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YILDIZ TECHNICAL UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

THE EFFECTS OF VIRTUAL AND HANDS-ON LABORATORY ENVIRONMENTS ON THE CONCEPTUAL KNOWLEDGE, INQUIRY SKILLS AND ATTITUDES OF MIDDLE SCHOOL STUDENTS

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A thesis submitted by Hasan Ozgur KAPICI in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY is approved by the committee on 25.02.2021 in Department of Mathematics and Science Education, Science Education Program.

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Hasan Ozgur KAPICI

Signature

Dedicated to my family

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Hasan Ozgur KAPICI

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LIST OF ABBREVIATIONS

GO-LAB	Global Online Science Laboratory
HHH	The condition using Hands-on Lab/Hands-on Lab/Hands-on Lab
HL	Hands-on Laboratory
HVH	The condition using Hands-on Lab/Virtual Lab/Hands-on Lab
VHV	The condition using Virtual Lab/Hands-on Lab/Virtual Lab
VL	Virtual Laboratory
VVV	The condition using Virtual Lab/Virtual Lab/Virtual Lab

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ABSTRACT

The Effects of Virtual and Hands-on Laboratory Environments on the Conceptual Knowledge, Inquiry Skills and Attitudes of Middle School Students

Hasan Ozgur KAPICI

Department of Mathematics and Science Education

Doctor of Philosophy Thesis

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In the current study, conditions where students worked with only a hands-on laboratory or only a virtual laboratory were compared with conditions in which combinations of the two laboratory environments were used. The main goal of the study was to investigate the effects of different laboratory environment experiences (hands-on only, virtual only, and two different combinations of these laboratories) on middle school students' conceptual knowledge, inquiry skills, and attitudes toward science courses and laboratories.

A quasi-experimental research design was used in the study. Participants were 143 seventh grade students from a public school. The study consisted of four conditions, corresponding to four different laboratory arrangements: hands-on only, virtual only, and two different combinations of hands-on and virtual laboratory environments. This study employed five different measurement tools to reach its goal, including multiple-choice and open-ended conceptual knowledge tests, an inquiry skills test, an attitude questionnaire, and interviews.

The findings indicate that middle school students' conceptual knowledge, inquiry skills, and attitudes toward science courses and laboratories improved significantly after working with the laboratories. Furthermore, using different laboratory environments in a combination was seen to yield significantly better results for students' conceptual knowledge than using only a virtual laboratory. Each laboratory set-up, especially the combined forms, provided important supports for students to deal with their misconceptions. Another finding was that there were no significant differences between the different arrangements of laboratories as far as enhancing students' inquiry skills. Conditions did not differ in terms of overall attitudes toward science courses and laboratories. The only difference between conditions was found for one sub-dimension of the attitude questionnaire that concerned practical work in science; the hands-on alone condition did not show significant improvement for this sub-dimension, while all other conditions did. Lastly, there was consistency between the results for the attitude questionnaire and the interviews.

Keywords: Hands-on laboratory, virtual laboratory, conceptual knowledge, inquiry skills, attitude

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ÖZET

Sanal ve Uygulamalı Laboratuvarların Ortaokul Öğrencilerinin Kavram Bilgileri, Sorgulama Becerileri ve Tutumları Üzerine Etkileri

Hasan Özgür KAPICI

Matematik ve Fen Bilimleri Eğitimi Anabilim Dalı

Doktora Tezi

Danışman: Doç. Dr. Hakan AKÇAY

Eş-Danışman: Prof. Dr. Ton DE JONG

Bu çalışmada yalnızca fiziksel uygulamalı laboratuvarda yapılan öğretim, yalnızca sanal laboratuvarda yapılan öğretim ve bu laboratuvar ortamlarının iki farklı kombinasyonunda yapılan öğretimle karşılaştırılmıştır. Çalışmanın amacı farklı laboratuvar ortamlarının (yalnızca fiziksel uygulamalı laboratuvar, yalnızca sanal laboratuvar ve bu laboratuvarların iki farklı kombinasyonu) ortaokul yedinci sınıf öğrencilerinin kavramsal bilgileri, sorgulama becerileri ve fen dersi ve laboratuvarına yönelik tutumları üzerindeki etkilerini incelemektir.

Çalışmada yarı deneysel araştırma deseni kullanılmıştır. Çalışma dört farklı sınıfta öğrenim gören 143 yedinci sınıf öğrencisi ile yapılmıştır. Her bir sınıf çalışmadaki farklı bir gruba atanmıştır. Bunlar yalnızca fiziksel uygulamalı laboratuvarı kullanan grup, yalnızca sanal laboratuvarı kullanan grup ve fiziksel uygulamalı ile sanal laboratuvarı iki farklı kombinasyonda kullanan iki gruptur. Çalışma hem uygulamalı laboratuvarda hem de sanal laboratuvarda öğretime uygun olan elektrik ünitesinde uygulanmıştır. Beş farklı veri toplama aracı kullanılmıştır. Bunlar, çoktan seçmeli kavramsal bilgi testi, açık uçlu kavramsal bilgi testi, sorgulama becerileri testi, tutum ölçeği ve yarı yapılandırılmış görüşmelerdir.

Çalışmanın sonuçlarına göre laboratuvar ortamında yapılan öğretim öğrencilerin kavramsal bilgileri, sorgulama becerileri ve fen dersi ve laboratuvarına yönelik tutumları üzerinde etkilidir. Ayrıca farklı laboratuvar ortamlarının beraber kullanıldığı gruplar kavramsal bilgileri bakımından sadece sanal laboratuvar kullanan gruba göre daha iyi sonuçlara ulaşmışlardır. Diğer ulaşılan sonuçlardan birisi ise her gruptaki öğrencilerin, özellikle de iki laboratuvar ortamını da kullanan öğrencilerin, kavram yanılgıları önemli ölçüde azalmıştır. Buna karşın öğrencilerin sorgulama becerilerinde gruplar arasında anlamlı fark bulunamamıştır. Grupların fen dersi ve laboratuvara yönelik tutumları arasında da anlamlı fark oluşmamasına rağmen, tutum ölçeğinin alt boyutlarından birisi olan fen deneylerine yönelik tutumları alt boyutunda sadece fiziksel uygulamalı laboratuvarı kullanan gruptaki öğrencilerin tutumları anlamlı olarak artmamıştır. Son olarak tutum ölçeği bulguları ile öğrencilerle yapılan mülakat bulguları uyumlu bulunmuştur.

