimedia instruction when they generate words or drawings or self-explain during learning. Self-explanation can be introduced by asking learners to describe the presented material to themselves during learning process (Roy & Chi, 2005). Mayer (2009) states according to this principle "Another way to foster generative processing of a multimedia lesson is to ask learners to engage in learning activities that require deep processing of the presented material" (p. 100).

According to voice principle, people learn better when the narration in multimedia lesson is spoken in a friendly human voice rather than a machine voice or a non-native voice (Mayer, 2011). It supports a sense of social presence, hence human voice helps a learner feel a social response to the presented message. For this reason, narration in a multimedia instruction should be given with human voice rather than a machine voice, and this human voice should be in a friendly, standard accent.

2.3.1 The redundancy principle

The redundancy principle states that when one item of information is presented in various forms at the same time, redundancy occurs. Several studies (Kalyuga et al., 2004; Leahy et al., 2003; Mayer et al., 2001; Mousavi et al., 1995) showed that students acquire knowledge more effectively from multimedia instructions containing visual materials and narration than from those containing visual materials, narration, and written text. According to Kalyuga et al. (1999), using several different sources for giving the same information or message may cause a split-attention effect and result in no learning. Mayer and Johnson (2008) explain this situation as learners' inability to focus on the same verbal message presented as audial text and written text form at the same time. Although there is a common belief that using written and spoken text at the same time may enrich presentations, there are several potential handicaps related to it: learners may experience cognitive overload due to pictorial materials, written text can cause overload to the visual channel, and when learners try to focus only on written text, they probably pay less attention to the pictorial materials in a presentation (Clark & Mayer, 2011).

In 1999, Kalyuga, Chandler, and Sweller conducted an experiment for testing the redundancy effect. Participants of the study were 34 first-year trade apprentices and trainees. Researchers developed two versions of multimedia instruction in electrical engineering. One group of participants were randomly assigned to study with a multimedia presentation containing a printed diagram on the screen and an audio message with spoken words (non-redundant); other participants were randomly assigned to study with a multimedia presentation containing a printed diagram and printed text on the screen along with an audio message with spoken words that were identical to the printed words (redundant). After studying with presentations, students were tested with a problem-solving test. Analysis of test scores showed that the non-redundant group's test scores were significantly higher than those of the redundant group, and with a large effect size (1.38).

Leahy, Chandler, and Sweller (2003) examined the transfer test performance of 48 elementary school children who studied temperature graphs using a graph with printed text (non-redundant), and a graph with printed text and concurrent audio commentary (redundant). No time limit for studying the given materials was specified for the non-redundant group, whereas 185 seconds (audio time) for studying the materials was specified for redundant group. At the end of the research, a redundancy effect was observed with an effect size of 1.13, but this effect might be attributed to the differences between the study times of the two groups (Mayer, 2014).

Austin (2009) conducted 4 experiments to examine the redundancy effect with multimedia conditions consisting of animations about lightning. A total of 460 university students studied lightning by viewing a short animated narration or a short animated narration with corresponding text. The study concluded that the group that viewed the animated narration outperformed the group that viewed animated narration with text on a transfer test.

By contrast, the outcomes of some experiments did not confirm the redundancy principle. One such study was conducted by Moreno and Mayer (2002) with a game about botany. The participants were 89 college students who studied with the game, some parts of which were assigned to them randomly. Some of them viewed animations and listened a narration about botany explanations (non-redundant), and others viewed animation, listened to a narration about botany explanations and saw on-screen text about what the narration explained (redundant). All conditions lasted between 10 and 16 minutes, depending on the pace of the learner. The result of experiment indicated that, although the non-redundant group's test performance was better than redundant group's test performance, there was a small effect size (d = .19).

2.3.2 The signaling principle

"The signaling (or cueing) principle, refers to the findings that multimedia learning materials become more effective when cues are added to guide learners' attention to the relevant elements of the material or to highlight the organization of the material" (Mayer, 2014, p. 263). Generally, multimedia learning environments have many extraneous components. Thus, learners, especially low-experienced ones, usually have trouble eliminating and focusing on important parts, and also it may bring extraneous cognitive overload to them. For this situation, Mayer (2005; 2011) has suggested a possible solution to this problem; convenient highlighting, namely, signaling, may be used in a multimedia learning environment for attracting learners' attention to the essential aspects of learning units. For essential processing, learners may use their limited cognitive capacities with the help of this signaling. The signaling principle can be applied to written material, spoken material, and visual material such as animation, videos, graphics, diagrams, photographs or pictures.

Loman and Mayer (1983) have studied the effect of signaled expository passage with an experiment. The subjects of the study were 102,10thgrade students (ages 15-17) attending a public school. The experimental materials consisted of a non-signaled passage or signaled passage about the life cycle of sea organism. The non-signaled passage contained descriptions of facts about the cycle and causal explanations of the phenomenon. The signaled passage consisted of a preview of main phases of the cycle, headings for the cycle phases, and logical connectives such as, "the result is" or "because of this," in addition to the non-signaled passages. Outcomes of the study showed that, whereas the signaling groups significantly outperformed the others on a recall test which required conceptual knowledge on high quality problem solutions, the non-signaling groups outperformed the others on a recall test which required conceptual knowledge on low quality problem solutions.

The signaling effect with a cause-and-effect system setting was examined by Mayer, Dyck and Cook (1984). Two experiments were conducted with 94 college students. In the first experiment, the researchers gave two types of learning materials: two sheets of paper with underpinning of the key variables about density and nonunderpinning. In the second experiment, the researchers also gave two types of learning materials as in the first experiment, but the learning unit was about the nitrogen cycle. From both experiments, they found out that signaling tended to enhance recall of conceptual information directly related to the cause-and-effect system, and to enhance problem solving performance.

Another study about signaling effect took a different perspective; Mautone and Mayer (2001) examined the effect of signaling with not only written text, but also narration and animation via three different experiments. In the first, 48 college students were assigned to either a signaled text group (n=23) or a non-signaled text group (n=25). They used two different single passages about airplane mechanics, signaled and non-signaled. In the signaled passage, critical words and characteristics of airplane mechanics were given in bold characters. The first experiment showed that signaling had no positive effect on retention scores, whereas it had a positive effect on transfer scores. In the second experiment, 48 college students were grouped as signaled speech group (n=24) or non-signaled speech group (n=24). The subject matter was the same as the first experiment, airplane mechanics. However, signaled or non-signaled spoken text tracks containing the same words as the corresponding written texts were used in this experiment. For emphasizing critical words and phenomenon in the signaled speech, texts were read more slowly and with deep intonation. The duration of the signaled speech was 4 minutes and 16 seconds, and the non-signaled speech was 3 minutes and 12 seconds. At the end of this experiment, the positive effect of signaling was observed on the retention and transfer scores. In the third experiment, college students studied using the same materials and apparatus as in experiments 1 and 2 that were synchronized to correspond with each other; signaled speech and signaled animation group (n=26), signaled speech and non-signaled animation group (n=18), non-signaled speech and signaled animation group (n=22), and non-signaled speech and non-signaled animation group (n=20). The last experiment showed that signaling for animation and narration did not have a significant effect on students' retention and transfer scores.

The meaning of signaling in multimedia knowledge representation was examined by Jamet, Govota, and Quaireau (2008). Two types of signaling, color change and stepwise presentation elements, were used with auditory explanations about the encephalic base of language construction to test the signaling principle. Undergraduate students (n=112) were randomly assigned to study learning materials with 4 different display conditions: static and non-signaled, static and signaled, sequential and non-signaled, and sequential and signaled. Static meant all images presented from beginning to end, ignoring spoken explanations, and sequential meant images synchronously presented with spoken explanations. Red was used for emphasizing important parts of presentations. In the non-salient versions, the images were always presented in gray. The study showed that the signaling groups did not outperform the non-signaling groups on the transfer test. This result contradicted the investigated claims of the signaling principle.

User reactions to signaling was investigated more closely with the evidence from eye movement experiments (Ozcelik, Arslan-Ari & Cagiltay, 2010). Forty undergraduate students participated in the experiment, where the researchers developed two different 91-second narration and illustration instructions in Turkish about how turbofan jet engines work. In the signaled version of the instruction, they presented terminological labels in the illustration using red when the item was voiced. Following the narration, the label was converted to black. On the other hand, label color was only black color in the non-signaled version. The analyses of data showed that the group which studied with the signaled material outperformed the group that studied with non-signaled material on matching and transfer tests. The researchers also collected eye movement data. Analysis of this data showed that signaling guided students to essential and relevant information, whereas the non-signaling group students usually ignored them.

2.3.3 The modality principle

The modality principle indicates that learning is more effective when visual materials and spoken text rather than visual materials and written text are presented. The multimedia principle generally maintains that if words and pictures are used together, meaningful learning occurs. On the other hand, the modality principle emphasizes that visual materials, especially animations, should be used with words formed in audial type instead of written type by taking into consideration the dual-channel assumption. In this way, it is possible to avoid extraneous cognitive load for learners. One may argue that there are three important points about the effects of this principle in the literature. Firstly, it can only show its effect under a system-control condition, and it may disappear under a learner-control condition (Ginns, 2005). Secondly, it is more effective when the important portions of an animation are signaled (Jeung, Chandler & Sweller, 1997). Thirdly, it is most effective when words used in a spoken-text are familiar to the learners (Harskamp, Mayer & Suhre, 2007). Additionally, it can be noted that claim of this principle has not been tested thoroughly in classroom settings using whole learning units with young children, and it has been tested usually in short implementations with adults and older students.

Mayer and Moreno (1999) examined how the spatial contiguity of text with animations and modality effect on learning, and which text presentation (audio or on-screen) is more effective. They conducted two experiments. In the first experiment, the participants were 132 college students. There were three different computer programs about the lightning process; all programs had the same 180-second animation about the subject, but first one had narration and the second had written text separated from the animation, and the third had written text integrated to describe each of the major events. Forty-one participants studied with material consisting of animation and narration (N group), 41 studied with material consisting of animation and integrated text (IT group), and 40 participants studied with material consisting of animation and separated text (ST group). The N group got considerably higher scores than the other groups on the recall test, with a high effect size (d = 1.00), on a problem-solving test with a high effect size (d = 1.06), and on a matching test with a high effect size (d = 1.32) for modality. In the second experiment, there were 118 participants. The researchers developed six types of computer programs to test the modality principle. Each program consisted of the same animation lasting 180 seconds about the processes of lightning. The differences between the animations of the versions were that the first had concurrent narration, the second had concurrent written text, the third had following narration, the fourth had followed narration, the fifth had following written text, and the sixth had followed written text. Twenty participants studied with concurrent narration and animation (NN group), 20 participants studied with concurrent text and animation (TT group), 18 participants studied with narration following animation (AN group), 20 participants studied with animation following narration (NA group), 20 participants studied with animation following text (TA group), and 20 participants studied with a material consist of text following narration (AT group). Overall outcomes indicated that all narration groups outperformed text groups in matching, retention, and transfer tests. Thus, modality effects were observed.

Another important study about the modality principle was conducted by Harskamp, Mayer, and Suhre (2007). The important aspect of the study is that it was applied in a science lesson in a school setting. The researchers carried out two experiments. In the first experiment, participants were 27 students in a Dutch secondary school (aged 16-17). The researchers used two types of modality in their lesson about animal behavior: an illustration and written text lesson and an illustration and narration lesson. In the illustrations, concrete concepts about animal behavior were used. The presentation time of the illustration pictures were the same in each version. Illustrations were separated into stages and users had the opportunity to decide on the next topic in both versions. Thirteen participants studied with material consisting of illustration and narration, and 14 participants studied with material consisting of illustration and text. After analysis of the participants' post-test scores, it was determined that the performance of the illustrations and narration group was greater than that of the illustrations and text group, yielding a high effect size (d = .80). In the second experiment, participants were 55 students in a Dutch secondary school (aged 16-17). This experiment was different from the first experiment in terms of the opportunity to repeat and the availability of self-study timing. Twenty-seven participants studied with material consisting of illustration and narration, and 28 studied with material consisting of illustration and text about animal behavior. Each group was divided into two sub-groups (fast-slow). A 2x2 between subjects ANOVA test revealed that while modality was observed for slow learners, it was not observed for fast learners.

In a study by Schüler, Scheiter, and Gerjets (2013), there were two different experiments for testing modality. In the first experiment, each one of four system-paced computer programs — (1) only spoken text, (2) only written text, (3) spoken text with animation, and (4) written text with animation about the phases of mitosis —was randomly given to 64 university students to study. All versions lasted 251 seconds. Students were tested individually. Analysis of students' recall and transfer test scores revealed that, although the multimedia principle was confirmed, the modality effect was not strongly evident in this setting, yielding a very small effect size (*d* = .04). The researchers attributed the result to presentation of longer text segments. In the second experiment, they tested the effect of learner-paced and system-paced settings on the modality effect. In the experiment, the researchers designed six multimedia conditions: (a) spoken text with system-paced animation, (b) spoken text with learner-paced animation, (c) written text with system-paced animation, (d) written text with learner-paced animation, (e) both spoken and written text for same explanation with system-paced animation, and (f) both spoken and written text for the same explanation with learner-paced animation about the phases of mitosis. Each one of them was randomly given to university students (n=122) to study. The system-paced versions lasted 251 seconds. The learner-paced versions had a forward button and a back button for moving between the phases of animations. A redundancy effect was observed with the system paced animations. Nevertheless, the researchers reported that there was only a small modality effect with the system and learner-paced presentations (*d* = .29).

Witteman and Segers (2009) examined the modality effect with 80 6th grade children (10.8 to 13.3 years old) in a public elementary school in Rotterdam, the Netherlands. They used computer-based learning material adapted from the work of

Mayer (2001) about the formation of lightning. The material was translated into Dutch and re-arranged for the children without changing the content. The study showed that, while the modality effect was observed after an immediate retention test, it was not observed at the second and third testing occasions.

The other study about the modality principle was conducted by Cheon, Crooks, and Chung (2013). They gathered data from undergraduate students (n=96) who were assigned to one of four experimental conditions about the formation of lightning: (a) spoken text and active pause, (b) spoken text and passive pause, (c) written text and active pause, and (d) written text and passive pause. All of the conditions had animations lasting 160 seconds. However, the active pause condition involved four pauses in the animation, and two questions were presented to students during each pause. The passive pause condition had no question during the animation. The results of the study showed that there were no significant effects of segmentation and modality although all test scores of the spoken-text groups were greater than all test scores of the written-text groups, yielding a small effect size (d = .08).

One of the most comprehensive meta-analysis studies on the modality effect was conducted by Ginns (2005). In this study, outcomes of 43 experiments from the performance of 1,887 participants were analyzed. The meta-analysis demonstrated that participants who studied with a multimedia condition which contained graphics and spoken text outperformed those who studied with a multimedia condition which contained graphics and written text. The remarkable point of this study is that the modality effect was tested with adults in 33 experiments, with high-school students in six experiments, and with primary-school students in four experiments. There are a few studies about the modality effect that focused on children in primary and middle school. This lack showed a research gap on modality effect, in 2005, and such gap has not been filled yet.

2.4 Abstract versus concrete representation

School science has many abstract concepts which are generally very difficult to understand. Thus, students may learn these concepts in an inaccurately and incompletely (Nicoll, 2001). For example, the concept of electricity may cause learners to develop many misconceptions about circuit elements, current, power and potential difference (Lee & Law, 2001; Engelhardt & Beichner, 2004). In this context, there is an ongoing discussion about which type of representation, abstract or concrete, is more beneficial in science education, particularly in learning about electricity.

Concrete visualization is very popular for teaching abstract concepts in schools. Some researchers (e.g., Dori et al., 2003) claimed that if abstract concepts of science are presented in a concrete way, students can understand these concepts more easily and the probability of the occurrence of active learning is higher. In a study by Jaakkola et al. (2014) with fifth and sixth graders showed that learning about electricity with concrete simulation components (e.g., light bulbs and battery) resulted in better learning compared to learning with abstract components (e.g., zigzag sign for resistors). On the other hand, there are some studies with counter argument in the literature. The researchers of those studies (e.g., Moreno, Ozogul & Reisslein, 2011; Johnson, Reisslein & Reisslein, 2014) examined abstract and concrete representations of electrical circuits, using engineering symbols and everyday circuit elements.

Moreno et al. (2011) analyzed the consequences of using abstract and concrete visual representations of electric circuit. The participants were tested in terms of learning perceptions, problem representations, and problem solving with 3 experiments. The first experimental condition was studied with 71 high school students (mean age 13.73), the second experiment with 128 high school students (mean age 15.43), and third experiment with 96 college students (mean age 25.70). Four different groups were formed: (1) an abstract diagram group, (2) a concrete diagram group, (3) an abstract and concrete diagrams group, and (4) a concrete cover story and abstract diagrams group. Analysis of the study data showed that group 3 performed better than both group 1 and group 2 on the problem-solving test, and outperformed group 2 and group 4 on the transfer test. Group 1 had notably better score than group 2, and group 4 on the transfer test. Another study on circuit representation was conducted with 162 undergraduate non-engineering students by Johnson et al. (2014). Results showed that abstract representation led to higher immediate and delayed transfer post-test scores. These two studies claimed that abstract representations result in better learning compared to concrete representations (Moreno et al., 2011; Johnson et al., 2014).

Concretization of an abstract concept often needs additional relevant information or materials. However, if this information or material is irrelevant to the concept in question, it may bring an extra complexity to a learning process. Contextualized details of concrete images alter learners' attention from the essential points of a learning concept. Some recent empirical evidence (e.g., Jaakkola & Veermans, 2014) supports this view in its claim that abstract representations usually provide better learning outcomes in science education compared to concrete representations. This negative assertion for concrete representations is probably observed more in inexperienced students taking an extensive amount of detail and limited cognitive capacity of human into account.

From another perspective, which representation type, concrete or abstract, is the more appropriate for younger students is still unclear. Only a few studies have been carried out with primary and secondary school students; many studies were done with adults and college students (Jaakkola & Veermans, 2014). Children under twelve years old are more adaptive to concrete operations in the problem solving process and they may be more focused in the learning process when the learning materials are presented concretely (Moyer, 2001). On the contrary, some studies (e.g., Kaminski, Sloutsky & Heckler, 2006) reported that children are not in need of concrete representation to understand abstract concepts as much as the older students are.

There is some research which examined different types of representation (concrete-contextualized, abstract, and mixed abstract-concrete) about science and mathematics units with middle school students. Some researchers (e.g., Ball, 1992; Moyer, 2001) claim that "children under the age of twelve are in the concrete operational stage of development in which thinking and problem solving are bound to the concrete representation." In contrast, other researchers (e.g., Kaminski, Sloutsky, & Heckler, 2006) asserted after a study with nineteen 6^{th} grade students (mean age = 11.8) that concrete representation is not essential for children to comprehend abstract concepts. On the other hand, Jaakkola and Vermans (2014) studied that how abstract and concrete simulation components affect learning in an electricity unit. The participants were 52 primary school students (11-12 years old). The analysis showed that concrete elements provide a better opportunity to understand electric circuits. A different study approach for "contextualized versus abstract representation" was conducted by Johnson, Reisslein, and Reisslein (2014). The study compared four sequences of representation (abstract-abstract, contextualized-contextualized, contextualized-abstract, or abstract-contextualized). They studied 343 middle school students (mean age = 12.7) in the southwestern United States. Participants had no prior knowledge about electrical circuits. The study showed that contextualized representations after abstract representations for the same items are more beneficial to students in near and far post tests.

2.5 Problems emerging from the literature review

An overview of the literature reveals many experimental studies about all principles of multimedia learning. Although there is much supporting empirical data for the principles, there are still some important criticisms about them.

According to Ginns (2005), realistic educational settings can be explained as class-based experiment in authentic classroom settings. Some researchers claimed that the principles tested in CTML studies were usually tested with unrealistic and narrow settings (Ballantyne, 2008). Similarly, Harskamp, Mayer, and Suhre (2007) pointed out some important criticisms, including a lack of experimental studies about the modality principle based on authentic classroom environment, although many of the studies were performed by Mayer and his colleagues. Criticisms about some other principles are that their effect on children's learning is not known. There were only a few studies concentrated on primary school students. Ginns (2005, 2006) performed two meta-analysis studies with almost 50 and 43 independent studies for closely examining modality and contiguity. He found only five studies investigating effects of the principles on primary school children. Mayer (2011) also pointed out the need for more research about the principles in realistic learning environments, needing to clarify the boundary conditions of the principles, to test these principles with computer-based environments, simulations, animations, and games. Nevertheless, most of the research about the principles tested with learning material was in English. There are a few experimental studies with children conducted by Harskamp, Mayer, and Suhre (2007), and Witteman and Segers (2010) in Dutch. There are some studies performed by Türk (2007) and Kozan (2009) in Turkey but both used learning materials in English. There are very few studies that examined the principles in Turkish (e.g., Kartal, 2010). This study examined the personalization principles with college students.