Anahtar Kelimeler: Uygulamalı laboratuvar, sanal laboratuvar, kavramsal bilgi, bilimsel süreç becerileri, tutum

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1
INTRODUCTION

1.1 Literature Review

In science education, laboratory activities have a central role in science learning; many students take advantage of science laboratory exercises in order to enhance their domain knowledge, and improve their inquiry skills and attitudes towards science (Hofstein & Lunetta, 2004; Roth, 1994; Tobin, 1990). Furthermore, increases in knowledge about the relations between learning and human brain (Bransford, Brown, & Cocking, 2000), developments in pedagogical approaches in science learning (Hofstein & Lunetta, 2004) and developments in educational technology (Zacharia & Olympiou, 2011) have provided new opportunities for the use of science laboratories. For example, virtual laboratories have started to be widely used in schools. On the other hand, hands-on laboratory environments are generally used and accepted in science classes. Yet, it is possible for teachers to face difficulties with hands-on laboratory environments such as preferring an improper teaching method, lack of domain knowledge or restrictions due to the laboratory environment (Nivalainen, Asikainen, Sormunen, & Hirvonen, 2010).

In order to handle problems due to the laboratory environment, a virtual laboratory environment provided by computer technology (de Jong, Linn, & Zacharia, 2013) can be offered as a solution, because it provides a safer, more portable, more time-efficient, and cheaper environment, for easily gathering and visualizing data (Hsu & Thomas, 2002). Another important advantage of a virtual laboratory is that it is easy to use with different types of context (de Jong et al., 2013). For example, unobservable concepts such as electricity (Kollöfel & de Jong, 2013) or light and colors (Olympiou, Zacharia, & de Jong, 2013) can be converted into concrete forms via a virtual laboratory environment. It also enables students to focus on key concepts and to disregard the detailed knowledge (Trundle & Bell, 2010). Furthermore, it is also suitable for integrating online scaffolding tools to help students through the inquiry-based learning process (de Jong, Sotiriou, & Gillet, 2014). All of these opportunities make virtual laboratory a useful science learning environment.

In other respects, a hands-on laboratory environment also has its own advantages. For example, it prompts students to experience being scientists in a laboratory environment through designing and implementing experiments and it enables students to touch the materials physically and helps them to develop their practical laboratory skills (de Jong et al., 2013). It is thought that touching materials physically may have an impact on a learner's working memory by decreasing cognitive load, and this may cause more conceptual learning (Zacharia & Olympiou, 2011). Advocates of this view claim that there are three basic modalities (visual, auditory, and tactual) which are crucial, and each have their own specific ways of contributing to the learning process (Burton & Sinclair, 2000a). If multiple modalities are used for information that is given, then the information will be distributed into these modalities, which reduces cognitive load (Chan & Black, 2006). A hands-on laboratory environment also allows manipulation of the variables via touching the materials physically (Zacharia & Olympiou, 2011). Zacharia and Olympiou (2011) defined manipulation as a process that requires a learner to intentionally interact with the material(s) and apparatus in a skillful manner (p. 318), such as by using motor skills. Students are able to use their hands in order to move, arrange and/or operate the materials (Zacharia & Olympiou, 2011). On the other hand, supporters of virtual laboratory environments assert that there is no well-grounded theoretical framework that explains touching the materials physically as a prerequisite for meaningful learning (Zacharia & Olympiou, 2011). Furthermore, Zacharia and de Jong (2014) stated that it is also possible to add a haptic component to a simulation that enables students to 'feel' the components in the simulation (e.g., Bivall, Ainsworth, & Tibell, 2011; Jones, Andre, Superfine, & Taylor, 2003; Jones, Minogue, Tretter, Negishi, & Taylor, 2006). Moreover, virtual laboratory environment supporters also claim that a virtual laboratory environment involves manipulation. It requires a similar process as in hands-on laboratory environments, but virtually rather than physically (Triona & Klahr, 2003; Zacharia & Olympiou, 2011), so motor skills that are not vital for learning are not used as much in a virtual laboratory (Triona & Klahr, 2003).

Because of the fact that each type of laboratory environment (hands-on and virtual laboratory) has its own advantages, researchers have started to investigate combinations and sequences of the two types of laboratory environment (Zacharia & de Jong, 2014). The literature shows that combinations or sequences of the two laboratory environments result in better conceptual understanding than using them alone (Chiu, Dejaegher, & Chao, 2015; Wang & Tseng, 2018; Zacharia & de Jong, 2014; Zacharia & Michael, 2016; Zacharia & Olympiou, 2011). For example, in a study done by Olympiou and Zacharia (2012), students who used a blended combination of hands-on and virtual laboratory environments gained more conceptual understanding about optics and colors than those who used hands-on or virtual laboratory environments alone. In another study, Jaakkola and Nurmi (2008) compared three conditions: hands-on laboratory environment, virtual laboratory environment, and virtual laboratory followed by hands-on laboratory environment. The findings revealed that the alternating condition was much better than the others in terms of students' conceptual understanding.