The other criticism of those studies is about the subject matter of studies. Gall (2004) asserted that these principles may not be observed in an immersive learning environment because they were mostly examined with a cause-and-effect system such as the understanding of physical and mechanical systems. Another important deficiency is that there is no experimental study investigating how the signaling of written text affect redundancy effect in a multimedia condition.

The other controversial issue in the literature is the nature of type of representations of animation, abstract or concrete, for better learning. Although there are some experimental studies which support the use of concrete representation for adult learners, some researchers argued that children are not in need of concrete representation to comprehend abstract concepts as older ones. (Kaminski, Sloutsky & Heckler, 2006).

Taking all these reasons into consideration, this study aims to examine the effects of modality, redundancy, and signaling effect in abstract and concrete representation of multimedia learning of electricity units in real middle school settings in Turkey. The study aimed to answer following seven research questions:

1. Do abstract and concrete representations of animations with the following five different text representations affect differently middle school students' learning of an electricity unit?
   - written text representations
   - signaled written text representations
   - spoken text representations
   - written text and spoken text representations
   - signaled written text and spoken text representations
2. Does the modality effect in a multimedia setting with abstract or concrete representation of animation hold true for middle school students' learning of an electricity unit?
3. Do the effects of spoken text modality and signaled written text modality on an electricity unit achievement differ in a multimedia setting with abstract or concrete representation of animation?
4. Does the redundancy effect in a multimedia setting with abstract or concrete representation of animation hold true for middle school students' learning of an electricity unit?
5. Do the effects of spoken text modality, and signaled written text and spoken text modality on an electricity unit achievement differ in a multimedia setting with abstract or concrete representation of animation?
6. Does the signaling effect in a multimedia setting with abstract or concrete representation of animation hold true for middle school students' learning of an electricity unit?

7. Do the effects of written text and spoken text modality, and signaled written text and spoken text modality on an electricity unit achievement differ in a multimedia setting with abstract or concrete representation of animation?

CHAPTER 3

METHODOLOGY

This chapter presents the methods and procedures followed in the current study. The chapter consists of the following sections: (1) research design, (2) sampling and participants, (3) treatments, (4) instruments, and (5) data collection procedure.

3.1 Research design

The current study was conducted with a pre-test and post-test quasi-experimental design. Participants of the study were not randomly assigned to the treatment groups. The independent variables of the study were multimedia conditions designed to teach an electricity learning unit in a middle school science course, science grades of students, and pre-test scores of students. The dependent variable of the study is students' achievement scores in the electricity unit. The difference between post-test scores and pre-test scores gives their achievement scores. Table 1 displays the study variables.

Table 1. Variables of the Study

Independent variables			Dependent variables
Multimedia conditions		Prior knowledge	Achievement in conceptual knowledge of the learning unit
Text type	Animation type		
Written	Abstract		
	Concrete	Science course	
Signaled	Abstract		Achievement in procedural knowledge of the learning unit
	Concrete		
Spoken	Abstract		
	Concrete		
Written+spoken	Abstract		
	Concrete	Electricity unit	Total achievement in the learning unit
Signaled written+spoken	Abstract		
	Concrete		

3.2 Sampling and participants

The target population of the study was fifth and sixth grade public middle school students in Turkey. The method of sampling was convenience sampling because there was no chance to access participants randomly. The research was conducted in the schools accessed with the help of computer teachers working in several schools in four different cities. For selection of the participants, the main criterion was that students should not have studied electricity unit before the experiment. Principals of schools and students' parents were informed about the aim of the research (see Appendix A), and the students were free to participate in the research or not. Data were collected from 855 students of 34 classes in four public middle schools in Balıkesir, Batman, Mersin, and Van (see Table 2). Twenty-nine students who did not have pre-test and post-test scores were dropped from the study.

Table 2. Participants of the Study

City	5th graders		6th graders		5th + 6th graders		
	Female	Male	Female	Male	Female	Male	Female + Male
Balıkesir	-	-	31	25	31	25	56
Batman	40	59	57	34	97	93	190
Mersin	164	181	-	-	164	181	345
Van	69	75	57	63	126	138	261
Total	273	315	145	122	418	477	855

Ten classes from each school in Batman, Mersin, and Van were selected to assign 10 multimedia conditions. It was found that the student numbers of 4 multimedia conditions were less than the student numbers of other 6 multimedia conditions. For this reason, 4 classes from Balıkesir were included in the study. Thus, the number of students studied with each multimedia condition was almost the same.

3.3 Treatments

In the study, there were 10 different types of multimedia conditions prepared by the researchers using Articulate Storyline 2 for answering the research questions of the study. These conditions aimed to access the same 19 learning objectives about electricity. During the preparation of the conditions, two middle school science teachers and two science learning researchers checked validity and effectiveness of the learning material. They made necessary changes and improvements. And also, they determined important concepts for electricity to be highlighted in signaled written text information. The learning objectives of the multimedia instruction were based on middle school science curriculum of the Turkish Ministry of Education for the sixth grade level electricity unit. They are given in Appendix B. They were introduced with their abbreviation (see Table 3). The instruction language in all multimedia conditions was Turkish, and the text in all multimedia conditions subsumed 82 sentences and 715 words. Audition and visibility time of textual information was a total of 6 minutes and 7 seconds.

Table 3. Treatment Conditions of the Study and Their Abbreviation

Multimedia condition	Abbreviation
Written text and abstract animation	W-A
Written text and concrete animation	W-C
Signaled written text and abstract animation	Sg-A
Signaled written text and concrete animation	Sg-C
Spoken text and abstract animation	Sp-A
Spoken text and concrete animation	Sp-C
Written text + spoken text and abstract animation	W+Sp-A
Written text+ spoken text and concrete animation	W+Sp-C
Signaled written + spoken text and abstract animation	Sg+Sp-A
Signaled written + spoken text and concrete animation	Sg+Sp-C

In the multimedia courseware, all conditions presented 24 screens with the inclusion of animations and text representations related to these objectives. Six introduction scenario screens and three task description screens of all conditions were the same in terms of animation representation, but they were different in terms of text representation. The text representation was prepared according to multimedia conditions. Each condition was divided into 15 segments. Each segment aimed to access one or two learning objectives, and lasted 10-30 seconds. They consisted of animation and textual information about electrical events. Students could see each segment only once. Transitions between the segments were provided by a mouse click when the users felt ready for new task. The researcher created the scenario of the courseware by considering participants' age and their background knowledge to attract their attention to learning materials. Treatment groups were determined according to the existing classes of the students in their schools. Treatment groups were assigned to multimedia conditions randomly. Students could access their assigned condition with the number of task areas given to observer teachers. Students had to click the task area indicated by the teacher to access the assigned multimedia condition (see Figure 2).

Figure 2 Task area selection screen of for all conditions

After the selection of task area, users had to enter the password of this area (see Figure 3). Passwords for each task area were unique and students in each treatment group had only one password.

Figure 3 Password entrance screen

After the entrance screen, if students selected the correct task area and entered the correct password, they were able to access the assigned multimedia condition to study the electricity unit. However, if they selected an incorrect task area or entered an incorrect password for the area, they were unable to access the assigned multimedia condition and received a warning screen. Specific characteristics of each condition will be provided in the titles under which these conditions are explained.

3.3.1 Written text with abstract animation (W-A) condition

In the W-A condition, textual information about electrical phenomena was presented in written form. Some of them were given in speech bubbles and others were given in message boxes. On the other hand, animations of the condition consisted of abstract components of electricity, for example, a zigzag sign for resistor, a cross in a circle sign for light bulbs, and the letter “A” in a circle for ammeter. Electrical events, for example, the current motion of an electric circuit from the positive pole to the negative pole of a battery sign was animated with scrolling dashed lines for about 10 seconds. Message boxes and speech bubbles were physically integrated into the animation in reference to the spatial contiguity principle of multimedia learning. Written textual information and abstract animation aimed to explain and demonstrate the electrical situation synchronously by considering the temporal contiguity principle of multimedia learning (see Figure 4).

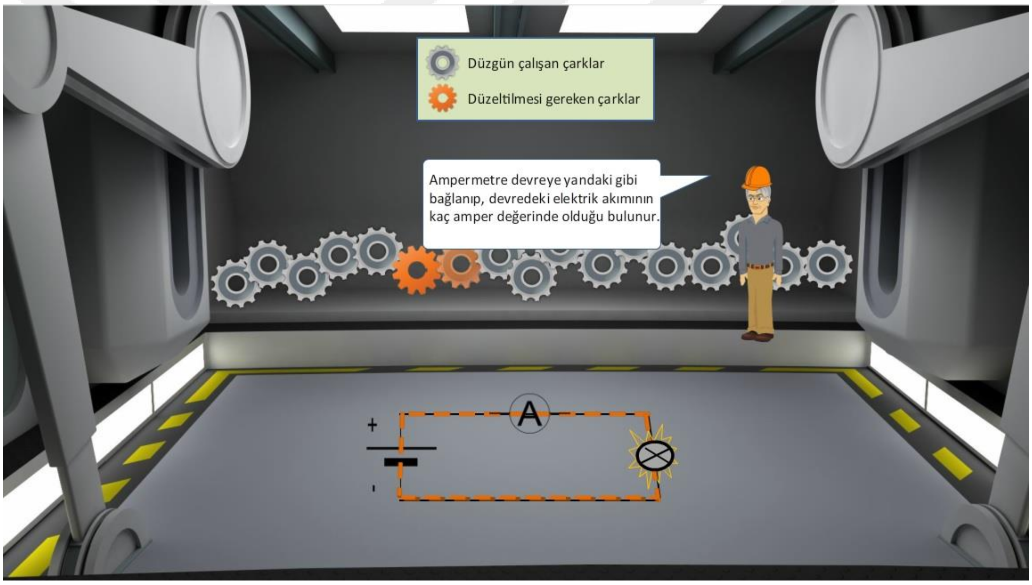

Figure 4 W-A condition screen

3.3.2 Written text with concrete animation (W-C) condition

In the W-C condition, textual information about an electrical event was also presented in written form, either in speech bubbles or message boxes as in the W-A condition. However, the main difference between the W-A and W-C conditions was that, while animations of the W-A condition consisted of abstract components about electricity, the W-C condition consisted of concrete components about electricity, such as pictures of batteries, light bulbs, and ammeters. For example, the animation of this segment showed how the agent connected an ampere meter to an electric circuit to measure electrical current (see Figure 5).

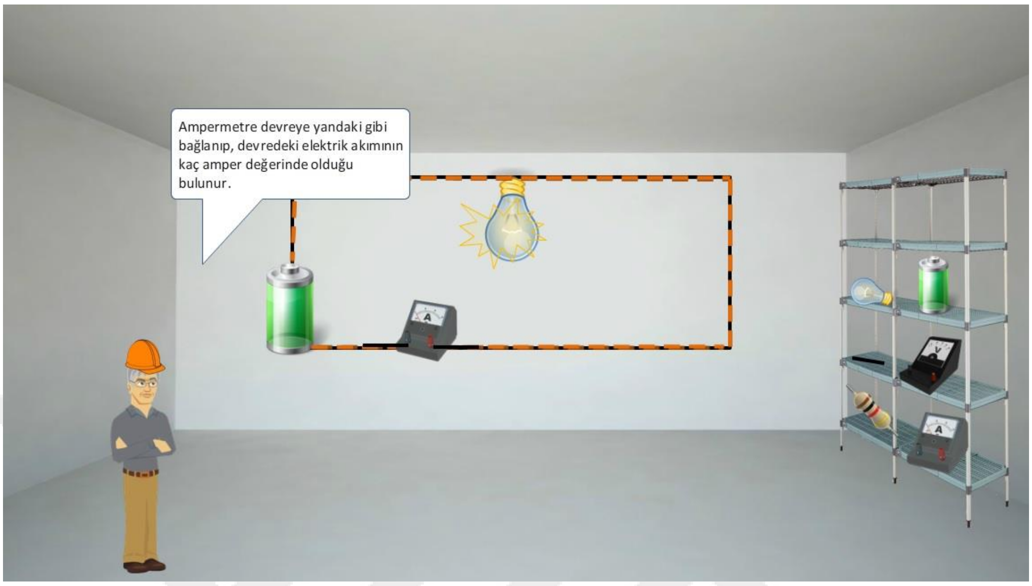

Figure 5 W-C condition screen

3.3.3 Signaled written text with abstract animation (Sg-A) condition

In the Sg-A condition, written text was used to give information about an electrical event as in the W-A and W-C conditions. The main difference was that keywords, elements, and concepts were highlighted in bold letters in this condition. A total of 118 of 715 words were bolded. Some of the bolded concepts were grounding, neutral body, ammeter, and voltage. On the other hand, animations of this condition were not different from the animations of the W-A condition. In other words, abstract components were used in animation representations. For example, the animation of a segment demonstrated that negative signs moved from the grounding sign to a sphere until negative and positive signs became equal to demonstrate grounding process (see Figure 6).

Figure 6 Sg-A condition screen

3.3.4 Signaled written text with concrete animation (Sg-C) condition

The Sg-C condition consisted of signaled written text as in the Sg-A condition, but it differs from the Sg-A condition in terms of animation representation. The animation in this condition consisted of concrete components as in the W-C condition. For example, in the grounding process, a soil picture was used instead of a grounding sign. In this condition, the animation of this segment showed that negative charges moved the balloon from the soil until the number of negative and positive charges were equal (see Figure 7).

Figure 7 Sg-C condition screen

3.3.5 Spoken text with abstract animation (Sp-A) condition

The Sp-A condition contained spoken texts to explain an electrical phenomenon. The same text as in the other conditions was used. However, while textual information was in written form in the other conditions, textual information was in narrative form in this condition. A male voice was used in the narration, in line with the gender of the agent in the courseware, and all events in words were spoken at a slow rate to accommodate the target population of the study. The animations were the same as other abstract conditions, and the narration period was the same as the time period of the written text in the other conditions (see Figure 8).

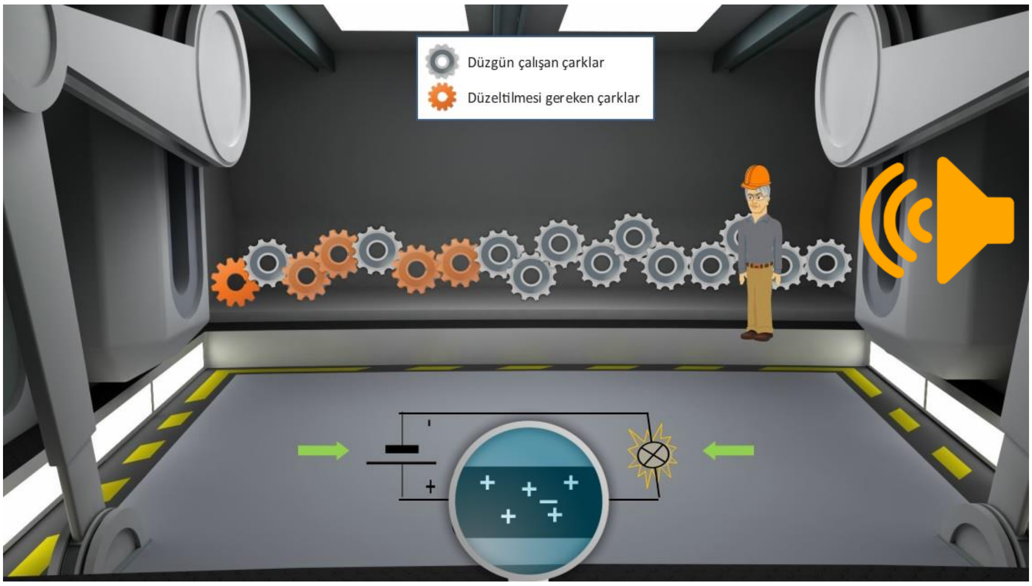

Figure 8 Sp-A condition screen

3.3.6 Spoken text with concrete animation (Sp-C) condition

The Sp-C condition contained the same spoken text as the Sp-A condition. The only difference between the two was the representation of animation components. The Sp-C condition used the same concrete components as the W-C and Sg-C conditions For example, the animation of this segment showed the movement of the negative charges on the electric circuit with a huge magnifying glass held by the agent (see Figure 9).

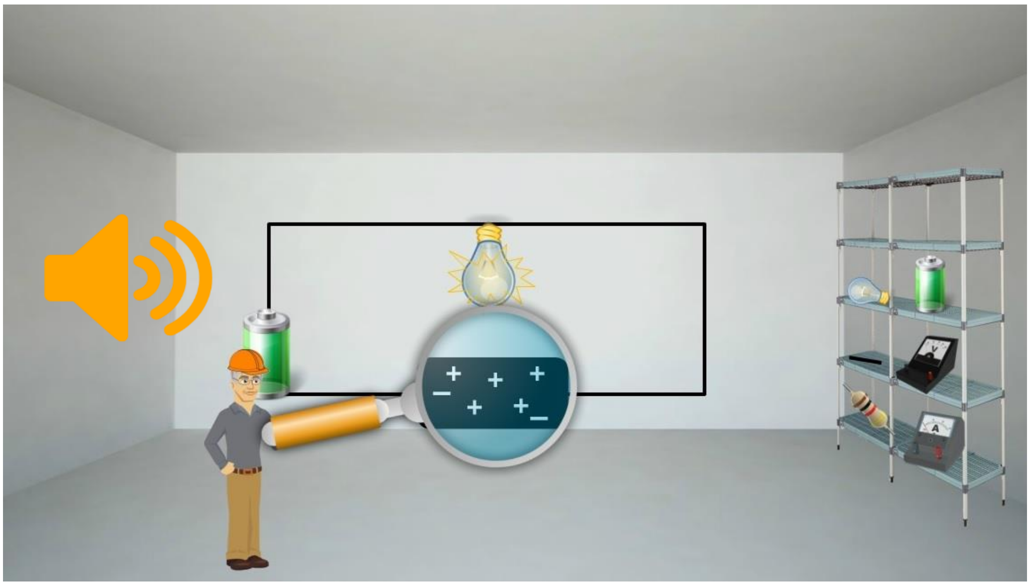

Figure 9 Sp-C condition screen

3.3.7 Written and spoken text with abstract animation (W+Sp-A) condition

The W+Sp-A condition is one of the four redundancy mode conditions of the study. Written text and spoken text were synchronously presented to give information about an electrical event. The written text was the same as the ones used in all written text conditions, and spoken text was the same as the ones used in all spoken text conditions. Its animation type consisted of abstract components, as in all abstract conditions. For example, Figure 10 presents an animation screen shot from the W+Sp-A condition: the electrical circuit is carried to examination machine by a carrier. After that, a huge magnifying glass presents the relationship between current, resistance and the tension for almost 15 seconds.