Another issue concerns the sequencing of laboratory environments, and whether a hands-on laboratory environment should be followed by a virtual laboratory environment or vice versa. Toth, Ludvico and Morrow (2014) stated that the sequence should be virtual laboratory first and then hands-on laboratory environment. They claimed that a virtual laboratory environment offers more opportunities for students such as simplification and augmentation, so it is more appropriate for teaching basic concepts about the topic. After that, taking advantage of a hands-on laboratory environment might enable students to gain deeper and more complex understanding. Similarly, Zacharia and de Jong (2014) concluded from their study that the sequencing of laboratory environments should be virtual laboratory followed by hands-on laboratory. They claimed that a virtual laboratory environment is more appropriate for learning key points about the topic, since it provides instant feedback that facilitates learning. They also advocated that students can deal with conceptual difficulties through using a virtual laboratory environment and then they will handle procedural problems through using a hands-on laboratory environment. In a study done by Sullivan, Gnesdilow, Puntambekar and Kim (2017), they designed two main laboratory arrangements, hands-on first then virtual laboratory or virtual laboratory first and then hands-on laboratory, and compared students' understanding of mechanics concepts after using these two different sequences of the laboratory environments. They concluded that there is no certain boundary between the two sequences, but found that a virtual laboratory environment might be more beneficial for learning fundamental physics concepts. These studies show that it is not clear what the best sequence of the two types of laboratory environments is.

Finally, Chen, Chang, Lai and Tsai (2014) emphasized that there are three main concerns that make it difficult to compare hands-on and virtual laboratory environments. These are "(i) *information accessibility and dynamic visualization*, (ii) *learners' prior sensory experience and learning of abstract concepts* and (iii) *effectiveness in terms of integrated and high-level cognitive and affective objectives* (p. 909)." Chen et al. (2014) explained the first concern as arising because hands-on and virtual laboratory environments display different amounts of information. This causes inequality between the two types of laboratory environment, because whereas a virtual laboratory enables students to observe intangible concepts, students who use hands-on laboratory do not have such an opportunity. A virtual laboratory also offers dynamic visualization, which is not possible in a hands-on laboratory environment. This gives rise to unbalanced designs when comparing the two laboratory environments. Their second concern arises because if students have had prior experience with physical materials, such as using a thermometer or voltmeter, then they might therefore gain knowledge without needing physicality within a virtual laboratory environment. In other words, prior physical experience has an impact on learning in virtual laboratory environment when compared to a hands-on laboratory. For the last concern, they advocate that studies of the use of laboratories in education should mainly focus on the learning of concepts. Nevertheless, other cognitive and affective outcomes should also be investigated (Chen, 2010), such as attitude towards laboratories or inquiry skills. Because changing attitudes or developing inquiry skills is not an easy task and requires more time, such studies may be limited in the literature.

However, it is obvious that students reach better results in inquiry-based hands-on and/or virtual laboratory environments when they are supported by teachers, worksheets or online scaffolding tools (de Jong et al., 2013). Virtual laboratory environments (or simulations) require much cognitive processing and include metacognitive complexities (Azevedo, 2005; de Jong, 1991; Scheiter & Gerjets, 2007), which causes problems for students. Most of these problems originate from *richness* of knowledge, *transparency* of the relations among that knowledge and *fidelity* of the information provided by computer-supported inquiry-based learning environments (Swaak & de Jong, 1996; Zacharia & Olympiou, 2011). Whereas richness is defined as the amount of knowledge and the variety of relations a student can extract from a virtual learning environment (Swaak, van Joolingen, & de Jong, 1998; Zacharia & Olympiou, 2011), transparency is identified as how easily students can perceive the content, variables and their relations for the topic presented to them (Swaak et al., 1998). Although richness is high in a virtual laboratory environment, since it presents all of the variables involved in a physical phenomenon, transparency is relatively low, so students find it difficult to describe all of the relations among the variables (Zacharia & Olympiou, 2011). And lastly, fidelity means the correspondence of the presented phenomenon with its real physical form (Scheiter, Gerjets, Huk, Imhof, & Kammerer, 2009). Because computer simulations concretize the invisible concepts in visible forms, fidelity is crucial to hinder possible misconceptions that students can have.

Another source of difficulty for students is the inquiry process. Students may have trouble generating hypothesis, designing and implementing proper experiments, interpreting data and making conclusions based on the results in an inquiry-based learning environment (de Jong & van Joolingen, 1998). In order to deal with such difficulties in a virtual learning environment, provided guidance plays a crucial role (D'Angelo et al., 2014). De Jong and Lazonder (2014) defined six types of guidance: *process constraints* that restrict or reduce students' activities in a virtual learning platform, a *performance dashboard* that provides information about students' results, *prompts* that are used to give specific directions about what to do in the learning process, *heuristics* that provide suggestions for students about what they should do, *scaffolds* that provide tools in order to help students with a learning process for which they lack proficiency (e.g., hypothesis scratchpad) and *direct presentation of information*, which is generally used when students lack prior knowledge or are unable to reach the information themselves. In order to determine the types of guidance to give students in an inquiry-based learning environment, students' cognitive and affective conditions and learning environment should be considered.

1.2 Objective of the Thesis

Because of the strong effects of guidance in an inquiry-based learning environment, a guided inquiry-based learning environment was used in the current study. Several scaffolding tools such as a hypothesis scratchpad, observation tool and conclusion tool were provided for students who used the virtual learning environment. For the students who used the hands-on laboratory environment, paper-based forms of such scaffolding tools were provided. Furthermore, the science teacher acted as a main facilitator during the learning process for the students in both of the laboratory environments. All conditions in the study followed the same guided inquiry-based learning approach and used the same curriculum materials. The fundamental difference between the conditions was the laboratory environments they used. Students in two conditions worked on the science topic in a pure hands-on laboratory environment or in a pure virtual laboratory environment. Those in the other two conditions worked on the science topic in different combinations of these laboratory environments. In this way, the effects of different arrangements of laboratory environments on middle school students' conceptual understanding, inquiry skills, and attitude towards science courses and laboratories were investigated.