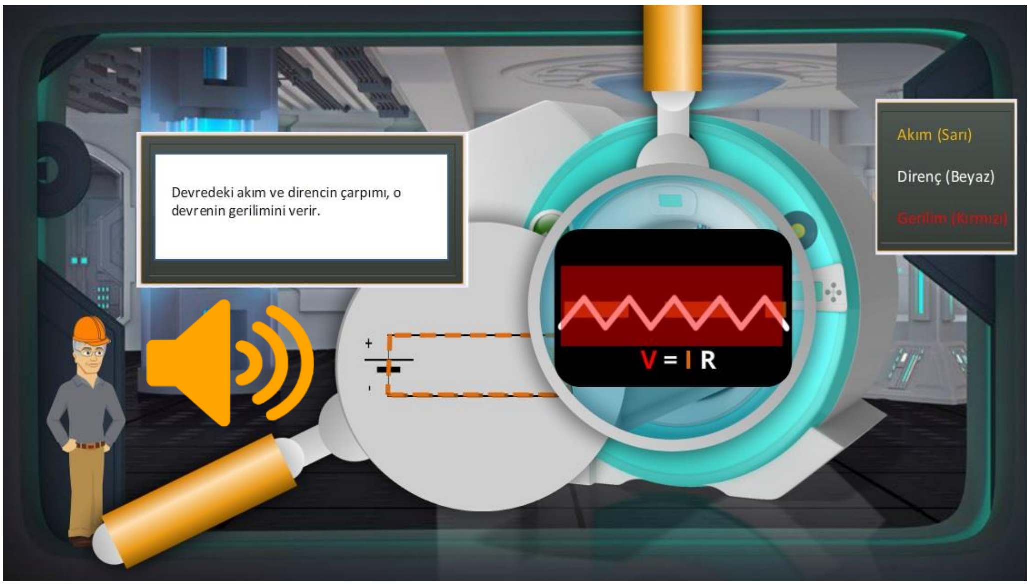

Figure 10 W+Sp-A condition screen

3.3.8 Written and spoken text with concrete animation (W+Sp-C) condition

The W+Sp-C condition was almost the same as the W+Sp-A condition except that this condition contained concrete components instead of abstract components in animations (see Figure 11).

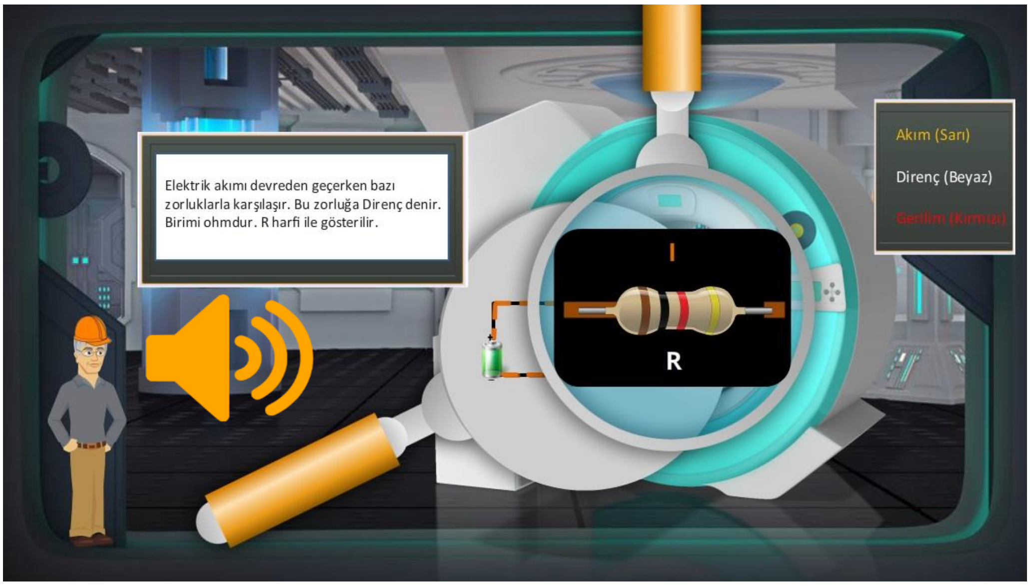

Figure 11 W+Sp-C condition screen

3.3.9 Signaled written and spoken text with abstract animation (Sg+Sp-A) condition

The Sg+Sp-A condition is another redundancy condition of multimedia instruction. Instead of written text in the W+Sp-A, signaled written texts were used in this condition. A total of 118 of 715 words were bolded. This condition helped investigate how redundancy mode with signaling mode would help learning compared to learning in non-redundant mode of courseware (see Figure 12).

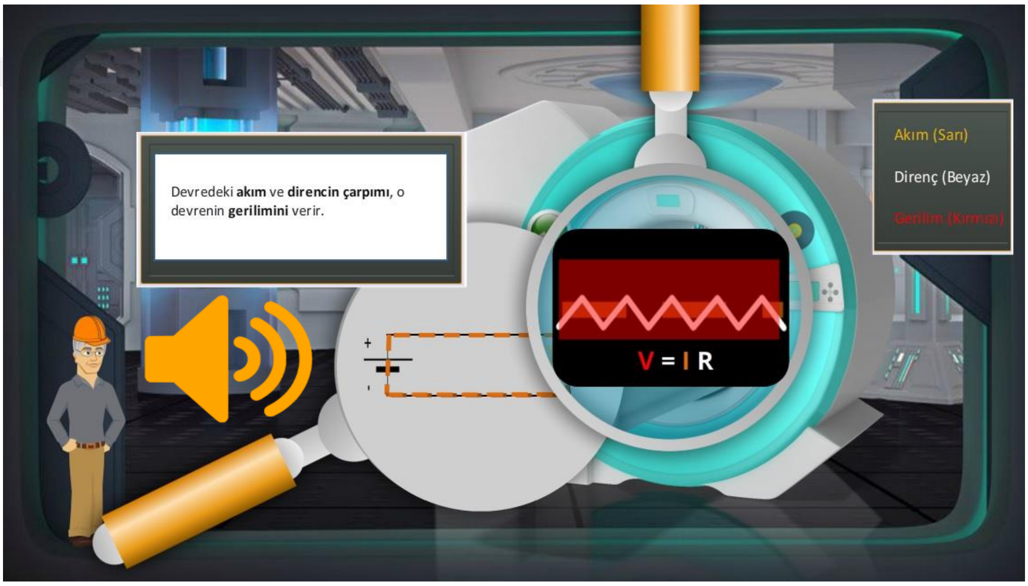

Figure 12 Sg+Sp-A condition screen

3.3.10 Signaled written and spoken text with concrete animation (Sg+Sp-C) condition

The Sg+Sp-C condition is the concrete animation version of the Sg+Sp-A (see Figure 13). This condition also helps to investigate, how redundancy mode with signaling mode will help learning in comparison to learning in non-redundant mode of courseware consisting of concrete animation.

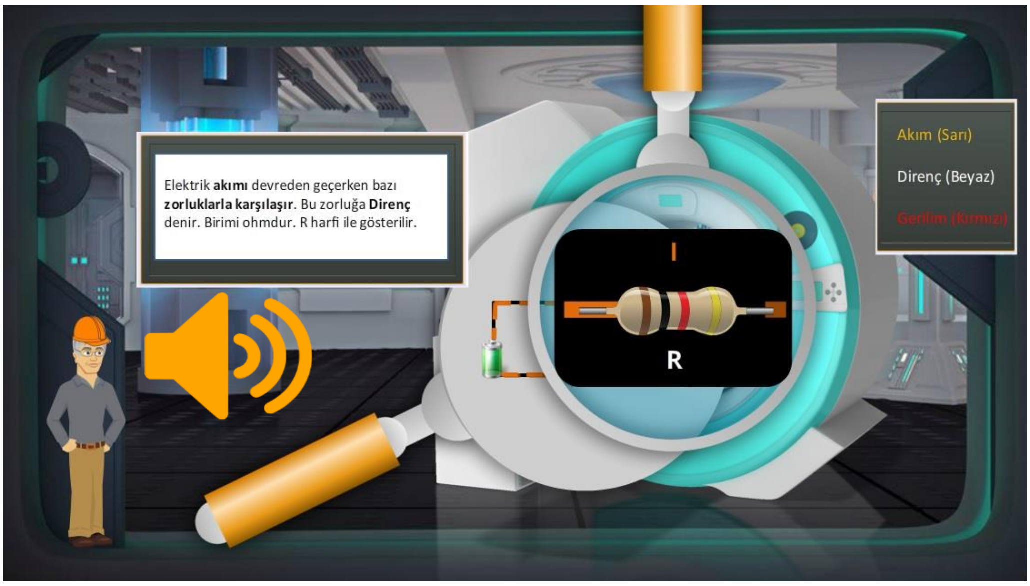

Figure 13 Sg+Sp-C condition screen

3.4 Instruments

In the study, two sets of data collection instruments were used: (1) a pre-test (see Appendix C) and (2) a post-test (see Appendix D). While the aim of the pre-test was to measure students' prior knowledge of electricity, the aim of the post-test was to measure students' electricity knowledge after they studied the unit with the multimedia courseware. These two tests were parallel to each other. Each test had 20 multiple-choice questions, each with four alternatives; there was one correct answer and three distracters for each question. Options were labeled from A to D. Nine test questions measured the students' conceptual knowledge of electricity, and the other 11 questions measured the students' ability to apply their knowledge of electricity in a novel situation (procedural knowledge). The test questions were adapted from the learning objectives of the sixth grade science course book of the Turkish Ministry of Education. After preparation of the questions, some items were revised with the help of a science teacher and a science learning researcher. For this reason, these scales can be assumed as valid. The internal consistency of the post-test was controlled through Cronbach's alpha. The Cronbach alpha coefficient of the post-test was .648, which indicates that the scale is questionable in terms of internal consistency, as Pallant (2001) states that “Ideally, the Cronbach Alpha coefficient of a scale should be above .7” (p. 85).

3.5 Data collection procedure

Prior to the data collection and treatments, ethical approval (see Appendix E) was obtained from the Committee on Human Research of Boğaziçi University (İNAREK). The study was conducted in three sessions; pre-test; treatment; post-test, taking place on two different days over a period of two weeks, according to the availability of the participating schools.

First of all, the computer teachers were informed in detail about the research, treatments, instruments, and data collection procedure of the study by the researchers via e-mail and telephone conversations. Their questions about the study were answered before the data collection. After all steps were clearly understood by the teachers, they began to data collection. Data collection took place in the participants’ schools. Before starting the experiment, the computer teachers of the participants informed participants’ parents about the procedure of the experiment, and proffered a written explanation consisting of the consent form (see Appendix A). Students were also informed about procedure of the experiment and that they were free to participate (or not) in the experiments.

In all the classes, on the first day, the computer teacher and the science teacher of the class worked cooperatively and all participants were given the pre-test to determine prior knowledge about electricity. The pre-test phase lasted approximately one lesson period (40 minutes). After a week, the second and third sessions of the study were performed on the same day. In the second session, students studied an electricity unit in one assigned multimedia condition on their own using a computer under the supervision of the computer teacher for about 25 minutes. After a 20-minute break, the third session started, with the computer teacher and the science teacher again working cooperatively to administer the post-test to measure the learning outcome of the electricity unit. The post-test phase also lasted approximately one lesson period (40 minutes).

CHAPTER 4

DATA ANALYSIS

In order to answer the research questions, a series of different statistical tests were conducted. Data sets of the student's' prior science grades, prior and after-treatment knowledge in the learning unit were first matched for each student and for each treatment group. The data were then checked to ensure that each student had scores for all three measurements, namely, a science grade, a pre-test score and a post-test score. Students who did not have all of these scores were dropped from the study. Twenty-nine students were dropped. In all statistical tests, the IBM SPSS statistical software (Version 23) was used.

Before explaining the specific statistical procedures conducted in the current study, I will describe how the treatment groups were matched with each other to analyse the data.

4.1 Abstract and concrete representations

To answer first question of the study (Do abstract and concrete representations of animations with five different text representations affect differently middle school students' learning of an electricity unit?), the following five different matched group comparisons were analyzed (see Table 4). The main criteria for matching were that the groups should contain the same type of text representation and that they should contain different types of animation representation. In this context, (1) W-A—W-C, (2) Sg-A—Sg-C, (3) Sp-A—Sp-C, (4) W+Sp-A—W+Sp-C and (5) Sg+Sp-A—Sg+Sp-C were matched groups for the first question.

Table 4. Matched Groups for First Question

Abstract versus Concrete
W-A—W-C
Sg-A—Sg-C
Sp-A—Sp-C
W+Sp-A—W+Sp-C
Sg+Sp-A—Sg+Sp-C

4.2 The modality effect in animation representation

To answer the second question of the study (Does the modality effect in a multimedia setting with abstract or concrete representation of animation hold true for middle school students' learning of an electricity unit?), the following two different matched groups were compared:

- Spoken text and abstract animation - written text and abstract animation
- Spoken text and concrete animation - written text and concrete animation

The main criteria for matching were that the groups should contain the same type of animation representation, and that they should contain different types of text representation (written or spoken). In this context, (1) Sp-A—W-A and (2) Sp-C—W-C were matched groups for the third question.

4.3 Modality and signaling in animation representation

To answer the third question of the study (Do the effects of spoken text modality and signaled written text modality on an electricity unit achievement differ in a multimedia setting with abstract or concrete representation of animation?), two different matched groups were compared:

- Spoken text and abstract animation – signaled written text and abstract animation

- Spoken text and concrete animation – signaled written text and concrete animation

The main criteria for matching were that the groups should contain the same type of animation representation, and that they should contain different types of text representation (signaled written or spoken). In this context, (1) Sp-A—Sg-A and (2) Sp-C—Sg-C were matched groups for the second question.

4.4 The redundancy effect in animation representation

To answer the fourth question of the study (Does the redundancy effect in a multimedia setting with abstract or concrete representation of animation hold true for middle school students' learning of an electricity unit?), two different matched groups were compared:

- Spoken text and abstract animation – spoken and written text, and abstract animation
- Spoken text and concrete animation – spoken and written text, and concrete animation

The main criteria for matching were that the groups should contain the same type of animation representation, and that they should contain different types of text representation (spoken or spoken and written). In this context, (1) Sp-A—W+Sp-A and (2) Sp-C—W+Sp-C were matched groups for the fourth question.

4.5 Redundancy with signaling materials in animation representation

To answer the fifth question of the study (Do the effects of spoken text modality, and signaled written text and spoken text modality on an electricity unit achievement differ in a multimedia setting with abstract or concrete representation of animation?), two different matched groups were compared:

- Spoken text and abstract animation – spoken and signaled written text, and abstract animation
- Spoken text and concrete animation – spoken and signaled written text, and concrete animation

The main criteria for matching were that the groups should contain the same type of animation representation, and that they should contain different types of text representation (spoken or spoken and signaled written). In this context, (1) Sp-A—Sg+Sp-A and (2) Sp-C—Sg+Sp-C were matched groups for the fifth question (see Table 9).

4.6 The signaling effect in animation representation

To answer the sixth question of the study (Does the signaling effect in a multimedia setting with abstract or concrete representation of animation hold true for middle school students' learning of an electricity unit?), two different matched groups were compared:

- Written text and abstract animation – signaled written text, and abstract animation
- Written text and concrete animation – signaled written text, and concrete animation

The main criteria for matching were that the groups should contain the same type of animation representation, and that they should contain different types of text representation (written or signaled written). In this context, (1) W-A—Sg-A and (2) W-C—Sg-C were matched groups for the sixth question.

4.7 Signaling with redundant materials in animation representation

To answer the seventh question of the study (Do the effects of written text and spoken text modality, and signaled written text and spoken text modality on an electricity unit achievement differ in a multimedia setting with abstract or concrete representation of animation?), two different matched groups were compared:

- Written and spoken text, and abstract animation – signaled written and spoken text, and abstract animation
- Written and spoken text, and concrete animation – signaled written and spoken text, and concrete animation

The main criteria for matching were that the groups should contain the same type of animation representation, and that they should contain different types of text representation (written or signaled written). In this context, (1) W+Sp-A—Sg+Sp-A and (2) W+Sp-C—Sg+Sp-C were matched groups for the seventh question.

For the data analysis of this study, quantitative methods were used. Firstly, the descriptive statistic of the achievement scores (difference between pre-test and post-test), the normal distributions and homogeneity of variance in each groups' data were examined before conducting hypothesis testing through either parametric or nonparametric methods.

4.8 Prior knowledge about unit and covariate effects

The study groups were assumed to be equal in terms of students' prior electricity knowledge before the data collection. Although the groups were randomly assigned to the treatment conditions, I compared the groups' prior knowledge of electricity unit after the data collection. Firstly, Shapiro-Wilk test, Kolmogorov-Smirnov test, and the central limit theorem assumption were checked for normal distribution of scores of each group. Secondly, Levene's test was conducted for the homogeneity check. Finally, the pre-test scores of each group were compared by using a one-way analyses of variance test (ANOVA), and that was confirmed by using Kruskal-Wallis H test due to absence of normal distributions in scores of some groups checked with Kolmogorov-Smirnov test.

The matched group comparison tests to find answers to the research questions were not only conducted with parametric tests but also conducted with nonparametric tests because the results of normality tests gave conflicted results. However, the size of the sample for each comparison group was sufficient (smallest group consisted of 67 students) for conducting parametric tests. For the homogeneity of variance check of the achievement scores of matched groups, Levene's test was carried out. To compare the matched groups, an independent sample t-test was used by assuming that the data was normally distributed and the homogeneity of variance was observed. On the other hand, all statistical analyses for research questions were also conducted with Mann-Whitney U test to compare the matched groups.

In order to test whether prior science score, prior knowledge about the learning unit and the multimedia treatments together or pairwise influence the students' learning of the unit, a general linear model 2x2x10 ANOVA test was conducted.

CHAPTER 5

RESULTS

This chapter provides the results of the data analyses conducted to answer the research questions. First, the descriptive statistics of the participants' achievement scores and distributions of the scores, and the homogeneity of variances of the score groups were examined before deciding the type of statistics for hypothesis testing. Specific findings for each research question of the study were then presented under title of the each group of research questions. Table 5 shows descriptive statistic of pre-test and post-test scores of the treatment groups.

Table 5. Descriptive Statistics for Students' Pre-test and Post-test Scores

Groups	Pre-test		Post-test	
	Mean	*St. Dev.*	Mean	*St. Dev.*
W-A	4.36	2.70	5.41	2.33
W-C	4.58	2.25	5.42	2.63
Sg-A	3.97	2.11	6.15	2.89
Sg-C	3.99	2.23	5.66	2.75
Sp-A	4.43	2.32	6.63	3.01
Sp-C	4.20	2.43	6.33	3.54
W+Sp-A	4.63	2.62	6.66	3.19
W+Sp-C	5.05	2.29	6.70	3.25
Sg+Sp-A	4.73	2.77	7.19	3.71
Sg+Sp-C	4.92	2.50	6.63	2.94

To check whether pre-test scores and achievement scores of matched groups were normally distributed, three different tests were used: (1) The Shapiro-Wilk test was conducted, although this test is usually used when the number of participants is lower than 50. The test revealed that it may be assumed that data of achievement scores for seven ($p > .05$) out of 10 treatment groups (see Appendix F, Table 48) and data of pre-test scores for two ($p > .05$) out of 10 treatment groups (see Appendix F, Table 49) are approximately normally distributed. (2) The Kolmogorov-Smirnov test was conducted. This test is usually checked when the number of participants is more than 50 in a group. According to the results, this analysis data of achievement scores for only two treatment groups (see Appendix F, Table 48) and data of pre-test scores for two treatment groups (see Appendix F, Table 49) of the current study ($p > .05$) were normally distributed (3) The central limit theorem indicates that if the size of groups is greater than 30, the data is approximately normally distributed (Field, Miles & Field, 2012). With this assumption, data for all treatment groups of the study may be assumed to be normally distributed because the number of participants in all groups was more than 30.

Based on the conflicting results of normality tests, achievement scores of the matched group were compared to find answers to the research questions not only with parametric tests but also with nonparametric tests. To conduct the parametric tests, four outliers in the W-C group, two outliers in the Sg-A group, four outliers in the Sg-C group, one outlier in the Sp-C group, and four outliers in the Sg+Sp-C group were excluded from the data sets. Then an independent sample t-test was conducted to compare the means achievement scores of each matched group. On the other hand, to be cautious, all parametric statistical tests for the research questions were confirmed with their equivalent nonparametric test; the Mann-Whitney U test was used to compare the achievement scores of matched groups. The Mann-Whitney U test is considered the nonparametric alternative to the independent t-test (Field, Miles & Field, 2012).

Similarly, the pre-test scores of the groups were compared not only with parametric tests but also conducted with nonparametric tests. To conduct parametric tests, an outlier in the W-C group, three outliers in the Sg-A group, two outliers in the Sg-C group, two outliers in the Sp-C group, 3 outliers in the W+Sp-A group, an outlier in the Sg+Sp-A group, and two outliers in the Sg+Sp-C group were excluded from the data. Then, a one-way ANOVA test was conducted to compare all groups. But, nevertheless, to be cautious, a one-way ANOVA parametric statistical test for the pre-test comparisons was confirmed with its equivalent nonparametric test, the Kruskal-Wallis H test. This test is considered the nonparametric alternative to the one-way ANOVA, and an extension of the Mann-Whitney U test to allow the comparison of the more than two independent groups (Field, Miles & Field, 2012).

5.1 Pre-test comparison

For the homogeneity check of pre-test scores, Levene's test was conducted. The homogeneity of variances for data of all groups was assessed using Levene's test and homogeneity of variances in the data sets ($p > .05$) was observed.

There was a statistically significant difference on pre-test scores between treatment groups as determined by the one-way ANOVA test (F (9, 814) = 1.957, p = .041) (see Table 6). This result was also confirmed by a Kruskal-Wallis H; $\chi 2$ (9) = 17.742, p = 0.038, with a mean rank pre-test score of 405.52 for the W-A group, 414.59 for W-C group, 366.11 for Sg-A group, 360.47 for the Sg-C group, 405.88 for the Sp-A group, 388.62 for the Sp-C group, 421.60 for the W+Sp-A group, 471.55

for the W+Sp-C group, 436.29 for the Sg+Sp-A group, and 456.53 for the Sg+Sp-C group (see Table 7). Although Tukey's test is more recommended by statisticians because it is less conservative, the Scheffe's test was used to find which treatment groups' mean of pre-test scores were significantly different from each other because treatment groups sample size were not equal. The result of post-hoc tests (one to one comparisons) showed that pre-test-mean scores of groups were not significantly different from each other (see Appendix F, Table 50).

Table 6. One-way ANOVA Test for Students' Pre-test Scores in Multimedia Conditions

Source	Sum of Squares	*df*	Mean Square	*F*	*Sig.*
Between Groups	103.586	9	11.510	1.957	0.041
Within Groups	4788.209	814	5.882		
Total	4891.795	823			

Table 7. Descriptive Statistics for the Students' Pre-test Scores in Multimedia Conditions

Groups	Mean	*St. Dev.*	n	Mean Rank
W-A	4.36	2.706	80	405.52
W-C	4.58	2.257	74	414.59
Sg-A	3.97	2.116	87	366.11
Sg-C	3.99	2.233	85	360.47
Sp-A	4.43	2.324	93	405.88
Sp-C	4.20	2.439	76	388.62
W+Sp-A	4.63	2.620	93	421.60
W+Sp-C	5.05	2.292	94	471.55
Sg+Sp-A	4.73	2.772	67	436.29
Sg+Sp-C	4.92	2.503	75	456.53
Total	4.48	2.438	824	

One particular set of data may be used for testing a hypothesis; when the same data is used for testing a second hypothesis, a Bonferroni correction ought to be conducted. Considering this fact, first, the above analysis of data was performed using Bonferroni corrections for multiple comparisons, and statistical significance was accepted at the $p < .0011$ level because significance level $p < .05$ was divided by the number of comparisons (45). After they were confirmed by a Scheffe's test. The Scheffe's tests are reported here in order to demonstrate more detailed information on the data sets.

5.2 Achievement scores

Achievement scores of the students were calculated by subtracting their pre-test scores from the post-test scores. Paired t-tests were conducted to determine whether there was a statistically significant mean difference between post-test and pre-test scores of each group. The analyses showed that each group's post-test scores mean was significantly higher than pre-test scores mean, yielding a medium or high effect size (see Table 8).

Table 8. Paired Sample Tests for Achievement Scores of Groups

Groups	Achievement		*t*	*df*	*Sig. (2-tailed)*	Cohen's *d*
	Mean	*St. Dev.*				
W-A	1.05	3.08	3.04	79	.003	.41
W-C	.84	2.67	2.69	73	.009	.34
Sg-A	2.18	3.21	6.34	86	.000	.86
Sg-C	1.67	3.10	4.96	84	.000	.66
Sp-A	2.20	3.43	6.19	92	.000	.81
Sp-C	2.13	3.61	5.13	75	.000	.70
W+Sp-A	2.02	3.52	5.53	92	.000	.69
W+Sp-C	1.65	3.39	4.71	93	.000	.58
Sg+Sp-A	2.46	3.65	5.51	66	.000	.75
Sg+Sp-C	1.71	3.25	4.54	74	.000	.62

5.3 Abstract and concrete representation of animation

5.3.1 Examination of abstract or concrete representation of animation with written text

An independent samples *t*-test was conducted to examine the effect of abstract or concrete representation of animations with written text representation on students' learning an electricity unit. Table 9 shows the descriptive statistics of the matched W-A and W-C groups. The homogeneity of variance for the data of both groups was assessed using Levene's test, and homogeneity of variances in the data sets ($p > .05$) was observed (see Table 10). The independent sample *t*-test revealed that there was not a significant difference between the achievement scores of the W-A group (M = 1.05, SD = 3.09) and the W-C group (M = .84, SD = 2.68); t (152) = .45, p = .650 (see Table 10). This result was also confirmed by a Mann-Whitney U test; U (152) = 2903.5, z = - .206, p = .837.

Table 9. Descriptive Statistics for Students' Achievement Scores in W-A and W-C Conditions

Groups	Mean	*St. Dev.*	n	Mean Rank
W-A	1.05	3.09	80	78.21
W-C	.84	2.68	74	76.74

Table 10. Independent Sample t-Test for Students' Achievement Scores in W-A and W-C Conditions

Levene Statistic						
F	*Sign.*	*t*	*df*	*Sig.* (2-tailed)	Mean Difference	Std. Error Difference
.655	.420	.454	152	.650	.212	.467

5.3.2 Examination of abstract or concrete representation of animation with signaled written text

An independent samples *t*-test was conducted to examine the effect of abstract or concrete representation of animations with signaled written text representation on students' learning an electricity unit. Table 11 shows the descriptive statistics of the matched Sg-A and Sg-C groups. The homogeneity of variance for the data of both groups was assessed using Levene's test, and homogeneity of variances in the data sets ($p > .05$) was observed (see Table 12). The independent sample t-test revealed that there was not a significant difference between the achievement scores of the Sg-A group ($M = 2.18$, $SD = 3.21$) and the Sg-C group ($M = 1.67$, $SD = 3.10$); $t\ (170) = 1.06$, $p = .288$ (see Table 12). This result was also confirmed by a Mann-Whitney U test; $U\ (170) = 3418.5$, $z = -\ .862$, $p = .389$.

Table 11. Descriptive Statistics for Students' Achievement Scores in Sg-A and Sg-C Conditions

Groups	Mean	*St. Dev.*	n	Mean Rank
Sg-A	2.18	3.21	87	89.71
Sg-C	1.67	3.10	85	83.22

Table 12. Independent Sample t-Test for Students' Achievement Scores in Sg-A and Sg-C Conditions

Levene Statistic						
F	*Sign.*	*t*	*df*	*Sig.* (2-tailed)	Mean Difference	Std. Error Difference
.295	.588	1.066	170	.288	.513	.482

5.3.3 Examination of abstract or concrete representation of animation with spoken text

An independent samples *t*-test was conducted to examine the effect of abstract or concrete representation of animations with spoken text representation on students' learning an electricity unit. Table 13 shows the descriptive statistics of the matched Sp-A and the Sp-C groups. The homogeneity of variance for the data of both groups was assessed using Levene's test and homogeneity of variances in the data sets ($p > .05$) was observed (see Table 14). The independent sample *t*-test revealed that there was not a significant difference between the achievement scores of the Sp-A group (M = 2.20, SD = 3.43) and the Sp-C group (M = 2.13, SD = 3.61); t (167) = .13, p = .894 (see Table 14). This result was also confirmed by a Mann-Whitney U test; U (167) = 3454.5, z = - .252, p = .801.

Table 13. Ranks for Students' Achievement Scores in Sp-A and Sp-C Conditions

Groups	Mean	*St. Dev.*	n	Mean Rank
Sp-A	2.20	3.43	93	85.85
Sp-C	2.13	3.61	76	83.95

Table 14. Independent Sample t-Test for Students' Achievement Scores in Sp-A and Sp-C Conditions

Levene Statistic						
F	*Sign.*	*t*	*df*	*Sig.* (2-tailed)	Mean Difference	Std. Error Difference
.079	.779	.134	167	.894	.073	.544

5.3.4 Examination of abstract or concrete representation of animation with written text and spoken text

An independent samples *t*-test was conducted to examine the effect of abstract or concrete representation of animations with written text and spoken text representation students' learning an electricity unit. Table 15 shows the descriptive statistics of the matched W+Sp-A and W+Sp-C groups. The homogeneity of variance for the data of both groups was assessed using Levene's test, and homogeneity of variances in the data sets ($p > .05$) was observed (see Table 16). The independent sample *t*-test revealed that there was not a significant difference between the achievement scores of the W+Sp-A group ($M = 2.02$, $SD = 3.52$) and the W+Sp-C group ($M = 1.65$, $SD = 3.39$); t (185) = .73, $p = .462$ (see Table 16). This result was also confirmed by a Mann-Whitney U test; U (185) = 4182, $z = -.513$, $p = .608$.

Table 15. Descriptive Statistics for Students' Achievement Scores in W+Sp-A and W+Sp-C Conditions

Groups	Mean	*St. Dev.*	n	Mean Rank
W+Sp-A	2.02	3.52	93	96.03
W+Sp-C	1.65	3.39	94	91.99

Table 16. Independent Sample t-Test for Students' Achievement Scores in W+Sp-A and W+Sp-C Conditions

Levene Statistic						
F	*Sign.*	*t*	*df*	*Sig.* (2-tailed)	Mean Difference	Std. Error Difference
.107	.744	.737	185	.462	.373	.506

5.3.5 Examination of abstract or concrete representation of animation with signaled written text and spoken text

An independent samples *t*-test was conducted to examine the effect of abstract or concrete representation of animations with signaled written text and spoken text representation on students' learning an electricity unit. Table 17 shows the descriptive statistics of the matched Sg+Sp-A and Sg+Sp-C groups. The homogeneity of variance for the data of both groups was assessed using Levene's test, and homogeneity of variances in the data sets ($p > .05$) was observed (see Table 18). The independent sample *t*-test revealed that there was not a significant difference between the achievement scores of the Sg+Sp-A group ($M = 2.46$, $SD = 3.65$) and the Sg+Sp-C group ($M = 1.71$, $SD = 3.25$); $t\ (140) = 1.30$, $p = .194$ (see Table 18). This result was also confirmed by a Mann-Whitney U test; $U\ (140) = 2273.5$, $z = -.982$, $p = .326$.

Table 17. Descriptive Statistics for Students' Achievement Scores in Sg+Sp-A and Sg+Sp-A Conditions

Groups	Mean	*St. Dev.*	n	Mean Rank
Sg+Sp-A	2.46	3.65	67	75.07
Sg+Sp-C	1.71	3.25	75	68.31

Table 18. Independent Sample t-Test for Students' Achievement Scores in Sg+Sp-A and Sg+Sp-C Conditions

Levene Statistic						
F	*Sign.*	*t*	*df*	*Sig.* (2-tailed)	Mean Difference	Std. Error Difference
1.441	.232	1.304	140	.194	.756	.580

5.4 The modality effect

5.4.1 Examination of modality effect in a multimedia setting with abstract representation of animation

An independent samples *t*-test was conducted to examine the modality effect in a multimedia setting with abstract representation of animation students' learning an electricity unit. Table 19 shows the descriptive statistics of the matched Sp-A and W-A groups. The homogeneity of variance for the data of both groups was assessed using Levene's test and homogeneity of variances in the data sets ($p > .05$) was observed (see Table 20). The independent sample *t*-test revealed that there was a significant difference between the achievement scores of the Sp-A group ($M = 2.20$, $SD = 3.43$) and the W-A group ($M = 1.05$, $SD = 3.08$); t (171) = 2.31, $p = .022$; $d = .35$ (see Table 20). The effect size for this analysis ($d = .35$) was found to exceed Cohen's (1988) convention for a medium effect. This result was also confirmed by a Mann-Whitney U test; U (173) = 3031, $z = - 2.109$, $p = .035$.

Table 19. Descriptive Statistics for Students' Achievement Scores in Sp-A and W-A Conditions

Groups	Mean	*St. Dev.*	n	Mean Rank
Sp-A	2.20	3.43	93	94.41
W-A	1.05	3.08	80	78.39

Table 20. Independent Sample t-Test for Students' Achievement Scores in Sp-A and W-A Conditions

Levene Statistic						
F	*Sign.*	*t*	*df*	*Sig.* (2-tailed)	Mean Difference	Std. Error Difference
2.811	.095	2.310	171	.022	1.154	.500

5.4.2 Examination of modality effect in a multimedia setting with concrete representation of animation

An independent samples *t*-test was conducted to examine the modality effect in a multimedia setting with concrete representation of animation on students' learning an electricity unit. Table 21 shows the descriptive statistics of the matched Sp-C and W-C groups. The homogeneity of variance for data of both groups was assessed using Levene's test, and homogeneity of variances in the data sets ($p > .05$) was not observed (see Table 22). The independent sample *t*-test revealed that there was a significant difference between the achievement scores of the Sp-C group ($M = 2.13$, $SD = 3.61$) and the W-C group ($M = .84$, $SD = 3.67$); $t\,(148) = 2.49$, $p = .014$; $d = .35$ (see Table 22). The effect size for this analysis ($d = .35$) was found to exceed Cohen's (1988) convention for a medium effect. This result was also confirmed by a Mann-Whitney U test; $U\,(148) = 2272.5$, $z = -\,2.039$, $p = .041$.

Table 21. Descriptive Statistics for Students' Achievement Scores in Sp-C and W-C Conditions

Groups	Mean	*St. Dev.*	n	Mean Rank
Sp-C	2.13	3.61	76	82.60
W-C	.84	3.67	74	68.21

Table 22. Independent Sample t-Test for Students' Achievement Scores in Sp-C and W-C Conditions

Levene Statistic						
F	*Sign.*	*t*	*df*	*Sig.* (2-tailed)	Mean Difference	Std. Error Difference
7.153	.008	2.494	148	.014	1.294	.519

5.5 Spoken text modality or signaled written text modality

5.5.1 Examination of effects of spoken text modality and signaled text modality with abstract representation of animation

An independent samples *t*-test was conducted to examine the effects of spoken text modality and signaled written text modality with abstract representation of animation on students' learning in a multimedia setting. Table 23 shows the descriptive statistics of the matched Sp-A and Sg-A groups. The homogeneity of variance for the data of both groups was assessed using Levene's test, and homogeneity of variances in the data sets ($p > .05$) was observed (see Table 24). The independent sample *t*-test revealed that there was not a significant difference between the achievement scores of the Sp-A group ($M = 2.20$, $SD = 3.43$) and the Sg-A group ($M = 2.18$, $SD = 3.21$); $t\ (178) = .47$, $p = .967$, (see Table 24). This result was also confirmed by a Mann-Whitney U test; $U\ (178) = 4026$, $z = -\ .056$, $p = .955$.

Table 23. Descriptive Statistics for Students' Achievement Scores of Students in Sp-A and Sg-A Conditions

Groups	Mean	*St. Dev.*	n	Mean Rank
Sp-A	2.20	3.43	93	90.71
Sg-A	2.18	3.21	87	90.28

Table 24. Independent Sample t-Test for Students' Achievement Scores in Sp-A and Sg-A Conditions

Levene Statistic						
F	*Sign.*	*t*	*df*	*Sig.* (2-tailed)	Mean Difference	Std. Error Difference
.888	.347	.047	178	.967	.020	.496

5.5.2 Examination of effects of spoken text modality and signaled written text modality with concrete representation of animation

An independent samples *t*-test was conducted to examine the effects of spoken text modality and signaled written text modality with concrete representation of animation on students' learning in a multimedia setting. Table 25 shows the descriptive statistics of the matched Sp-C and Sg-C groups. The homogeneity of variance for the data of both groups was assessed using Levene's test, and homogeneity of variances in the data sets ($p > .05$) was observed (see Table 26). The independent sample *t*-test revealed that there was not a significant difference between the achievement scores for the Sp-C group ($M = 2.13$, $SD = 3.61$) and the Sg-C group ($M = 1.67$, $SD = 3.10$); $t(159) = .87$, $p = .385$ (see Table 26). This result was also confirmed by a Mann-Whitney U test; $U(159) = 3045$, $z = -.630$, $p = .529$.

Table 25. Descriptive Statistics for Students' Achievement Scores in Sp-C and Sg-C Conditions

Groups	Mean	*St. Dev.*	n	Mean Rank
Sp-C	2.13	3.61	76	83.43
Sg-C	1.67	3.10	85	78.82

Table 26. Independent Sample t-Test for Students' Achievement Scores in Sp-C and Sg-C Conditions

Levene Statistic						
F	*Sign.*	*t*	*df*	*Sig.* (2-tailed)	Mean Difference	Std. Error Difference
2.607	.108	.870	159	.385	.461	.530

5.6 The redundancy effect

5.6.1 Examination of redundancy effect in a multimedia setting with abstract representation of animation

An independent samples *t*-test was conducted to examine the redundancy effect in a multimedia setting with abstract representation of animation on students' learning an electricity unit. Table 27 shows the descriptive statistics of the matched Sp-A and W+Sp-A groups. The homogeneity of variance for the data of both groups was assessed using Levene's test, and homogeneity of variances in the data sets ($p > .05$) was observed (see Table 28). The independent sample *t*-test revealed that there was not a significant difference between the achievement scores for the Sp-A group (M = 2.20, SD = 3.43) and the W+Sp-A group (M = 2.02, SD = 3.52); t (184) = .35, p = .720 (see Table 28). This result was also confirmed by a Mann-Whitney U test; U (184) = 4193.5, z = - .358, p = .720.

Table 27. Descriptive Statistics for Students' Achievement Scores in Sp-A and W+Sp-A Conditions

Groups	Mean	*St. Dev.*	n	Mean Rank
Sp-A	2.20	3.43	93	94.91
W+Sp-A	2.02	3.52	93	92.09

Table 28. Independent Sample t-Test for Students' Achievement Scores in Sp-A and W+Sp-A Conditions

Levene Statistic						
F	*Sign.*	*t*	*df*	*Sig.* (2-tailed)	Mean Difference	Std. Error Difference
.001	.975	.358	184	.720	.183	.510

5.6.2 Examination of redundancy effect in a multimedia setting with concrete representation of animation

An independent samples *t*-test was conducted to examine the redundancy effect in a multimedia setting with concrete representation of animation on students' learning an electricity unit. Table 29 shows the descriptive statistics of the W+Sp-C and the Sp-C matched groups. The homogeneity of variance for data both groups was assessed using Levene's test, and the homogeneity of variances in the data sets ($p > .05$) was observed (see Table 30). The independent sample *t*-test revealed that there was not a significant difference between the achievement scores of the Sp-C group ($M = 2.13$, $SD = 3.61$) and the W+Sp-C group ($M = 1.65$, $SD = 3.39$); $t\ (168) = .89$, $p = .372$ (see Table 30). This result was also confirmed by a Mann-Whitney U test; $U\ (168) = 3389.5$, $z = -\ .575$, $p = .566$.

Table 29. Descriptive Statistics for Students' Achievement Scores in Sp-C and W+Sp-C Conditions

Groups	Mean	*St. Dev.*	n	Mean Rank
Sp-C	2.13	3.61	76	87.90
W+Sp-C	1.65	3.39	94	83.56

Table 30. Independent Sample t-Test for Students' Achievement Scores in Sp-C and W+Sp-C Conditions

Levene Statistic						
F	*Sign.*	*t*	*df*	*Sig.* (2-tailed)	Mean Difference	Std. Error Difference
.309	.579	.895	168	.372	.483	.539

5.7 Spoken text modality or signaled written text and spoken text modality

5.7.1 Examination of effects of spoken text modality, and signaled written text modality and spoken text modality with abstract representation of animation

An independent samples *t*-test was conducted to examine the effects of spoken text modality, and signaled written text and spoken modality with abstract representation of animation in a multimedia setting on an electricity unit achievement. Table 31 shows the descriptive statistics of the matched Sp-A and Sg+Sp-A groups. The homogeneity of variance for the data of both groups was assessed using Levene's test, and the homogeneity of variances in the data sets ($p > .05$) was observed (see Table 32). The independent sample *t*-test revealed that there was not a significant difference between the achievement scores for the Sp-A group ($M = 2.20$, $SD = 3.43$) and the Sg+Sp-A group ($M = 2.46$, $SD = 3.65$); t (158) = -.45, $p = .648$ (see Table 32). This result was also confirmed by a Mann-Whitney U test; U (158) = 3016, z = -.346, $p = .730$.