It is obvious that using combinations of hands-on and virtual laboratory environments gives better results for students' development of conceptual understanding. Yet, there is no certain framework dictating which laboratory environment should be used first. In the related literature, there are only a few studies addressing this issue (e.g., Sullivan et al., 2017; Zacharia & de Jong, 2014; Zacharia & Olympiou, 2011) and they mainly did not lead to a certain view. This study also aims to contribute to this issue about how to combine different laboratory environments to achieve better learning processes. In other words, one of the main goals of the study is to compare the effects of hands-on and virtual laboratory environments in different combinations on middle school students' development of conceptual understanding about the topic of electricity, inquiry skills and attitude towards science courses and laboratories.

Virtual laboratory environments are not common in Turkey. Students usually design and implement experiments in hands-on laboratory environments. This study aims to reveal what middle school students in Turkey think about the virtual laboratory environment. Three of the conditions had a chance to compare the two different laboratory environments. The effects of using a virtual laboratory environment on middle school students' attitude towards science courses and laboratories was explored not only by the attitude scale, but also through the interviews. The quantitative data gathered by the attitude scale was compared with the students' views gathered by the interviews. In this way, there was a chance to examine whether the data gathered from quantitative and qualitative sources was consistent.

1.3 Original Contributions

From a national perspective, studies about virtual laboratory environments are not prevalent in Turkey. This study presents findings about whether introducing virtual laboratory into middle school students' science curriculum may have advantages or not for their development of conceptual understanding, inquiry skills, and attitudes towards science courses and laboratories. From an international perspective, this study contributes to the line of work that has investigated the effects of different combinations of laboratory environments on middle school students' development of conceptual understanding, inquiry skills, and attitudes towards science course and laboratories.

1.4 Research Questions

In this study, a comparison between a hands-on laboratory alone, a virtual laboratory alone and different combinations of hands-on and virtual laboratory environments for middle school students' development conceptual understanding, inquiry skills, and attitudes towards science courses and laboratories was made. Participants were seventh grade students from a public school. The topic was a unit on electricity. The following research questions were investigated in the current study.

- Do seventh grade middle school students who learn about the domain of electricity in a pure hands-on laboratory, in a pure virtual laboratory, or in two different combinations of these laboratory environments, differ in their acquisition of
  - conceptual knowledge and understanding,
  - inquiry skills, and
  - improved attitudes towards science courses and laboratories?

- What are the difficulties that seventh grade students faced and the advantages they experienced while learning with virtual laboratories compared to hands-on laboratories?
- What are the difficulties and opportunities that the science teacher encountered in designing and applying the coursework that involved a virtual laboratory environment?

1.5 Limitations and Assumptions of the Study

Finally, the results of this study should be interpreted taking the study's limitations into account. First, using the same tests at pretest and posttest could have been a possible threat to internal validity in the form of a testing effect. However, it was assumed that the time that elapsed between the pretest and posttest and the total number of questions the tests contained minimized the students' opportunity to memorize the questions. Another limitation is that students had no prior experience with virtual laboratory environments, and this could have been a disadvantage for them. The next limitation is that because there were four different seventh grade groups that were taught by the same science teacher. Two of these groups were assigned to the conditions in which hands-on laboratory used alone or virtual laboratory used alone. I had another two groups to use the different combinations of hands-on and virtual laboratories. One of these groups started with a virtual laboratory environment, continued with a hands-on laboratory environment, and ended with a virtual laboratory environment. That's why, this group was coded as VHV. On the other side, the other group started with a hands-on laboratory environment, continued with a virtual laboratory, and ended with a hands-on laboratory environment. Because of this, this group was coded as HVH. I did not have another group where I could do further investigation of different combinations of hands-on and virtual laboratory environments by the same science teacher. Finally, due to practical circumstances we used a quasi-experimental set-up. Different conditions (and thus classes) did not differ on scores on the pretests, but random assignment of students to conditions would have ruled out possible class-related effects.

2
THEORETICAL FRAMEWORK

2.1 Scientific Literacy

One of the primary goals of reforms in science education is to educate individuals to be scientifically literate (National Research Council, 1996). Scientifically literate people use scientific information to make decisions about daily life events, debate about important issues that are related to science, technology and society and are economically productive individuals (National Research Council, 1996). Bybee (1997) defined a scientifically literate individual as a person who is able to use scientific knowledge, determines problems and offers solutions with evidence and is able to make decisions by himself/herself. Individuals gain scientific knowledge and attitudes and inquiry skills throughout their formal learning process at schools (Derman, 2014). In this respect, science education has an important role in terms of forming individuals to be people who can use inquiry skills and have positive attitudes toward science (Çepni, Ayvacı, & Bacanak, 2004). For this reason, there is a debate among science educators about which learning approach best fits for educating students to be scientifically literate (Brickman, Gormally, Armstrong, & Hallar, 2009). Based on the discussions among researchers, it has been concluded that inquiry-based learning is one approach to helping students to be scientifically literate individuals for the future (Wen et al., 2020).

2.1.1 Computer-Supported Inquiry-Based Science Learning and the Importance of Guidance

Inquiry-based science learning has been used in science education, because it enables students to build a personal knowledge base that is scientific and that can be used to predict and explain what they observe around them (van Joolingen, de Jong, & Dimitrakopoulou, 2007). In such a learning environment, it is expected that students identify problems, gather and analyze data, make inferences and assess their own progressive process (van Joolingen & Zacharia, 2009). In other words, it is supposed that students follow scientists' path so as to gain scientific knowledge (Zacharia et al., 2015).