Table 31. Descriptive Statistics for Students' Achievement Scores in Sp-A and Sg+Sp-A Conditions

Groups	Mean	*St. Dev.*	n	Mean Rank
Sp-A	2.20	3.43	93	79.43
Sg+Sp-A	2.46	3.65	67	81.99

Table 32. Independent Sample t-Test for Students' Achievement Scores in Sp-A and Sg+Sp-A Conditions

Levene Statistic						
F	*Sign.*	*t*	*df*	*Sig.* (2-tailed)	Mean Difference	Std. Error Difference
.279	.598	-.457	158	.648	-.258	.566

5.7.2 Examination of effects of spoken text modality, and signaled written text modality and spoken text modality with concrete representation of animation

An independent samples *t*-test was conducted to examine the effects of spoken text modality, and signaled written text and spoken modality with concrete representation of animation in a multimedia setting on an electricity unit achievement. Table 33 shows the descriptive statistics of the matched Sg+Sp-C and the Sp-C groups. The homogeneity of variance for data of both groups was assessed using Levene's test, and he homogeneity of variances in the data sets ($p > .05$) was observed (see Table 34). The independent sample *t*-test revealed that there was not a significant difference between the achievement scores for the Sp-C group ($M = 2.13$, $SD = 3.61$) and the Sg+Sp-C group ($M = 1.71$, $SD = 3.25$); t (149) = .759, $p = .449$ (see Table 34). This result was also confirmed by a Mann-Whitney U test U (149) = 2737, $z = -.423$, $p = .673$.

Table 33. Descriptive Statistics for Students' Achievement Scores in Sp-C and Sg+Sp-C Conditions

Groups	Mean	*St. Dev.*	n	Mean Rank
Sp-C	2.13	3.61	76	77.49
Sg+Sp-C	1.71	3.25	75	74.49

Table 34. Independent Sample t-Test for Students' Achievement Scores in Sp-C and Sg+Sp-C Conditions

Levene Statistic						
F	*Sign.*	*t*	*df*	*Sig.* (2-tailed)	Mean Difference	Std. Error Difference
.957	.330	.759	149	.449	.425	.560

5.8 The signaling effect

5.8.1 Examination of signaling effect in a multimedia setting with abstract representation of animation

An independent samples *t*-test was conducted to examine the signaling effect in a multimedia setting with abstract representation of animation on students' learning an electricity unit. Table 35 shows the descriptive statistics of the matched W-A and Sg-A groups. The homogeneity of variance for data of both groups was assessed using Levene's test, and the homogeneity of variances in the data sets ($p > .05$) was observed (see Table 36). The independent sample *t*-test revealed that there was a significant difference between the achievement scores for Sg-A group ($M = 2.18$, $SD = 3.21$) and W-A group ($M = 1.05$, $SD = 3.08$); $t(184) = 2.32$, $p = .021$; $d = .35$ (see Table 36). The effect size for this analysis ($d = .35$) was found to exceed Cohen's (1988) convention for a medium effect. This result was also confirmed by a Mann-Whitney U test; $U(165) = 2838.5$, $z = -2.073$, $p = .038$.

Table 35. Descriptive Statistics for Students' Achievement Scores in Sg-A and W-A Conditions

Groups	Mean	*St. Dev.*	n	Mean Rank
Sg-A	2.18	3.21	87	91.37
W-A	1.05	3.08	80	75.98

Table 36. Independent Sample t-Test for Students' Achievement Scores in Sg-A and W-A Conditions

Levene Statistic						
F	*Sign.*	*t*	*df*	*Sig.* (2-tailed)	Mean Difference	Std. Error Difference
.583	.446	2.323	165	.021	1.134	.488

5.8.2 Examination of signaling effect in a multimedia setting with abstract representation of animation

An independent samples *t*-test was conducted to examine the signaling effect in a multimedia setting with concrete representation of animation on students' learning an electricity unit. Table 37 shows the descriptive statistics of the W-C and Sg-C matched groups. The homogeneity of variance for data of both groups was assessed using Levene's test, and the homogeneity of variances in the data sets ($p > .05$) was observed (see Table 38). The independent sample *t*-test revealed that there was not a significant difference between the achievement scores for Sg-C group ($M = 1.67$, $SD = 3.10$) and W-C group ($M = .84$, $SD = 2.67$); $t\ (157) = 1.79$, $p = .074$ (see Table 38). This result was also confirmed by a Mann-Whitney U test $U\ (157) = 2693$, $z = -1.571$, $p = .116$.

Table 37. Descriptive Statistics for Students' Achievement Scores in Sg-C and W-C Conditions

Groups	Mean	*St. Dev.*	n	Mean Rank
Sg-C	1.67	3.10	85	85.32
W-C	.84	2.67	74	73.89

Table 38. Independent Sample t-Test for Students' Achievement Scores in Sg-C and W-C Conditions

Levene Statistic						
F	*Sign.*	*t*	*df*	*Sig.* (2-tailed)	Mean Difference	Std. Error Difference
1.175	.280	1.798	157	.074	.833	.463

5.9 Written text and spoken text modality or signaled written text and spoken text modality

5.9.1 Examination of effects written text and spoken text modality or signaled written text and spoken text modality with abstract representation of animation

An independent samples *t*-test was conducted to examine the effects of written text and spoken text modality, and signaled written text and spoken text modality in a multimedia setting with abstract representation of animation on electricity unit achievement. Table 39 shows the descriptive statistics of the matched Sg+Sp-A and W+Sp-A groups. The homogeneity of variance for data of both groups was assessed using Levene's test, and the homogeneity of variances in the data sets ($p > .05$) was observed (see Table 40). The independent sample *t*-test revealed that there was not a significant difference between the achievement scores for Sg+Sp-A group ($M = 2.46$, $SD = 3.65$) and W+Sp-A group ($M = 2.02$, $SD = 3.52$); t (158) = .76, $p = .441$ (see Table 40). This result was also confirmed by a Mann-Whitney U test; U (158) = 2920, $z = -.679$, $p = .497$.

Table 39. Descriptive Statistics for Students' Achievement Scores in Sg+Sp-A and W+Sp-A Conditions

Groups	Mean	*St. Dev.*	n	Mean Rank
Sg+Sp-A	2.46	3.65	67	83.42
W+Sp-A	2.02	3.52	93	78.40

Table 40. Independent Sample t-Test for Students' Achievement Scores in Sg+Sp-A and W+Sp-A Conditions

Levene Statistic						
F	*Sign.*	*t*	*df*	*Sig.* (2-tailed)	Mean Difference	Std. Error Difference
.230	.632	.769	158	.443	.441	.573

5.9.2 Examination of effects written text and spoken text modality or signaled written text and spoken text modality with abstract representation of animation

An independent samples *t*-test was conducted to examine the effects of written text and spoken text modality, and signaled written text and spoken text modality in a multimedia setting with concrete representation of animation on electricity unit achievement. Table 41 shows the descriptive statistics of the Sg+Sp-C and W+Sp-C matched groups. The homogeneity of variance for data of both groups was assessed using Levene's test and the homogeneity of variances in the data sets ($p > .05$) was observed (see Table 42). The independent sample *t*-test revealed that there was not a significant difference between the achievement scores for Sg+Sp-C group ($M = 1.71$, $SD = 3.25$) and W+Sp-C group ($M = 1.65$, $SD = 3.39$); $t\ (167) = .11$, $p = .911$ (see Table 42).

Table 41. Descriptive Statistics for Students' Achievement Scores in Sg+Sp-C and W+Sp-C Conditions

Groups	Mean	*St. Dev.*	n
Sg+Sp-C	1.71	3.25	75
W+Sp-C	1.65	3.39	94

Table 42. Independent Sample t-Test for Students' Achievement Scores in Sg+Sp-C and W+Sp-C Conditions

Levene Statistic						
F	*Sign.*	*t*	*df*	*Sig.* (2-tailed)	Mean Difference	Std. Error Difference
.238	.626	.112	167	.911	.058	.516

5.10 Covariate effects

5.10.1 Covariate effects on the achievement score

In order to test whether prior science score level, prior unit knowledge level about the learning unit and the multimedia treatments together or pairwise influence the students' learning of the unit, a general linear model 2x2x10 ANOVA test was conducted.

To conduct test of covariate effects, the participants' prior science grades and their scores in the electricity pre-test were first inspected to categorize the grades and scores. In categorization of prior science grades, categorization rules of the NONE was used. The prior science grades lower than 55 out of 100 constituted the low science grade group (n = 375), and the ones higher than or equal to 55 out of 100 constituted the high science grade group (n = 449). Similarly, categorization of participants' knowledge of the electricity unit before the treatments was based on their pre-test scores, whose mean is 4.48 out of 20. The pre-test scores lower than 4.48 constituted the low unit knowledge group (n = 429), and the ones higher than 4.48 constituted the high unit knowledge group (n = 395). According to a general linear model 2x2x10 ANOVA test, the following statistical outcomes were found (see Table 43);

(1) There was not a statistically significant three-way interaction between the multimedia treatment, students' prior science level and their pre-test level on achievement score of students, $F(9, 784) = .776$, $p = .636$.

(2) There was not a statistically significant two-way interaction between students' prior science level and their pre-test level on achievement score of students, $F(1, 784) = 1.027$, $p = .311$.

(3) There was not a statistically significant two-way interaction between the multimedia treatment and students' pre-test level on achievement score of students, F (9, 784) = .748, p = .655.

(4) There was not a statistically significant two-way interaction between the multimedia treatment and students' prior science level on achievement score of students, F(9, 784) = 1.159, p = .318.

However, all these three independent variables, multimedia treatments [F (9, 784) = 2.674, p = .005], students' prior science level [F (1, 784) = 87.031, p = .0001], and students' unit pre-test level [F (1, 784) = 169.914, p = .0001] independently influence students' unit achievement scores.

Table 43. Three-way ANOVA Test for Students' Achievement Scores in Multimedia Conditions

Source	Type III Sum of Squares	*df*	Mean Square	*F*	*Sig.*	Partial Eta Squared
Treatment	204.348	9	22.705	2.674	.005	.030
Science	738.979	1	738.979	87.031	.000	.100
Pretest	1442.737	1	1442.737	169.914	.000	.178
Treatment * Science	88.586	9	9.843	1.159	.318	.013
Treatment * Pretest	57.162	9	6.351	.748	.665	.009
Science * Pretest	8.719	1	8.719	1.027	.311	.001
Treatment * Science * Pretest	59.514	9	6.613	.779	.636	.009
Error	6656.912	784	8.491			
Total	11765.000	824				

5.10.2 Covariate effects on the conceptual achievement score

In order to test whether prior science score level, prior unit knowledge level and the multimedia treatments together or pairwise influence the students' conceptual achievement in the unit, a general linear model 2x2x10 ANOVA test was conducted. According to a general linear model 2x2x10 ANOVA test, the following statistical outcomes were found (see Table 44):

(1) There was not a statistically significant three-way interaction between the multimedia treatment, students' prior science level and their pre-test level on conceptual achievement score of students, $F(9, 784) = .318$, $p = .969$.

(2) There was not a statistically significant two-way interaction between students' prior science level and their pre-test level on conceptual achievement score of students, $F(1, 784) = .053$, $p = .818$.

(3) There was not a statistically significant two-way interaction between the multimedia treatment and students' pre-test level on conceptual achievement score of students, $F(9, 784) = .676$, $p = .731$.

(4) There was not a statistically significant two-way interaction between the multimedia treatment and students' prior science level on conceptual achievement score of students, $F(9, 784) = .565$, $p = .826$.

However, all these three independent variables, multimedia treatments [$F(9, 784) = 2.398$, $p = .011$], students' prior science level [$F(1, 784) = 45.658$, $p = .0001$], and students' unit pre-test level [$F(1, 784) = 98.879$, $p = .0001$] independently influence students' unit conceptual achievement scores. Table 45 shows the descriptive statistics for students' conceptual knowledge in pre-test and post-test.

Table 44. Three-way ANOVA Test for Students' Conceptual Achievement Scores in Multimedia Conditions

Source	Type III Sum of Squares	*df*	Mean Square	*F*	*Sig.*	Partial Eta Squared
Treatment	79.174	9	8.797	2.398	.011	.027
Science	167.525	1	167.525	45.658	.000	.055
Pretest	362.799	1	362.799	98.879	.000	.112
Treatment * Science	18.661	9	2.073	.565	.826	.006
Treatment * Pretest	22.311	9	2.479	.676	.731	.008
Science * Pretest	.194	1	.194	.053	.818	.000
Treatment * Science * Pretest	10.505	9	1.167	.318	.969	.004
Error	2876.588	784	3.669			
Total	4169.000	824				

Table 45. Descriptive Statistics for Students' Conceptual Knowledge in Pre-test and Post-test

Groups	Pre-test		Post-test		Achievement		Cohen's
	Mean	*St. Dev.*	Mean	*St. Dev.*	Mean	*St. Dev.*	*d*
W-A	2.19	1.52	2.61	1.48	.42	1.87	.27
W-C	2.31	1.51	2.74	1.69	.43	1.88	.26
Sg-A	1.99	1.38	3.09	1.66	1.10	1.75	.72
Sg-C	1.99	1.58	2.79	1.76	.80	2.10	.47
Sp-A	2.11	1.65	2.90	1.80	.80	2.24	.45
Sp-C	1.86	1.49	3.21	2.08	1.36	1.98	.74
W+Sp-A	2.16	1.66	3.16	1.84	1.00	2.04	.57
W+Sp-C	2.44	1.61	3.19	1.88	.76	2.10	.42
Sg+Sp-A	2.25	1.71	3.57	2.03	1.31	2.22	.70
Sg+Sp-C	2.17	1.48	3.27	1.96	1.09	2.26	.63

5.10.3 Covariate effects on the procedural achievement score

In order to test whether prior science score level, prior unit knowledge level and the multimedia treatments together or pairwise influence the students' procedural achievement in the unit, a general linear model 2x2x10 ANOVA test was conducted. According to a general linear model 2x2x10 ANOVA test, the following statistical outcomes were found (see Table 46);

(1) There was not a statistically significant three-way interaction between the multimedia treatment, students' prior science level and their pre-test level on procedural achievement score of students, $F(9, 784) = .991$, $p = .446$.

(2) There was not a statistically significant two-way interaction between students' prior science level and their pre-test level on procedural achievement score of students, $F\ (1, 784) = 1.549$, $p = .214$.

(3) There was not a statistically significant two-way interaction between the multimedia treatment and students' pre-test level on procedural achievement score of students, $F\ (9, 784) = .847$, $p = .573$.

(4) There was not a statistically significant two-way interaction between the multimedia treatment and students' prior science level on procedural achievement score of students, $F(9, 784) = 1.214$, $p = .283$.

However, two independent variables, students' prior science level [$F\ (1, 784) = 49.767$, $p = .0001$], and students' unit pre-test level [$F\ (1, 784) = 87.991$, $p = .0001$] independently influence students' unit procedural achievement scores but multimedia treatments [$F\ (9, 784) = 2.398$, $p = .084$] independently do not influence students' unit procedural achievement scores. Table 47 shows the descriptive statistics for students' procedural knowledge in pre-test and post-test.

Table 46. Three-way ANOVA Test for Students' Procedural Achievement Scores in Multimedia Conditions

Source	Type III Sum of Squares	*df*	Mean Square	*F*	*Sig.*	Partial Eta Squared
Treatment	62.470	9	6.941	1.703	.084	.019
Science	202.806	1	202.806	49.767	.000	.060
Pretest	358.576	1	358.576	87.991	.000	.101
Treatment * Science	44.514	9	4.946	1.214	.283	.014
Treatment * Pretest	31.059	9	3.451	.847	.573	.010
Science * Pretest	6.312	1	6.312	1.549	.214	.002
Treatment * Science * Pretest	36.355	9	4.039	.991	.446	.011
Error	3194.903	784	4.075			
Total	4564.000	824				

Table 47. Descriptive Statistics for Students' Procedural Knowledge in Pre-test and Post-test

Groups	Pre-test		Post-test		Achievement		Cohen's
	Mean	*St. Dev.*	Mean	*St. Dev.*	Mean	*St. Dev.*	*d*
W-A	2.18	1.69	2.68	1.63	.63	2.24	.30
W-C	2.27	1.28	3.06	1.83	.41	1.97	.50
Sg-A	1.98	1.26	2.87	1.83	1.08	2.19	.56
Sg-C	2.00	1.30	2.87	1.60	.97	1.95	.59
Sp-A	2.32	1.40	3.73	1.93	1.41	2.21	.83
Sp-C	2.34	1.47	3.12	1.78	.78	2.12	.47
W+Sp-A	2.47	1.65	3.49	1.92	1.02	2.30	.56
W+Sp-C	2.62	1.51	3.51	1.91	.89	2.28	.51
Sg+Sp-A	2.48	1.55	3.63	2.15	1.15	2.22	.61
Sg+Sp-C	2.75	1.79	3.36	1.68	.61	2.11	.35

CHAPTER 6

DISCUSSION AND CONCLUSION

The main purpose of the study was to examine the effects of modality, redundancy, and signaling principles in a multimedia setting with abstract or concrete representations of animation on learning about electricity. Earlier research on these principles has mostly been conducted with college students and adults in narrow and unrealistic experimental learning settings, and in cause-and-effect systems. Their effect on young students' learning in real school settings needed investigation. The current research, therefore, studied how various verbal and pictorial presentation types influence middle school students' learning in a multimedia instruction.

In this chapter, first, the results of the data are discussed in view of the literature and possible implications of the findings are presented. Finally, limitations of the study and recommendations for further research are provided.

6.1 Abstract versus concrete

The first question of the study focused on whether abstract or concrete representation of animations with text representations (written, signaled written, spoken, written and spoken, or signaled written and spoken) affect middle school students' learning of electricity.

Five different independent sample t-tests were performed for five different text representation types to compare achievement scores of the matched groups and, accordingly, to answer this question. All tests revealed that the mean achievement scores of the matched groups were not significantly different. Such findings confirmed earlier findings (e.g., Kaminski, Sloutsky & Heckler, 2006) alleging that children do not need concrete representation to understand science concepts. However, this finding is in contrast with yet other research studies; for example, Jaakkola et al. (2014) found that concrete components in a multimedia instruction resulted in better learning compared to abstract components. Moyer (2001) claimed that children are more adaptive to concrete representations. In addition, a few other researchers (e.g., Moreno et al., 2011; Johnson et al., 2014) found out that the use of abstract representations results in better learning compared to concrete representations.

Mayer and Moreno (2003) advised that special attention should be paid when the type of visual representation is used in multimedia animations because it may cause cognitive overload for learners. The degree of cognitive load correlated with abstract or concrete representation may change according to learning unit, learning objectives, and students' background knowledge (Dwyer, 1978). Sometimes, using an abstract representation may be beneficial to students' learning. Similarly, after a study with college school students, Tversky et al. (2002) asserted that a basic abstract representation may be more helpful than several concrete examples to present information to learners because it allows learners to easily focus on learning objectives. The current study also showed that multimedia designers may not need to use concrete representation throughout a courseware for a learning unit.

6.2 The modality effect

The second question of the study focused on the modality effect on a multimedia setting with abstract or concrete representation of animation for middle school students' learning electricity. Two different independent sample t-tests were conducted to compare achievement of spoken text groups and the written text groups studying with a multimedia instruction consisting of abstract or concrete representation of animation. The tests revealed that there was a significant difference between the achievement scores of spoken text groups and written text groups. The spoken text representation groups — Sp-A (M = 2.20, SD = 3.43) and Sp-C (M = 2.13, SD = 3.61) — had significantly higher achievement scores than the written text representation groups: W-A (M = 1.05, SD = 3.08) and W-C (M = .84 SD = 3.67) in electricity unit. While this result confirms the findings of many other studies investigating the modality effect (e.g., Mayer & Moreno, 1999), the result is not the same for all studies (e.g., Cheon et al., 2013) which had counter-arguments for modality. The first assumption of CTML, the dual-channel assumption, advises one to present information in more than one modality (Mayer, 2001). Similarly, some researchers (e.g., Mousavi et al., 1995; Velayo & Quirk, 2000) found that students performed better when information was presented with dual modality. While this assumption claims that human information-processing system consists of an auditory channel and a visual channel, the limited capacity assumption asserts that each of these channels is limited to processing information simultaneously (Baddeley, 1992). The achievement score differences between the two matched groups may be explained by claims of these assumptions because, while the spoken text groups had opportunity to study with a multimedia instruction consisting of auditory explanations and abstract or concrete animation, the written text groups studied with a multimedia instruction consisting of visual text explanations and abstract or concrete animation. The written text groups probably had to split their attention between pictorial information and textual information. This plausible situation caused trouble for their limited visual channel capacity.

The third question of the study examined whether the effects of the spoken text modality and the signaled written text modality on an electricity unit achievement differ in a multimedia setting with abstract or concrete representation of animation. Two different independent sample t-tests were conducted to compare the achievement of the spoken text groups and the signaled written text groups studying in a multimedia instruction with abstract or concrete representation of animation and, accordingly, to answer this question. The tests revealed that the spoken text representation groups — Sp-A (M = 2.20, SD = 3.43) and Sp-C (M = 2.13, SD = 3.61) — had higher achievement scores than the signaled written text representation groups Sg-A (M = 2.18, SD = 3.21) and Sg-C (M = 1.67, SD = 3.10) in the electricity unit, but the difference was not significant. This finding is not in line with the modality principle of the CTML. According to CTML, presenting visual pictorial information and visual textual information simultaneously in a multimedia instruction overloads students' visual channel. Signaling used in the written text possibly reduced extraneous processing in the students' visual channel by providing guidance which may have helped them to focus on the most important concepts, detail, and information in the multimedia instruction.

The findings for the second question of the study suggest that the modality principle may be applied to middle school learners when they study abstract or concrete representations of animation of multimedia learning in a science context. However, the finding for the third question of the study must be interpreted with caution, as this finding provides conflicting results for the modality principle. The result from these findings have implications for the CTML and may provide valuable information for multimedia instruction designers and educators; that is, if it is possible to present textual information in spoken form, it should be presented; but if it is not, it should be presented in the form of written text with signaling.

6.3 The redundancy effect

The fourth question of the study explored the redundancy effect on a multimedia setting with abstract or concrete representation of animation for middle school students' learning electricity. To answer this question, two different independent sample t-tests were conducted by comparing achievement of the redundant text groups and the non-redundant text groups studying with a multimedia instruction consisting of abstract or concrete representations of animation. The tests revealed that the non-redundant groups — Sp-A (M = 2.20, SD = 3.43) and Sp-C (M = 2.13, SD = 3.61) — have higher achievement scores than the redundant groups: W+Sp-A (M = 2.02, SD = 3.52) and W+Sp-C (M = 1.65, SD = 3.39) in electricity unit; nevertheless, the difference was not significant. According to CTML, it was predicted that the non-redundant groups would get higher achievement scores than the redundant groups; Kalyuga et al. (2004), also found that using only a spoken text presentation in a multimedia instruction provided better learning than using spoken text and written text presentation at the same time. That is due to the fact that using several different sources for giving the same information or message may cause split-attention effect, and results in no learning. In addition, Clark and Mayer (2011) claimed that learners probably pay less attention to the pictorial materials in a multimedia instruction when redundant materials are used. Many researchers (e.g., Austin, 2009; Clark & Lean, 2011; Leahy et al., 2003) advised that when designing an online learning environment, redundancy should be considered. Further, Moreno and Mayer (2002) found that written and spoken text representation together gave a greater learning opportunity to students compared to the spoken text only presentation. However, the result of this study showed that redundancy did not have a significantly positive or negative effect on learning. Similarly, McTigue (2009), studied the redundancy effect with middle school students in science instruction, and his study did not support the redundancy principle. He argued that the redundancy principle should not be applied to younger learners in a classroom setting (2009). Mayer (2009) further asserted that there is a possible visual or verbal channel overload for learners with a redundant presentation. One possible explanation for this result is that the students who studied with redundant instruction probably ignored the written text representation, and hence unintentionally avoided cognitive overload. If eye-tracking tools had been used to collect data from the participants during the multimedia instruction, whether they ignored the written text representation or not could be determined more precisely.

The fifth question of the study focused on whether the effects of the spoken text modality, and the signaled written text and spoken text modality on the electricity unit achievement differ in a multimedia setting with abstract or concrete representation of animation. The main difference of this question from the previous question is that this one aims to investigate how redundancy is affected by redundant signaled written text in a multimedia instruction. Two different independent sample t-tests were conducted to compare the achievement of the redundant text groups and the non-redundant text groups studying with a multimedia instruction consisting of abstract or concrete representation of animation and, accordingly, to answer this question. The tests provided two different results in terms of redundancy effect: (1) one test conducted with students studying with abstract representation revealed that the redundant group — Sg+Sp-A (M = 2.46, SD = 3.65) — had higher achievement scores than the non-redundant groups Sp-A (*M* = 2.20, *SD* = 3.43), but the difference was not significant (*d* = .07). (2) The other test conducted with the students studying concrete representation revealed that the non-redundant group — Sp-C (*M* = 2.13, *SD* = 3.61) — had higher achievement scores than the redundant group: Sg+Sp-C (*M* = 1.71, *SD* = 3.25), but the difference was not significant (*d* = .12). These findings are in contrast with the redundancy principles of the CTML. For example, Moreno and Mayer (2002) had conducted a study to test redundancy effect in a multimedia game, and they also found only a small effect size (*d* = .19) of redundancy. If the students had studied with the multimedia instruction consisting of redundant signaled written text, the authors explained, the students might have ignored the redundant material, and their processing of the material might have been similar to those who studied with the multimedia instruction consisting of non-redundant material.

6.4 The signaling effect

In order to investigate the signaling principle, the sixth question of the study focused on the signaling effect on a multimedia setting with abstract or concrete representations of animation for middle school students' learning electricity. To answer this question, two comparisons were made. Two different independent sample t-tests were conducted to compare the written text and the signaled written text groups studying with a multimedia instruction consisting of abstract or concrete representation of animation: (1) the first test conducted with students studying in a multimedia instruction consisting of abstract representation of animation revealed that the signaling group — Sg-A (*M* = 2.18, *SD* = 3.21) — had significantly higher achievement scores than the non-signaling group — W-A (*M* = 1.05, *SD* = 3.08) — in an electricity unit; (2) the second test conducted with students studying in a multimedia instruction consisting of concrete representation of animation revealed that the signaling group — Sg-C (*M* = 1.67, *SD* = 3.10) — had higher achievement scores than the non-signaling group — W-C (*M* = .84, *SD* = 2.67) — on an electricity unit, but the difference was not significant. Mayer (2009) stated that "signaling reduces extraneous processing by guiding the learner's attention to the key elements in the lesson and guides the learner's building of connections between them" (p. 108). Multimedia learning environments may contain many extraneous or unimportant components. Thus, learners, especially low-experienced ones, usually have trouble eliminating unimportant components and focusing on important components, and these environments may also bring extraneous cognitive overload to them. Ozcelik et al. (2010) conducted a research study and collected eye movement data with an eye-tracking device. Their data showed that signaling guided students to essential and relevant information about the learning unit, whereas non-signaling group students usually ignored them. According to CTML, it is expected that a signaling group will significantly outperform the non-signaling group in achievement. The current study does not entirely agree with CTML, and does not agree with the signaling principle of CTML because, while the achievement of the group with abstract representation was significantly affected by signaling effect, the group with the concrete representation was not. A possible explanation is that even though students in the non-signaling group with concrete representation of animation had to split their attention between the text and animation, they still had time to construct a mental model of the information. On the other hand, the non-signaling group with an abstract representation of animation possibly did not have time to construct a mental model of the information. This conflicting result may serve as a catalyst for additional research.

The seventh question of the study investigated whether the effects of written text and spoken text modality, and signaled written text and spoken text modality on electricity unit achievement differ in a multimedia setting with abstract or concrete representation of animation. The main difference of this question from the previous question is that this question aims to examine whether the signaling effect holds true for a multimedia instruction with redundant materials. To answer this question, two statistical comparisons were made: Two different independent sample t-tests were conducted to compare the written text and the signaled written text groups studying a multimedia instruction with abstract or concrete representation of animation. In contrast to the earlier studies of signaling principles (e.g., Ozcelik et al., 2010), the tests revealed that the signaling groups — Sg+Sp-A (M = 2.46, SD = 3.65) and Sg+Sp-C (M = 1.71, SD = 3.25) — had higher achievement scores than the non-signaling groups: the W+Sp-A group (M = 2.02, SD = 3.52) and the W+Sp-C (M = 1.65, SD = 3.39) on an electricity unit, but the difference was not significant. This may be explained as all of the compared groups possibly ignored the written or signaled written text, and they listened to the spoken text to acquire information.

6.5 Covariate effects of prior knowledge about the learning unit and prior science grade, and treatment on learning

In order to investigate how prior science grade, prior knowledge of the unit and the multimedia treatments together or pairwise influence the students' learning of the unit, a general linear model 2x2x10 ANOVA test was conducted. The test revealed that there were not any significant three-way or two-way interactions among prior science scores, prior knowledge about the unit, or the multimedia treatments on students' achievement scores. In addition, two similar tests were conducted to investigate how these three independent variables affect students' conceptual and procedural knowledge in the learning unit. These two tests also revealed that there were not any significant three-way or two-way interactions among prior science scores, prior knowledge about the unit and the multimedia treatments on students' conceptual and procedural knowledge. However, while all these three independent variables independently influenced the learning of conceptual knowledge, only students' prior science scores and prior knowledge about the unit independently influenced students' learning of procedural knowledge. The treatment did not significantly affect learning of procedural knowledge. To construct procedural knowledge, students should apply conceptual knowledge in new situations. The treatments of the study provided students with limited opportunities to practice and apply conceptual and procedural knowledge in different settings and problem cases.

6.6 Implication for practice

The current study has beneficial theoretical and practical implications for the CTML, and may provide valuable information for multimedia designers and teachers.

The present study is the first to directly examine the modality, redundancy, and signaling effects on abstract and concrete representations of an animation of electricity unit in real middle school settings. The findings about modality effect are largely consistent with the predictions of the CTML (Mayer & Moreno, 1999; Mayer, 2005; Mayer, 2009). The modality principle emphasizes that visual materials, especially animations, should be used with words formed in audial type instead of written type. From a practical standpoint, these findings suggest that multimedia designers as well as teachers should take advantage of the modality principle when developing learning material for middle school students. They should prefer using narration rather than on-screen text with visual materials in a multimedia instruction for more effective learning. In this way, it is possible to avoid extraneous cognitive load for learners. However, the findings of the present study were not in agreement with the findings of some research about redundancy principle (e.g., Austin, 2009; Clark & Lean, 2011; Leahy et al., 2003) and signaling principle (e.g., Loman & Mayer, 1983; Mayer et al., 1984). The result of the current study showed that redundancy and signaling did not have a significantly positive or negative effect on learning. One possible explanation for this result is that the students who studied with redundant instruction probably ignored the written text representation, and hence unintentionally avoided cognitive overload. In addition, even though students in the non-signaling group had to split their attention between the text and animation, they still had time to construct a mental model of the information. For this reason, these principles need further research to examine with middle school level.

Additionally, the present study aimed to examine applying the modality, redundancy, and signaling principles would be beneficial when using with abstract and concrete representations of animations. According to Mayer and Moreno (2003), special attention should be paid when the type of visual representation is used in multimedia animations because it may cause cognitive overload for learners. The findings about animation representation type are consistent with some previous studies (e.g., Kaminski, Sloutsky & Heckler, 2006). This study found that children do not always need concrete representation to understand science concepts, and suggests that multimedia designers may not always need to use concrete representation throughout a courseware for a learning unit. Sometimes, using an abstract representation may be beneficial to students' learning. Multimedia designers and teachers should be aware of the degree of cognitive load correlated with abstract or concrete representation may change according to learning unit, learning objectives, and students' background knowledge.

6.7 The limitation of the study and recommendations for further research

This study was limited by following factors in terms of sampling and methodology. The results of the study should be cautiously generalized to larger population of students. While the study was conducted with large number of students in four schools in four different cities, convenience sampling was used, so the current study should be replicated using a true experimental design in order to increase generalizability.

The second limitation of the study was the lack of additional instruments such as a measure of reading comprehension skills, working memory and attitude towards the treatment conditions. These measurements may provide further information about variables which are critical to learning. In addition to this, interviewing students may provide some useful information the principles of multimedia.

Using only immediate post-testing in the study may be considered a limitation. A delayed post-test for the learning unit was not conducted. After a certain period of time, students' learning and recall should be measured.

The differences between abstract and concrete representation of animation were not sufficiently presented, because the electricity unit had many abstract concepts and it was difficult to present them in a concrete way in computer-based settings. For this reason, the current study should be replicated with different treatment materials (e.g., hands-on activities along with multimedia materials) aimed to teach science content in order to increase generalizability.

The findings cannot be generalized to multimedia instructions for all science learning units in middle school. More research is necessary to find out whether or not the effects of CTML and the principles of multimedia learning can be generalized to other middle school units.

Finally, measuring cognitive load may allow testing of the multimedia principles more accurately. Eye-tracking and electroencephalography can be used to examine the multimedia principles of CTML thoroughly.

APPENDIX A

PARTICIPANT INFORMATION AND CONSENT FORM

KATILIMCI BİLGİ ve ONAM FORMU

Araştırmanın adı: Elektrik konusu öğreniminde çoklu öğrenme ortamlarında somut ve soyut gösterimlerle duyu biçimi, gereksizlik ve dikkat çekme ilkelerinin etkilerinin incelenmesi

Proje Yürütücüsü: Prof. Dr. Yavuz Akpınar (Tez Danışmanı)

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Proje konusu:

Bu çalışma "duyu biçimi, gereksizlik ve dikkat çekme ilkelerinin etkisinin elektrik konusu öğreniminde bilgisayar ortamındaki somut ve soyut gösterimlerle öğrenmeye etkisini incelemeyi" amaçlamaktadır. Çalışma öncesi katılımcıların elektrik konusu ön bilgilerini ölçmek için bir ön test verilecektir. Çalışmada katılımcılar fen ve teknoloji müfredatlarında yer alan elektrik konusunu altı farklı bilgisayar yazılımından kendilerine atanan bir tanesi ile çalışacaklardır. Katılımcılar bireysel çalışmalarını tamamladıktan sonra elektrik konusundaki bilgilerini ölçmek için çalışma öncesinde verilen ön test paralel olan bir son test verilecektir. Bu çalışmaların yürütülmesi okuldaki bir ders öğretmeni ve bilgisayar öğretmeninin gözetimi ile gerçekleşecektir. Onam: Bu çalışma bilimsel bir amaçla yapılmaktadır ve katılımcı bilgilerinin gizliliği esas tutulmaktadır. Bu çalışma kapsamında yapılacak bilgisayar yazılımlarıyla elektrik konusu öğretimi etkinliklerinde öğrencilerden alınacak elektrik ön ve son test sınav puanları ile soyut düşünme testi puanları gizli tutulacaktır. Bir öğrencinin sadece kendi puanları kendisiyle paylaşılacak, diğer öğrenciler ve başkalarının herhangi bir öğrencinin ilgili puanlarına ulaşımı olmayacaktır. Veriler derlendikten sonra öğrenci isimleri kodlanacak (ör. Ayşe Ak için 2016_101_0, Ali Er için 2016_102_1 gibi) ve verilerin işlenmesi ve raporlanması sırasında bu kodlar kullanılacaktır. Elde edilen verilerin herhangi bir öğrenci ismi ve okul ismi ile birlikte paylaşılması söz konusu olmayacaktır. Yapmak istediğimiz araştırmanın katılımcılara risk getirmesi beklenmemektedir. Söz konusu araştırmanın tez çalışmasına olduğu kadar öğretmen ve öğrencilerinize de katkısının olacağı düşünülmektedir. Tez çalışması hakkında ek bilgi almak istediğiniz takdirde lütfen Boğaziçi Üniversitesi Bilgisayar ve Öğretim Teknolojileri Eğitimi Bölümü Araştırma Görevlisi Ekrem Kutbay ile temasa geçmekten çekinmeyiniz (Telefon: 02123597789 / 05373802217 Adres: BOGAZİÇİ ÜNİVERSİTESİ EGİTİM FAKÜLTESİ, ETA B BLOK 502 KUZEY KAMPÜS ETİLER 34342, İstanbul). Araştırmayla ilgili haklarınız konusunda yerel etik kurullarına da danışabilirsiniz.

Bana anlatılanları ve yukarıda yazılanları anladım. Formun bir örneğini aldım / almak istemiyorum (bu durumda araştırmacı bu kopyayı saklar).

Çalışmaya katılmayı kabul ediyorum.

Katılımcı Adı-Soyadı:…………………………………..
İmzası:………………………………………………
Tarih (gün/ay/yıl):........./.........../.............

Varsa Katılımcının Vasisinin Adı-Soyadı:..
İmzası:...
Tarih (gün/ay/yıl):........./.........../.............

18 YAŞ ALTI KATILIMCI VARSA:
Varsa Katılımcının VELİSİNİN Adı-Soyadı:..
İmzası:...
Tarih (gün/ay/yıl):........./.........../.............

Hekim/genetikçi Adı-Soyadı:…………………………………..
İmzası:...
Tarih (gün/ay/yıl):........./.........../.............

APPENDIX B

LEARNING OBJECTIVES OF THE INSTRUCTIONAL MATERIALS

Students will be able

- to state that some materials or bodies can be electrified when they come into contact with each other.
- to state that after being electrified in the same way, two materials of the same kind repulse each other without touching.
- to state that after being electrified in a different way, two materials of different kinds attract each other without touching.
- to conclude that there are two kinds of electrical charge based on the results of experiments and to describe that those electric charges are referred to as positive (+) and negative (–).
- to state that the same electric charges repulse each other and different electric charges attract each other.
- to refer to the bodies which have equal amount of positive and negative electric charges as “neutral bodies”.
- to interpret from observation that when a charged body comes into contact with another body, the other body is charged with the same electrical charge and those bodies, then, can then repulse each other.
- to state that bodies exchange negative charges during the electrification process and to interpret that the exchange process results in a positive or negative charge excess (charge imbalance).
- to refer to the flow of negative charge from charged bodies to soil and from soil to charged bodies as “grounding”.

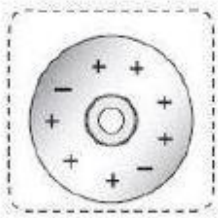
- to state that electric current is a type of energy transfer.
- to express that electrical energy resources provide electric current for a circuit.
- to state that there should be a closed circuit in order to have current in an electric circuit.
- to state that the direction of the current in an electric circuit is adopted from the positive pole to the negative pole of the generator, and to demonstrate the direction of the current on a circuit schema.
- to show how to connect an ammeter to a circuit and to state that a unit of current is referred to as “ampere”.
- to identify voltage as the indication of an energy gap that will lead to a current between two ends of a conductor.
- to show how to connect a voltmeter to a circuit and to tell that the voltage unit is referred to as “volt”.
- to interpret the relationship between the voltage between the ends of a circuit component and the current passing through it.
- to identify resistance as the division of the voltage between two ends of a circuit component by the current going through it.
- to describe Volt/Ampere value as equivalent to “Ohm”.

APPENDIX C

PRETEST

(The test was translated into English by the researcher.)

1-



Which of the following is true about charge condition of the object on the left?

a) It is a positively charged object
b) It is a negatively charged object
c) It is a neutral object
d) It is a both negatively and positively charged object

2-

What can be said about the interaction that will occur between the objects above, when they approach to each other?

a) The comb and the mug stay still
b) The comb pulls the mug
c) The mug repulses the comb
d) The comb and the mug pull each other

Answer the 3rd and 4th questions according to states of the objects below.

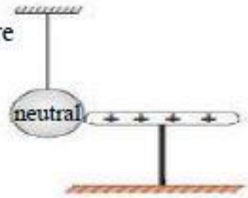
3- Which of the above is/are neutral object(s)?

a) Only K b) Only L c) K and L d) K, L and M

4- What can be said about the last charges of the object K and the object L, if the object K touches the object L?

a) The objects K and L are positively charged
b) The objects K and L are negatively charged
c) K is positively charged, while L is negatively charge
d) K and L are neutral

5- Which of the following happens when the neutral conductive sphere touches the positively charged stick on the right?



a) Positive charges move from the stick to the sphere
b) Negative charges move from the sphere to the stick
c) Negative charges move from the stick to the sphere
d) Positive charges move from the sphere to the stick

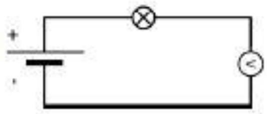
6- How do the materials electrified in the same way react, when they approach to each other?