Although there are many different ways to use inquiry-based science learning at school, many researchers have advocated that computer-supported learning environments are one of the most appropriate ways, because they is suitable for using multiple representations, can provide instant and individual feedback, and may provide scaffolding with respect to students' needs (Furtak, Seidel, Iverson, & Briggs, 2012; Gerjets, Scheiter, & Schuh, 2008; van der Meij & de Jong, 2006). In particular, computer simulations help students to recall their prior knowledge (e.g., through developing hypothesis) and enable them to reconstitute knowledge effectively (e.g., the data gathered from experiments or other sources is not consistent with the hypothesis) (de Jong, 2011). In the study done by van Joolingen, de Jong and Dimitrakopoulou (2007), they identified several aspects showing the appropriateness of computer simulations for creating inquiry-based learning environments. One is that computer simulations make it easier to design experiments about wide-scale phenomena in a simplified version. For example, this situation is usually valid for astronomy topics that cannot be investigated without computer simulations. Another is that computer simulations can provide scaffolding tools such as a hypothesis or conclusion tool or a data viewer, which enable students to manage their own learning process. Computer simulations are also suitable for supporting collaborative learning among students in order to share and discuss data and results. The last point that they emphasized in their study is that computer-supported environments might enable students to create their own models based on their theories. In this way, students' possible misconceptions might be revealed.

Because unguided discovery learning gives worse results for students' conceptual understanding (Lazonder, 2014), computer-supported inquiry-based learning requires guidance for students. For example, some studies (e.g., de Jong & van Joolingen, 1998; Mulder, Lazonder, & de Jong, 2011) have shown that students have trouble while developing hypotheses, designing experiments and collecting data. There are also recent meta-synthesis studies (e.g., Alfieri, Brooks, Aldrich, & Tenenbaum, 2011; Furtak et al., 2012; Lazonder & Harmsen, 2016; Minner, Levy, & Century, 2010) that have shown that guided inquiry-based learning is more effective than unguided inquiry learning and direct instruction (de Jong & Lazonder, 2014). However, there is debate about the amount of guidance and when it should be given to students (Lazonder, 2014).

One of the two main perspectives claims that students should have all relevant knowledge and skills before designing and implementing their own experiments by themselves (Kirschner, Sweller, & Clark, 2006). The other view advocates that guidance (support) should be provided *just-in-time* or on an *on-demand basis* while students are in an inquiry-based learning process (Hmelo-Silver, Duncan, & Chinn, 2007).

The help provided to students may be in the form of cognitive tools or scaffolds for computer-supported learning environments (van Joolingen et al., 2007). De Jong and Lazonder (2014) categorized the types of support into six different forms. One is *process constraints*, which aim to diminish the complexity of the learning environment by limiting the number of options for students to deal with. This type of guidance can be used when students have fundamental inquiry skills and are able to apply those during the investigations but have insufficient experience to use them for more demanding circumstances. Another form of support is a *performance dashboard*, which provides students with data about their learning progress and also gives information about the knowledge they have gained knowledge. This type of support enables students to understand their own learning process and learning outcomes. Another type of guidance is *prompts*, which act as a reminder for students to complete the learning task. It is mainly used when students have the related skills but may not use them by themselves. *Heuristics* are another type of guidance in computer-supported inquiry-based learning environments. They are similar to prompts but more specific, because they provide suggestions about how to perform a particular action. They are used when students have no knowledge about when and how to continue their task. Another support type is *scaffolds*. They act as components of the learning process and are used when the task is too complicated or when students lack the competence to handle the learning process. The last type of support defined by de Jong and Lazonder (2014) is *direct presentation of information*. Although this type of support is contrary to the nature of inquiry-based learning, it is used when students lack prior knowledge or they are unable to perform the main task.

There are no certain conclusions about the relation between the types of guidance and students' grade levels or age. In other words, the effectiveness of guidance types in inquiry-based learning environments with respect to grade levels and age is a matter of discussion. However, based on the literature, de Jong and Lazonder (2014) advocated that more open types of guidance are more suitable for older students.

Another topic related to guidance types is that whether supportive tools might be used in a combined form such as prompts and scaffolds together, or whether they should be used separately. There are also contradictory results about this issue in the related literature. Some studies (e.g., Fund, 2007; Zhang, Chen, Sun, & Reid, 2004) have concluded that the more guidance students receive, the higher their posttest scores (de Jong & Lazonder, 2014). Other studies (e.g., Eckhardt, Urhahne, Conrad, & Harms, 2013) reached totally opposite results, in which the group who received the combined guidance types had lower posttest scores (de Jong & Lazonder, 2014).

In conclusion, it can be said that guided inquiry-based learning is more effective than unguided inquiry learning, but there is still uncertainty about the amount and types of guidance to present to students. These (amount and types of guidance) might be different based on the students' age and grade levels.

2.2 Cognitive Load Theory

Guidance might be important in inquiry-based learning environment because appropriate support may help students to cope with the limitations of working memory and enable them to store new knowledge in long-term memory (de Jong & Lazonder, 2014). Working memory is responsible for the processing of information (de Jong, 2010, p. 105). It is comprised of partially independent processors that are related to different sensory channels (Hollender, Hofmann, Deneke, & Schmitz, 2010, p. 1279). There are two main deficiencies of working memory, which are that it holds a limited amount of information and that content held in working memory is lost in a very short time without reiteration (Sweller, 2005). That is why instructional designs should take these limitations into consideration.

Furthermore, there are relations between working memory and long-term memory. Long-term memory is a kind of storage where information is held. Cognitive activities, such as learning, done by a human are driven by information held in long-term memory (Sweller, 2005). One efficient way to deal with the limitations of working memory while learning new information is by using stored knowledge held in long-term memory (Sweller, 2005). In other words, understanding of a concept may be explained based on the relations between working memory and long-term memory (Marcus, Cooper, & Sweller, 1996). Sweller (2005) stated that schemas held in long-term memory direct the organization of the information processed in working memory. In other cases, for example, if there is no schema or organized information about new knowledge, then random generation based on tests of effectiveness is used (Sweller, 2005). Rather than randomly organizing information and then testing for effectiveness, schemas held by other people can be used to organize the information (Sweller, 2005, p. 26). On the other hand, many instructional designs, like all inquiry-based instruction, prefer to involve random generation followed by testing, instead of other people's knowledge (Sweller, 2005). Based on these facts, cognitive load theory was developed mainly by Paas, Renkl and Sweller (2003), Sweller (1994; 2005) and Sweller and Chandler (1991). Sweller (2005) defined cognitive load theory as an instructional theory based on our knowledge of human cognitive architecture that specifically addresses the limitations of working memory (p. 28). There are three basic categories identified in the theory, which are: extraneous, intrinsic and germane cognitive load.

Extraneous cognitive load is caused by improper instructional designs that ignore the limitations of working memory and do not directly promote learning (de Jong, 2010; Sweller, 2005). Instructional designers want to minimize extraneous cognitive load. There are several principles to follow for doing this, such as the use of worked examples, avoidance of split attention, redundancy, attention to the expertise-reversal effect and attention to the modality effect. A worked example, for example, decreases extraneous cognitive load by eliminating search (Sweller, 2005). Another principle, avoidance of split attention, claims that learner's attention shouldn't be divided over multiple sources of information; instead, different sources of information should be integrated temporally and physically (Ayres & Sweller, 2014), if all of the sources are required for understanding (Hollender et al., 2010). Avoidance of redundancy is another principle that also deals with multiple sources of information. Sweller (2005) explained that if there are multiple sources and both of the sources present the same information in different forms, then one of the sources is enough for understanding and the other source is unnecessary. Eliminating the second source may reduce the extraneous cognitive load. This is called reduction of redundancy. The expertise-reversal effect is another reason for extraneous cognitive load. Detailed and exhaustive information might be useful for novice learners but not for experts, because although the information is necessary for novice learners, it is redundant for expert individuals (Kalyuga, Ayres, Chandler, & Sweller, 2003; Sweller, 2005). Last but not least, the modality effect has an important role in decreasing extraneous cognitive load. Instead of integrating different sources of information physically, verbal material should be presented in spoken form rather than written form (Sweller, 2005). All of these principles are vital for reducing extraneous cognitive load, which is not directly relevant for learning; learners should not spend their time and resources on the processes that cause extraneous cognitive load (de Jong, 2010).

Intrinsic cognitive load is another cornerstone for cognitive load theory. It is related to the complexity of information and the interactivity of the elements (Sweller, 2005). In other words, material that contains a large number of interactive elements is regarded as more difficult than material with a smaller number of elements and/or with low interactivity (de Jong, 2010, p. 106). As a consequence, intrinsic cognitive load tries to explain why some types of materials are more difficult than others and how this may influence the load on memory (de Jong, 2010, p. 107). Whereas low interactivity material refers to simple and single elements such as words or numbers, high interactivity means that single or simple elements are combined, such as sentences or adding/subtracting numbers (Sweller, 1994). Because of the fact that intrinsic cognitive load is related to the material, instructional designs have no impact on it (de Jong, 2010). Furthermore, it cannot be changed (Hasler, Kersten, & Sweller, 2007). Some ways to reduce intrinsic cognitive load have been suggested in the related literature, such as a simple to complex approach (van Merriënboer, Kirschner, & Kester, 2003) and a part-whole approach (van Merriënboer, Kester, & Paas, 2006). These approaches are seen to be compatible with cognitive load theory because both of the approaches start with a few elements and the complexity increases step by step (van Merriënboer & Sweller, 2005).

The third type of cognitive load is *germane cognitive load*. Cognitive load theory advocates that learning occurs through construction and automation of schemas (Sweller, van Merriënboer, & Paas, 1998). Germane cognitive load is a kind of cognitive load caused by effortful learning that results in schema construction and automation (Sweller, 2005, p. 27). Mayer (2002) stated that organization of information, interpreting and classifying it, inferring and exemplifying are some required processes for constructing schemas, which are important insofar as they help to reduce the load on working memory (Anglin, Vaez, & Cunningham, 2004). Instructional designs help students to experience these processes in order to engage in schema construction and automation, and in this way, germane cognitive load increases (de Jong, 2010). To sum up, germane cognitive load stems from schema construction, which is useful for teaching (Hollender et al., 2010).

These three types of cognitive load are additive (Sweller, 2005, p. 27). Sweller (2005) claimed that in order to improve learning, extraneous cognitive load should be decreased through proper instructional procedures. In this way, free capacity in working memory increases. This capacity can be used by germane cognitive load, which is helpful for learning. In addition, if the complexity of the information is low, there is lower intrinsic cognitive load, and then the capacity for germane cognitive load may increase even with high levels of extraneous cognitive load since low intrinsic cognitive load gives rise to low overall cognitive load (Sweller, 2005). In conclusion, the relations among these three types of cognitive load are asymmetrical and loop-shaped (Kılıç Çakmak, 2007). Kılıç Çakmak (2007) said that reducing the extraneous cognitive load via efficient instructional designs will provide extra capacity for germane cognitive load in working memory and then schemas will be constructed more easily. After schemas are constructed, intrinsic cognitive load will decrease at the next step.

2.3 Multimedia Learning

Similar to cognitive load theory, the theory of multimedia learning also focuses on working memory (Mayer, 2005). The theory of multimedia learning was mainly developed by Richard E. Mayer and other cognitive psychology researchers. These researchers claim that multimedia instruction encourages the way that the human brain learns (Sorden, 2012, p. 155). The theory uses cognitive load theory in explaining how to develop proper multimedia-based learning environments (Mayer & Moreno, 2002). The main principle of multimedia learning is that individuals learn better when words and pictures are presented together, instead of using them apart (Mayer, 2005). Mayer (2005) defined words as spoken or written text and defined pictures as graphs, illustrations, maps and photos in a static form, or animations and videos in a dynamic form. In his study, Mayer (2005) introduced the cognitive structure of the theory as shown in Figure 2.1.