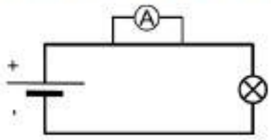
a) They repulse each other
b) They pull each other
c) They stay still
d) One pulls, while the other repulses

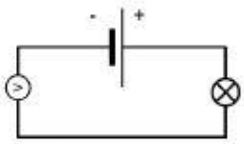
7- How do the materials electrified in different ways react, when they approach to each other?

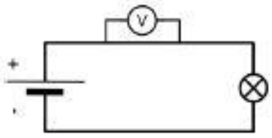
a) They repulse each other
b) They pull each other
c) They stay still
d) One pulls, while the other repulses

8- Which of the following circuits display correct connection of a voltmeter?

a) 

b) 

c) 

d) 

9- Which of the following is used to measure the tension in an electric circuit?

a) Ampere meter b) Power supply c) Ohmmeter d) Voltmeter

10- Which of the following is used to measure the current in an electric circuit?

a) Ampere meter b) Conducting wire c) Ohmmeter d) Voltmeter

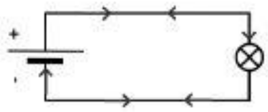
11- Which of the following is the unit for electric current?

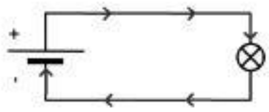
a) Ampere b) Liter c) Ohm d) Volt

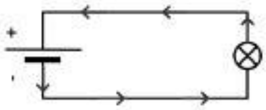
12- Which of the following is the unit for resistance?

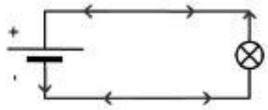
a) Ampere b) Kilogram c) Ohm d) Volt

13- Which of the following correctly shows direction of movement of the negative charges in the given electric circuits?

a) 

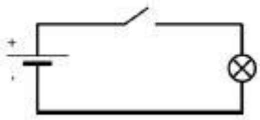
b) 

c) 

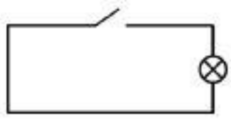
d) 

14- Which of the following circuits does the light source give light?

a) 

b) 

c) 

d) 

15- Which of the following statements is correct?

a) Electrification occurs, when all objects touch each other.
b) There are three kinds of electric charge.
c) The direction of the negative charges and the direction of the current in an electric circuit are reverse.
d) The charges in action in the electric circuit are positive.

16-

I. The flow of negative charge from charged objects to solid is named as grounding
II. The flow of positive charge from charged objects to solid is named as grounding
III. The flow of negative charge from solid to objects is named as grounding
IV. The flow of positive charge from solid to objects is named as grounding

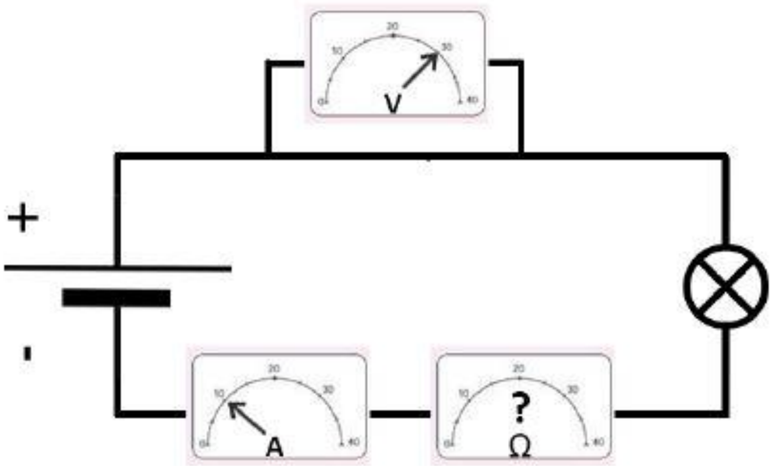
Which of the above statements is/are correct?

a) Only I b) Only III c) II and IV d) I and III

17- Which one of the following is the equation that shows the relationship between current, tension and resistance?

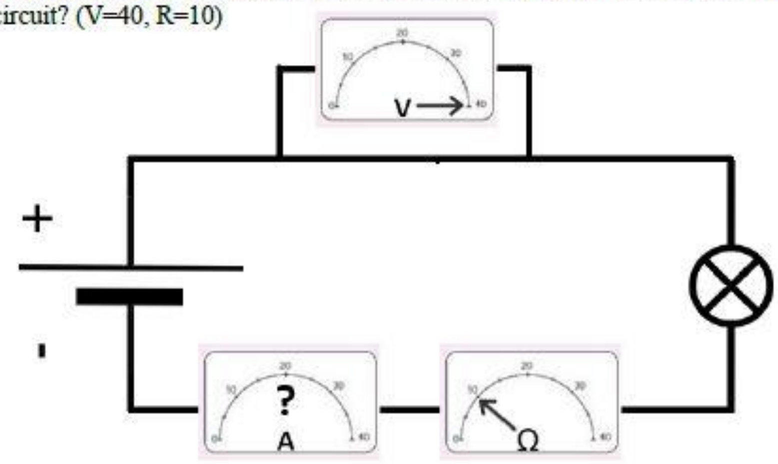
a) I = V.R b) R = V.I c) V = I.R d) R = I

18- In the following circuit, ampere meter measures the current passing through the circuit, and voltmeter measures the tension. According to those measurements, how many ohms is the resistance of the conductor in the circuit? (V=30, A=10)



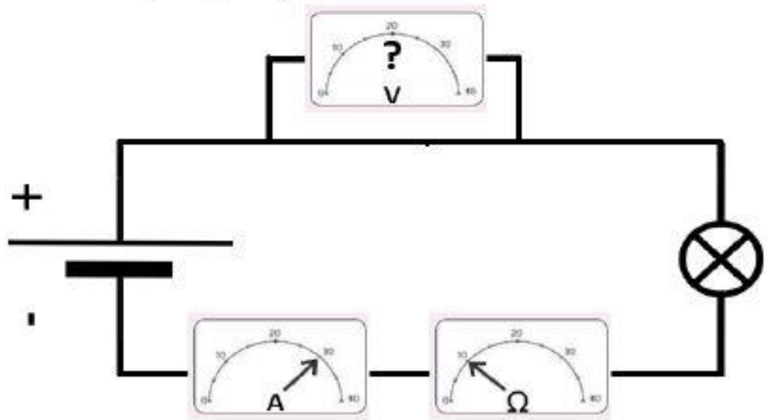
a) 3 b) 10 c) 30 d) 300

19- In the following circuit, voltmeter measures the tension of the circuit, and ohmmeter measures its resistance. According to those measurements, how many amperes is the current in the circuit? (V=40, R=10)



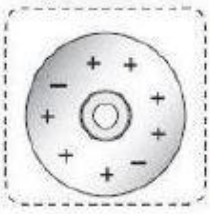
a) 4 b) 20 c) 40 d) 400

20- In the following circuit, ampere meter measures the current passing through the circuit, and ohmmeter measures the resistance. According to those measurements, how many volts is the tension of the circuit? (A=30, R=10)



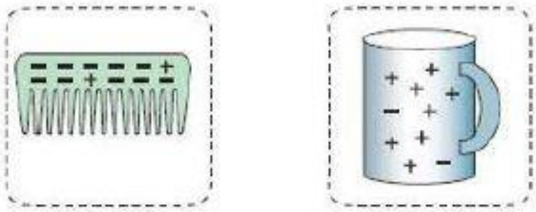
a) 3 b) 30 c) 300 d) 400

PRETEST (ORIGINAL TURKISH)

1- 

Sol tarafta yük durumu verilen cisim için aşağıdakilerden hangisi söylenebilir?

a) Pozitif yüklü cisimdir
b) Negatif yüklü cisimdir
c) Nötr cisimdir
d) Hem pozitif hem de negatif yüklü cisimdir

2- 

Yukarıda yük durumları verilen tarak ve kupa birbirlerine yaklaştırıldıklarında etkileşimleri hakkında ne söylenebilir?

a) Tarak ve kupa sabit kalır.
b) Tarak kupayı çeker.
c) Kupa tarağı iter.
d) Tarak ve kupa birbirlerini çekerler.

3. ve 4. soruları aşağıdaki cisimlerin durumlarına göre cevaplayınız.

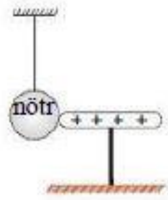
3- Nötr olan cisim ya da cisimler hangi seçenekte doğru verilmiştir?

a) Yalnız K b) Yalnız L c) K ve L d) K, L ve M

4- K cismi L cismine dokundurulsa K ve L'nin son yükleri için ne söylenebilir?

a) K ve L cisimleri pozitif yüklüdür.
b) K ve L cisimleri negatif yüklüdür.
c) K pozitif iken L negatif yüklüdür.
d) K ve L nötr 'dür.

5- Yandaki şekildeki nötr iletken küre, pozitif yüklü çubuğa dokunduruldüğunda aşağıdakilerden hangisi gerçekleşir?



a) Çubuktan küreye pozitif yükler hareket eder.
b) Küreden çubuğa negatif yükler hareket eder.
c) Çubuktan küreye negatif yükler hareket eder.
d) Küreden çubuğa pozitif yükler hareket eder.

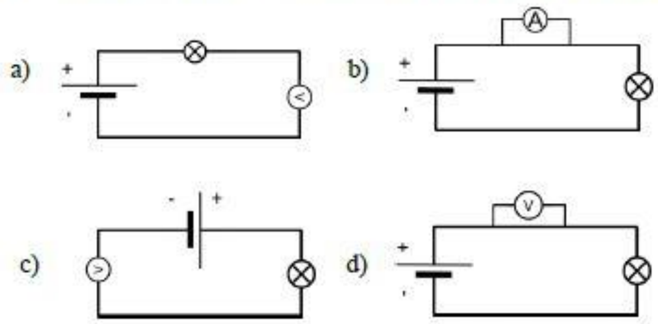
6- Aynı yolla elektriklenmiş maddeler birbirlerine yaklaştırıldıklarında nasıl tepki verirler?

a) Birbirlerini iterler.
b) Birbirlerini çekerler.
c) Hareketsiz kalırlar.
d) Biri iterken diğeri çeker.

7- Farklı yolla elektriklenmiş maddeler birbirlerine yaklaştırıldıklarında nasıl tepki verirler?

a) Birbirlerini iterler.
b) Birbirlerini çekerler.
c) Hareketsiz kalırlar.
d) Biri iterken diğeri çeker.

8- Voltmetre aşağıda verilen devrelerden hangisinde doğru bağlanmıştır?



9- Elektrik devresindeki gerilim aşağıdakilerden hangisi ile ölçülebilir?

a) Ampermetre b) Güç kaynağı c) Ohmmetre d) Voltmetre

10- Elektrik devresindeki akım aşağıdakilerden hangisi ile ölçülebilir?

a) Ampermetre b) İletken tel c) Ohmmetre d) Voltmetre

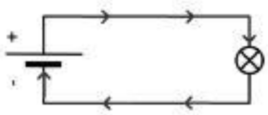
11- Elektrik akımının birimi aşağıdakilerden hangisidir?

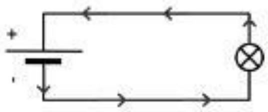
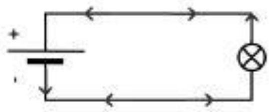
a) Amper b) Litre c) Ohm d) Volt

12- Direnç birimi aşağıdakilerden hangisidir?

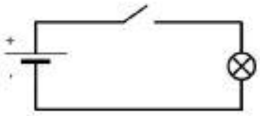
a) Amper b) Kilogram c) Ohm d) Volt

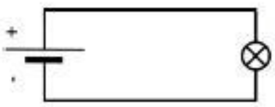
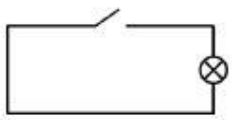
13- Elektrik devresindeki negatif yüklerin hareket yönü aşağıdakilerden hangisinde doğru verilmiştir?

a)  b) 

c)  d) 

14- Aşağıdaki devrelerin hangisinde ışık kaynağı ışık verir?

a)  b) 

c)  d) 

15- Aşağıdaki ifadelerden hangisi doğrudur?

a) Bütün cisimler birbirlerine temas ettiklerinde elektriklenme meydana gelir.
b) Deneysel sonuçlara dayanarak üç cins elektrik yükü olduğu sonucuna varılır.
c) Bir elektrik devresindeki negatif yüklerin yönü ile akımın yönü terstir.
d) Elektrik devresindeki hareket halinde olan yükler pozitif olanlardır.

16-

I. Yüklü cisimlerden toprağa negatif yük akışı topraklama olarak adlandırılır.
II. Yüklü cisimlerden toprağa pozitif yük akışı topraklama olarak adlandırılır.
III. Topraktan cisimlere negatif yük akışı topraklama olarak adlandırılır.
IV. Topraktan cisimlere pozitif yük akışı topraklama olarak adlandırılır.

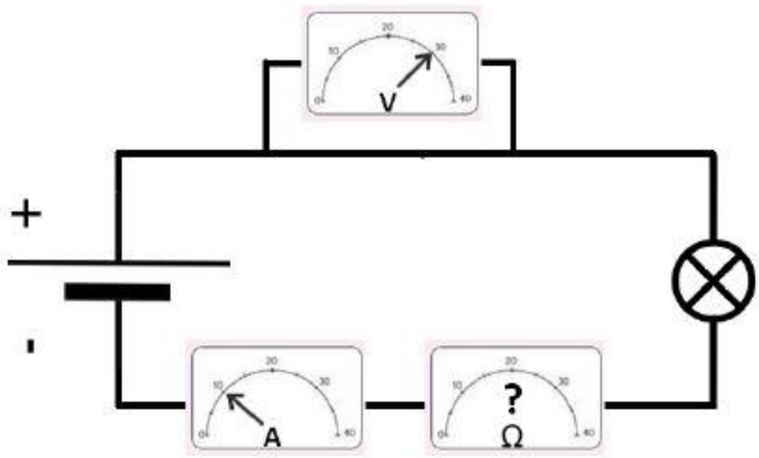
Yukarıdaki ifadelerden hangisi ya da hangileri doğrudur?

a) Yalnız I b) Yalnız III c) II ve IV d) I ve III

17- Aşağıdakilerden hangisi, akım, gerilim ve direnç arasındaki ilişkiyi gösteren eşitliktir?

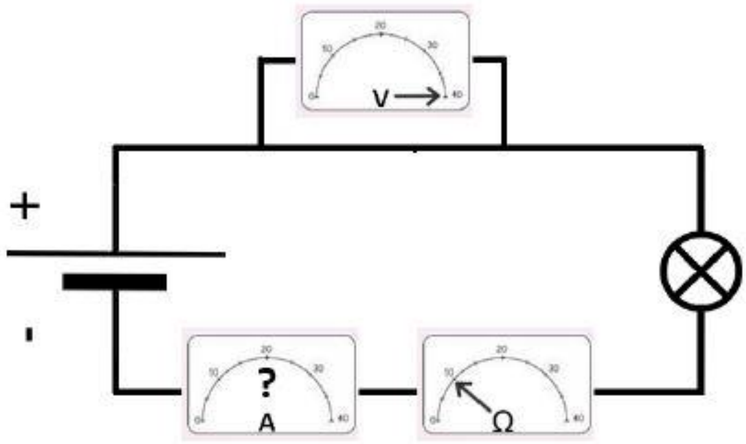
a) $I = V.R$ b) $R = V.I$ c) $V = I.R$ d) $R = I/V$

18- Aşağıdaki devrede ampermetre devreden geçen akımı, voltmetre ise gerilimi ölçmektedir. Bu ölçümlere göre devredeki iletkenin direnci kaç ohm olur? (V=30, A=10)



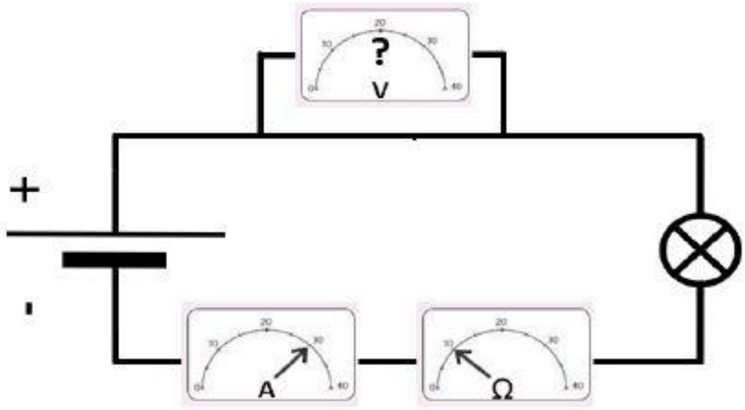
a) 3 b) 10 c) 30 d) 300

19- Aşağıdaki devrede voltmetre devrenin gerilimini, ohmmetre ise direncini ölçmektedir. Bu ölçümlere göre devredeki elektrik akımı kaç amper olur? (V=40, R=10)



a) 4 b) 20 c) 40 d) 400

20- Aşağıdaki devrede ampermetre devreden geçen akımı, ohmmetre ise direnci ölçmektedir. Bu ölçümlere göre devrenin gerilimi kaç volt olur? (A=30, R=10)



a) 3 b) 30 c) 300 d) 400

APPENDIX D

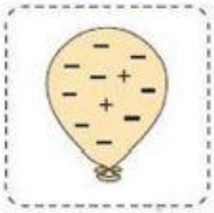
POSTTEST

(The test was translated into English by the researcher.)

1- 

Which of the following is true about charge condition of the object on the left?

a) It is a positively charged object
b) It is a negatively charged object
c) It is a neutral object
d) It is a both negatively and positively charged object

2-  

What can be said about the interaction that will occur between the objects above, when they approach to each other?

a) The kettle and the balloon stay still
b) The kettle pulls the balloon
c) The kettle and the balloon repulse each other
d) The kettle and the balloon pull each other

Answer the 3rd and 4th questions according to states of the objects below.

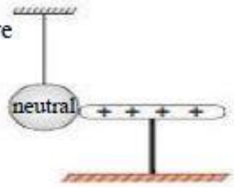
3- Which of the above is/are neutral object(s)?

a) Only K b) Only L c) K and L d) K, L and M

4- What can be said about the last charges of the object K and the object M, if the object K touches the object M?

a) The objects K and M are positively charged
b) The objects K and M are negatively charged
c) K is positively charged, while M is negatively charge
d) K and M are neutral

5- Which of the following happens when the neutral conductive sphere touches the positively charged stick on the right?



a) Positive charges move from the stick to the sphere
b) Negative charges move from the sphere to the stick
c) Negative charges move from the stick to the sphere
d) Positive charges move from the sphere to the stick

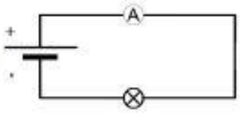
6- How do the materials electrified in the same way react, when they approach to each other?

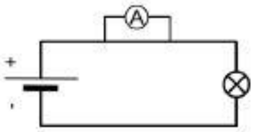
a) They repulse each other
b) They pull each other
c) They stay still
d) One pulls, while the other repulses

7- How do the materials electrified in different ways react, when they approach to each other?

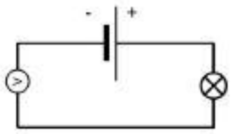
a) They repulse each other
b) They pull each other
c) They stay still
d) One pulls, while the other repulses

8- Which of the following circuits display correct connection of an ampere meter?

a) 

b) 

c) 

d) 

9- What does an ohmmeter measure?

a) Ampere circuit b) Weight c) Resistance d) Tension

10- What does a voltmeter measure?

a) Length b) Tension c) Resistance d) Electric current

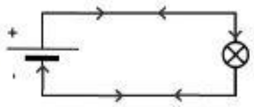
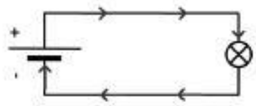
11- Which one of the following is unitised with ohm?

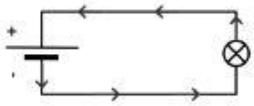
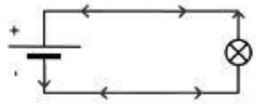
a) Tension b) Resistance c) Weight d) Electric current

12- Which one of the following is unitised with volt?

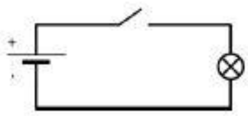
a) Electric current b) Resistance c) Tension d) Length

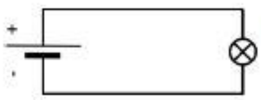
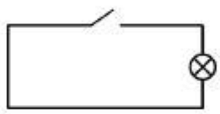
13- In which of the following is correctly shows direction of movement of negative charges in electric circuit given correctly?

a) 
b) 

c) 
d) 

14- In which of the following circuits does the light source give light?

a) 
b) 

c) 
d) 

15- Which of the following statements is correct?

a) Electrification occurs, when all objects touch each other.
b) There are three kinds of electric charge.
c) The direction of the negative charges and the direction of the current in an electric circuit are reverse.
d) The charges in action in the electric circuit are the positive ones.

16-

I. The flow of negative charge from charged objects to solid is named as grounding
II. The flow of positive charge from charged objects to solid is named as grounding
III. The flow of negative charge from solid to objects is named as grounding
IV. The flow of positive charge from solid to objects is named as grounding

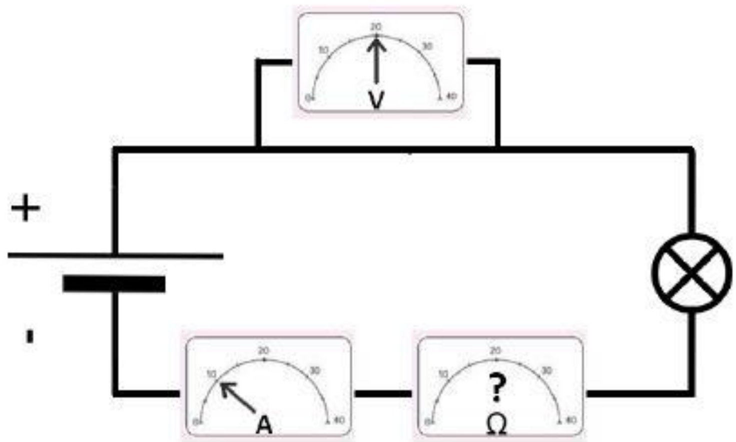
Which of the above statements is/are correct?

a) Only I b) Only III c) II and IV d) I and III

17- Which one of the following is the equation that show the relationship between current, tension and resistance?

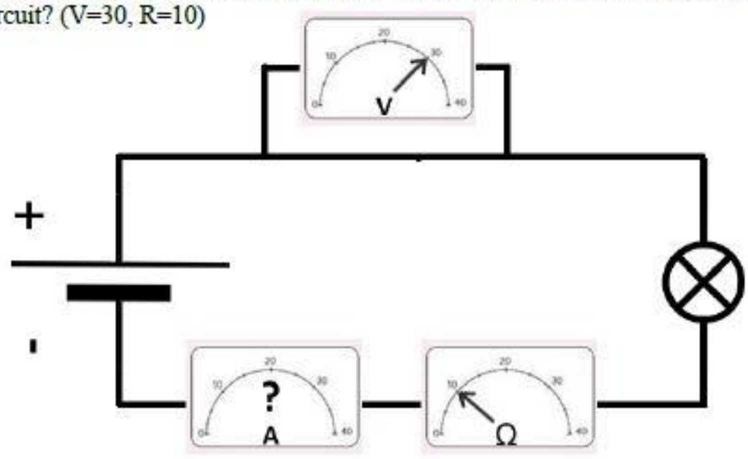
a) $I = V.R$ b) $R = V.I$ c) $V = I.R$ d) $R = I$

18- In the following circuit, ampere meter measures the current passing through the circuit, and voltmeter measures the tension. According to those measurements, how many ohms is the resistance of the conductor in the circuit? (V=20, A=10)



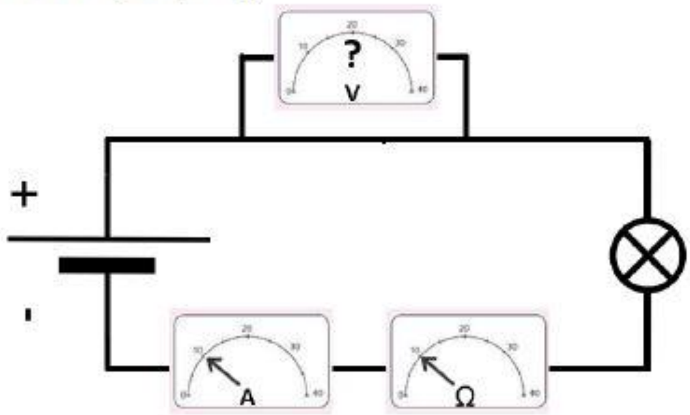
a) 3 b) 3 c) 30 d) 200

19- In the following circuit, voltmeter measures the tension of the circuit, and ohmmeter measures its resistance. According to those measurements, how many amperes is the current in the circuit? (V=30, R=10)



a) 2 b) 3 c) 30 d) 40

20- In the following circuit, ampere meter measures the current passing through the circuit, and ohmmeter measures the resistance. According to those measurements, how many volts is the tension of the circuit? (A=10, R=10)



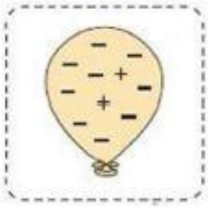
a) 3 b) 20 c) 100 d) 400

1-

Sol tarafta yük durumu verilen cisim için aşağıdakilerden hangisi söylenebilir?

a) Pozitif yüklü cisimdir.
b) Negatif yüklü cisimdir.
c) Nötr cisimdir.
d) Hem pozitif hem de negatif yüklü cisimdir.

2-



Yukarıda yük durumları verilen tencere ve balon birbirlerine yaklaştırıldıklarında etkileşimleri hakkında ne söylenebilir?

a) Tencere ve balon sabit kalır.
b) Tencere balonu çeker.
c) Balon ve tencere birbirlerini iterler.
d) Tencere ve balon birbirlerini çekerler.

3. ve 4. soruları aşağıdaki cisimlerin durumlarına göre cevaplayınız.

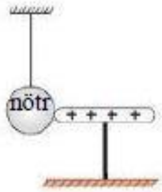
3- Nötr olan cisim ya da cisimler hangi seçenekte doğru verilmiştir?

a) Yalnız K b) Yalnız L c) K ve L d) K, L ve M

4- K cismi M cismine dokundurulsa K ve M'nin son yükleri için ne söylenebilir?

a) K ve M cisimleri pozitif yüklüdür.
b) K ve M cisimleri negatif yüklüdür.
c) K negatif iken M pozitif yüklüdür.
d) K ve M nötr 'dür.

5- Yandaki şekildeki nötr iletken küre, pozitif yüklü çubuğa dokundurulduğunda aşağıdakilerden hangisi gerçekleşir?



a) Çubuktan küreye pozitif yükler hareket eder.
b) Küreden çubuğa negatif yükler hareket eder.
c) Çubuktan küreye negatif yükler hareket eder.
d) Küreden çubuğa pozitif yükler hareket eder.

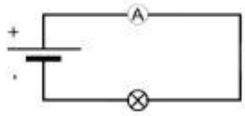
6- Aynı yolla elektriklenmiş maddeler birbirlerine yaklaştırıldıklarında nasıl tepki verirler?

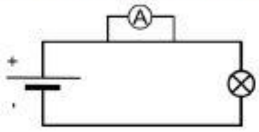
a) Birbirlerini iterler.
b) Birbirlerini çekerler.
c) Hareketsiz kalırlar.
d) Biri iterken diğeri çeker.

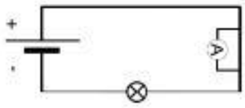
7- Farklı yolla elektriklenmiş maddeler birbirlerine yaklaştırıldıklarında nasıl tepki verirler?

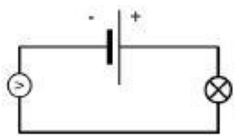
a) Birbirlerini iterler.
b) Birbirlerini çekerler.
c) Hareketsiz kalırlar.
d) Biri iterken diğeri çeker.

8- Ampermetre aşağıda verilen devrelerden hangisinde doğru bağlanmıştır?

a)


b)


c)


d)


9- Ohmmetre aşağıdakilerden hangisini ölçmek için kullanılır?

a) Akım b) Ağırlık c) Direnç d) Gerilim

10- Voltmetre aşağıdakilerden hangisini ölçmek için kullanılır?

a) Uzunluk b) Gerilim c) Direnç d) Akım

11- Ohm aşağıdakilerden hangisinin ölçü birimidir?

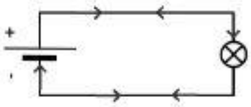
a) Gerilim b) Direnç c) Ağırlık d) Akım

12- Volt aşağıdakilerden hangisinin ölçü birimidir?

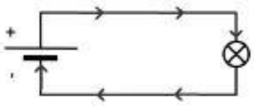
a) Akım b) Direnç c) Gerilim d) Uzunluk

13- Elektrik devresindeki elektrik akımının hareket yönü aşağıdakilerden hangisinde doğru verilmiştir?

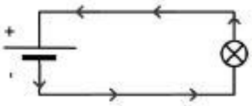
a)



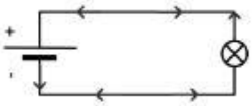
b)



c)



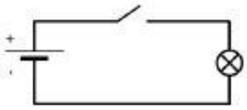
d)



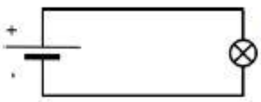
14- Aşağıdaki devrelerin hangisinde ışık kaynağı ışık verir?

a)

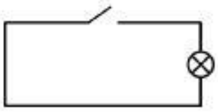
b)



c)



d)



15- Aşağıdaki ifadelerden hangisi doğrudur?

a) Bütün cisimler birbirlerine temas ettiklerinde elektriklenme meydana gelir.
b) Deneysel sonuçlara dayanarak üç cins elektrik yükü olduğu sonucuna varılır.
c) Bir elektrik devresindeki negatif yüklerin yönü ile akımın yönü terstir.
d) Elektrik devresindeki hareket halinde olan yükler pozitif olanlardır.

16-

I. Yüklü cisimlerden toprağa negatif yük akışı topraklama olarak adlandırılır.
II. Yüklü cisimlerden toprağa pozitif yük akışı topraklama olarak adlandırılır.
III. Topraktan cisimlere negatif yük akışı topraklama olarak adlandırılır.
IV. Topraktan cisimlere pozitif yük akışı topraklama olarak adlandırılır.

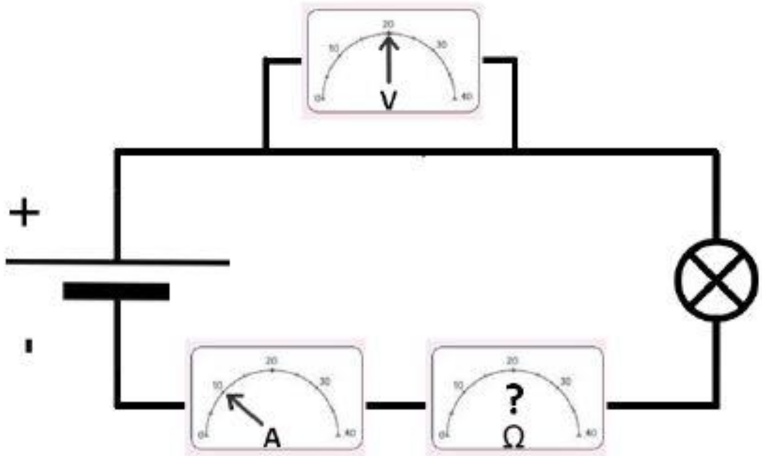
Yukarıdaki ifadelerden hangisi ya da hangileri doğrudur?

a) Yalnız I b) Yalnız III c) II ve IV d) I ve III

17- Aşağıdakilerden hangisi, akım, gerilim ve direnç arasındaki ilişkiyi gösteren eşitliktir?

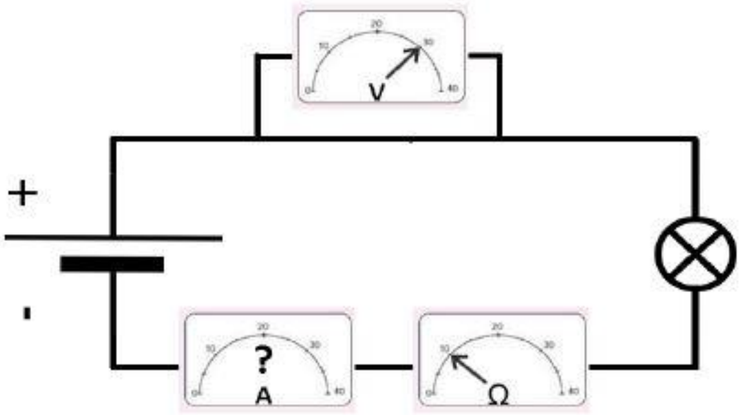
a) I = V.R b) R = V.I c) V = I.R d) R = I/V

18- Aşağıdaki devrede ampermetre devreden geçen akımı, voltmetre ise gerilimi ölçmektedir. Bu ölçümlere göre devredeki iletkenin direnci kaç ohm olur? (V=20, A=10)



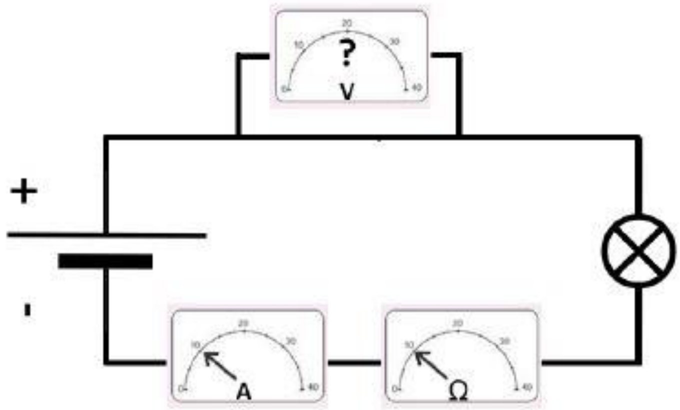
a) 2 b) 3 c) 30 d) 200

19- Aşağıdaki devrede voltmetre devrenin gerilimini, ohmmetre ise direncini ölçmektedir. Bu ölçümlere göre devredeki elektrik akımı kaç amper olur? (V=30, R=10)



a) 2 b) 3 c) 30 d) 40

20- Aşağıdaki devrede ampermetre devreden geçen akımı, ohmmetre ise direnci ölçmektedir. Bu ölçümlere göre devrenin gerilimi kaç volt olur? (A= 10, R=10)



a) 2 b) 20 c) 100 d) 400

APPENDIX E

ETHICAL APPROVAL

T.C.
BOĞAZİÇİ ÜNİVERSİTESİ
İnsan Araştırmaları Kurumsal Değerlendirme Alt Kurulu

12 Mayıs 2016

Sayı: 2016/12

Ekrem Kutbay
Eğitim Teknolojisi
Eğitim Fakültesi

Sayın Araştırmacı,

"Elektrik Konusu Öğreniminde Çoklu Öğrenme Ortamlarında Somut ve Soyut Gösterimlerle Duyu Biçimi, Gereksizlik ve Dikkat Çekme İlkelerinin Etkilerinin İncelenmesi" başlıklı projeniz ile ilgili olarak yaptığınız SBB-EAK 2016/5 sayılı başvuru, İnsan Araştırmaları Kurumsal Değerlendirme Alt Kurulu tarafından 12 Mayıs 2016 tarihli toplantıda incelenmiş ve uygun bulunmuştur.

Saygılarımızla,

İnsan Araştırmaları Kurumsal Değerlendirme Alt Kurulu

Doç. Dr. Ebru Kaya

Doç. Dr. Mehmet Yiğit Gürdal

Yrd. Doç. Dr. Gül Sosay

Yrd. Doç. Dr. Mehmet Nafi Artemel

Dr. Nur Yeniçeri

APPENDIX F

DETAILED ANALYSIS TABLES

Table 48. Normality Tests for the Students' Achievement Scores in Multimedia Conditions

Groups	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	*df*	*Sig.*	Statistic	*df*	*Sig.*
W-A	.156	80	.000	.965	80	.026
W-C	.116	74	.015	.971	74	.089*
Sg-A	.154	87	.000	.948	87	.002
Sg-C	.105	85	.022	.977	85	.138*
Sp-A	.116	93	.004	.977	93	.101*
Sp-C	.117	76	.012	.970	76	.064*
W+Sp-A	.141	93	.000	.969	93	.026
W+Sp-C	.086	94	.086*	.978	94	.117*
Sg+Sp-A	.133	67	.005	.974	67	.174*
Sg+Sp-C	.100	75	.061*	.982	75	.366*

*. This is a lower bound of the true significance.

Table 49. Normality Tests for the Students' Pretest Scores in Multimedia Conditions

Groups	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	*df*	*Sig.*	Statistic	*df*	*Sig.*
W-A	.090	80	.169*	.962	80	.019
W-C	.156	74	.000	.946	74	.003
Sg-A	.124	87	.002	.962	87	.012
Sg-C	.157	85	.000	.960	85	.010
Sp-A	.150	93	.000	.964	93	.012
Sp-C	.152	76	.000	.954	76	.008
W+Sp-A	.133	93	.000	.949	93	.001
W+Sp-C	.126	94	.001	.971	94	.032
Sg+Sp-A	.103	67	.074*	.969	67	.092*
Sg+Sp-C	.141	75	.001	.969	75	.060*

*. This is a lower bound of the true significance.

Table 50. Multiple Comparisons of One-Way ANOVA for the Students' Pre-test Scores in Multimedia Conditions

(I) Group	(J) Group	(I-J) Mean Difference	Std. Error	Sig.
W-A	W-C	-.219	.391	1.000
	Sg-A	.397	.376	.999
	Sg-C	.374	.378	.999
	Sp-A	-.068	.370	1.000
	Sp-C	.165	.388	1.000
	W+Sp-A	-.272	.370	1.000
	W+Sp-C	-.691	.369	.940
	Sg+Sp-A	-.369	.402	1.000
	Sg+Sp-C	-.558	.390	.991
W-C	Sg-A	.616	.384	.979
	Sg-C	.593	.386	.984
	Sp-A	.151	.378	1.000
	Sp-C	.384	.396	1.000
	W+Sp-A	-.053	.378	1.000
	W+Sp-C	-.472	.377	.997
	Sg+Sp-A	-.150	.409	1.000
	Sg+Sp-C	-.339	.397	1.000
Sg-A	Sg-C	-.023	.370	1.000
	Sp-A	-.465	.362	.996
	Sp-C	-.232	.381	1.000
	W+Sp-A	-.669	.362	.945
	W+Sp-C	-1.088	.361	.430
	Sg+Sp-A	-.766	.394	.925
	Sg+Sp-C	-.954	.382	.716
Sg-C	Sp-A	-.442	.364	.997
	Sp-C	-.209	.383	1.000
	W+Sp-A	-.646	.364	.958
	W+Sp-C	-1.065	.363	.475
	Sg+Sp-A	-.743	.396	.940
	Sg+Sp-C	-.932	.384	.751
Sp-A	Sp-C	.233	.375	1.000
	W+Sp-A	-.204	.356	1.000
	W+Sp-C	-.623	.355	.961
	Sg+Sp-A	-.301	.389	1.000
	Sg+Sp-C	-.490	.376	.995

Table 50. (Continued) Multiple Comparisons of One-Way ANOVA for the Students’ Pre-test Scores in Multimedia Conditions

(I) Group	(J) Group	(I-J) Mean Difference	Std. Error	Sig.
Sp-C	W+Sp-A	-.437	.375	.998
	W+Sp-C	-.856	.374	.813
	Sg+Sp-A	-.534	.406	.995
	Sg+Sp-C	-.723	.395	.948
W+Sp-A	W+Sp-C	-.419	.355	.998
	Sg+Sp-A	-.097	.389	1.000
	Sg+Sp-C	-.286	.376	1.000
W+Sp-C	Sg+Sp-A	.322	.388	1.000
	Sg+Sp-C	.133	.376	1.000
Sg+Sp-A	Sg+Sp-C	-.189	.408	1.000

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