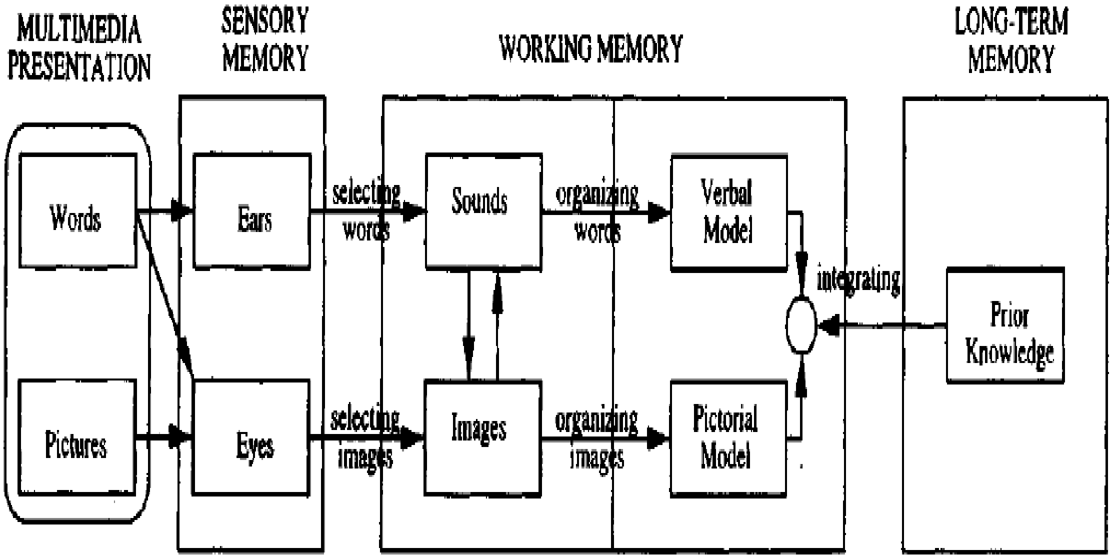


Figure 2.1 Cognitive theory of multimedia learning (Mayer, 2005, p. 44)

Mayer (2005) explained that the human cognitive structure is comprised of three main parts, which are sensory memory, working memory and long-term memory. Stimuli in the form of verbal and non-verbal structures are received by the sensory memory through ears and eyes. Pictures and written forms of texts are held as exact visual images for a very short duration in visual sensory memory. Similarly, speech forms of words and other sounds are held as exact auditory images for a very short time in auditory sensory memory. The arrow from word to ears indicates the registered form of spoken text in ears and the arrow from words to eyes indicates the registered form of written/drawn text in eyes. The arrow from pictures to eyes represents the registered picture in the eyes. Mayer (2005) claimed that working memory is composed of two parts. Visual images of pictures and sound images of words come into working memory as raw materials to the left side, through visual and auditory modalities. In the right side of working memory, knowledge construction occurs through verbal and pictorial models and the transfer between them. The arrow from sounds to images means the conversion from spoken form to visual form. For example, when an individual hears the word ‘dog’, they form the mental image of dog. The arrow from images to sounds represents the opposite form of process: when someone sees a dog, they can mentally hear the word ‘dog’. There is also long-term memory on the right side of the figure. After organizing the material into coherent form in working memory, related prior knowledge is brought from long-term memory and integrated with the organized material. The arrow from long-term memory to working memory indicates this process.

The major cognitive processes in multimedia learning are represented with the arrows labeled as selecting words, selecting images, organizing words, organizing images and integrating (Mayer, 2005). He divided sensory memory and working memory into two channels, one of which deals with auditory and verbal forms of the materials while the other channel deals with visual images and non-verbal forms of the materials. Due to the fact that the working memory capacity is limited, just a few images can be held in the visual channel of working memory and just a few sounds can be held in the auditory channel of working memory (Mayer, p. 45). Mayer (2005) explained that selecting words and images from sensory memory in working memory, organizing words and images in working memory and integrating the prior knowledge from long-term memory with the organized material in working memory enable an individual to be active during these processes, which is vital for meaningful learning.

The framework mentioned above was developed based on three assumptions that were forwarded by Mayer (2005). He (2005) defined these assumptions as dual channels, limited capacity and active processing. For the dual channels assumption, he said that the human cognitive structure has two channels for processing information. When someone receives information through eyes, then the information begins by being processed in the visual channel. Similarly, when the information is received in the form of sound, then it goes to the auditory channel. Indeed, this assumption is mainly based on Paivio’s dual coding theory (Paivio, 1990) and Baddeley’s working memory model (Baddeley, 1986; 1992). Furthermore, although the information is received through one channel, an individual may convert the representation from one channel to the other (Mayer, 2005).

The limited capacity assumption is related to each channel’s limited capacity of a given time (Mayer, 2005). He explained this as meaning that when an illustration or animation is presented, the learner can hold only a few items in his/her working memory at any time. These held items represent pieces of the presented material. Similarly, when an individual is exposed to a verbal expression, the learner can just hold a few words in his/her working memory at any one time. The roots of the limited capacity assumption are based on Sweller's cognitive load theory and Baddeley's working memory model.

The third assumption is the active-processing assumption, which means that humans actively engage in cognitive processing to construct a coherent mental representation of their experiences (Mayer, 2005, p. 50). These cognitive processes include being interested in the material, selecting and organizing the incoming information and integrating it with the knowledge from long-term memory (Mayer, 2005).

Based on these three assumptions introduced for the cognitive theory of multimedia learning, Mayer (2005) advocated that learners should engage in five cognitive processes, in order to achieve meaningful learning, which were also mentioned on Figure 2.1 showing cognitive structure of multimedia learning. He (2005) identifies these processes as "(i) selecting relevant words for processing in verbal working memory, (ii) selecting relevant images for processing in visual working memory, (iii) organizing selected words into a verbal mental model, (iv) organizing selected images into a visual mental model and (v) integrating verbal and visual representations as well as prior knowledge" (p. 54). Selection of words and images is required because of the limited capacity of working memory. Each channel, that is verbal and visual, has capacity limitations, so only selected part(s) of the information can pass through sensory memory. After receiving selected verbal and/or visual information, another cognitive process, which is organizing them, starts. Whereas the verbal knowledge structuring process occurs in the auditory channel, the visual knowledge structuring process takes place in the visual channel. Learners try to build connections among pieces of information that they received. Yet, due to the limitations of working memory, it is not possible to connect all relations among pieces of information, so simple constructions have priority. The last process is the most crucial step, in which word-based and visual-based representations are integrate with each other and also with the prior knowledge called from long-term memory. This integration process happens in both the visual and the verbal channel and includes the coordination between them. This step might be difficult for learners because it requires heavy use of cognitive capacity. Learners should focus on the underlying structure of the visual and verbal representations and be able to use prior knowledge, stored in long-term memory, when necessary (Mayer, 2005, p. 57).

Mayer and Moreno (2002) stated that learners gain deeper learning in multimedia learning, since they receive multi-medium presentations, instead of through a single medium. They claim that multimedia works better, but not always. In order to investigate when multimedia works efficiently, they examined four different conditions for computer-based multimedia learning: contiguity aids, coherence aids, modality aids and redundancy aids. For example, in contiguity aids, visual and verbal representations were presented to students simultaneously. When learners were exposed to such a condition, they performed better than the group who received a single representation at a time (Mayer & Moreno, 2002). This finding is compatible with the cognitive theory of multimedia learning, because when the representations are presented successively, then learners receive the full information twice which contradicts the limited capacity of working memory. Mayer and Moreno (2002) also examined coherence aids, which means presenting information with some extra information or background music. When they compared the two groups, the one who received a concise narrated animation in which basic visual and verbal information were presented simultaneously achieved a better score than the other group, who were exposed to the same presentations with extra words and sounds. This result also supports the role of the limited capacity of working memory in multimedia learning's cognitive structure. Modality aids were also investigated by Mayer and Moreno (2002). The aim of modality aids is to reduce the load on working memory by directing the information into the auditory or visual different channels. They compared the learning outcomes of students who were taught through animation and narration with the group who learnt from animation and text. They concluded that the students in animation and narration group outperformed the others. This result also supports the identified cognitive structure of multimedia learning. Redundancy aids are another type of aid in computer-supported multimedia learning. Mayer and Moreno (2002) compared two groups in their study. One group received instruction based on animation and narration; the other group was taught with animation, narration and on-screen text. The result showed that the animation and narration group reached a better score. Mayer and Moreno (2002) stated that adding on-screen text may cause a split-attention effect and may give rise to working memory overload. All of these types of aids focus on the same critical point, which is the limited capacity of working memory.

2.4 The Advantages of Physicality in a Hands-on Laboratory Environment

Besides their role in cognitive processes of learning, the other important issue related to virtual laboratory environments is physicality. Physicality refers to actual, active and intentional tactile actions done by someone in order to realize an object’s hardness, temperature, surface shape, or weight, and so on (Loomis & Lederman, 1986). In a hands-on laboratory environment, touch sensory input is provided by directly touching the physical materials and apparatus (Zacharia, 2015). Yet, it is difficult to provide such physicality in a virtual laboratory environment, because all materials are on screen and there is no direct touching of the materials. In order to handle this situation, haptic devices can be added to the virtual laboratory environment. As yet, it is not certain whether physicality is a prerequisite for learning in science. Some studies (e.g., Kontra, Lyons, Fischer, & Beilock, 2015) have found that students in hands-on laboratory environments, in which physicality is available, gained more knowledge than those using virtual laboratory environments without touch sensory input or haptic devices. On the other hand, studies (e.g., Zacharia, Olympiou, & Papaevripidou, 2008) have also concluded that a virtual laboratory environment is more beneficial for students than a hands-on laboratory environment. However, there are also studies (e.g., Zacharia & Olympiou, 2011) that concluded that each type of laboratory environment is equally effective for students’ conceptual understanding. With regard to these studies, Zacharia (2015) stated that physicality is not necessary for learning, because in some studies, students without physical touching or haptic devices reached better scores than their counterparts, who were taught in a hands-on laboratory environment, where touch sensory input was active. Zacharia (2015) together with other researchers (e.g., Triona & Klahr, 2003) have advocated that manipulation is more important for learning than physicality is. “Manipulation requires the learner to intentionally interact with the material and apparatus in a skillful manner” and does not necessarily require touching the materials (Zacharia, 2015, p. 117). In other respects, physicality might be required for developing certain motor skills, especially for young students.

There are two main theoretical perspectives related to tactile manipulation, which are embodied cognition and an additional (touch) sensory channel (Zacharia, 2015, p. 118). According to the embodied cognition theory, learning (or thinking) necessitates actual and dynamic activations of sensory and motor systems (Barsalou, Kyle Simmons, Barbey, & Wilson, 2003; Fischer & Zwaan, 2008; Niedenthal, 2007). Sensorimotor experiences drawn from embodied cognition are helpful for meaningful learning (Zacharia, 2015). Kontra et al. (2015) explained that when the content that will be taught is connected with physical activities, the ensuing activation of sensory and motor systems might promote learners' reasoning ability. Within the context of science education, usage of touchable manipulatives encourages performance of physical sensorimotor actions, which cause students to construct motor schemas that can help them to develop conceptual metaphors, which are certain student-based science concepts (Zacharia, 2015).

Another theory about the importance of physicality in learning is the additional (touch) sensory channel theory. McNeil and Jarvin (2007) stated that providing additional touching opportunities for students enables them to receive more knowledge about the manipulative included in the experiment, such as its physical structure, temperature and so on. Adding tactile experience of a physical phenomenon to the visual and auditory modalities may have an impact on learning more complex concepts (Bivall et al., 2011), because each modality has its own processing channel (Burton & Sinclair, 2000). In other words, the information might be divided over multiple processing channels, which decreases cognitive load (Chan & Black, 2006). Zacharia and Olympiou (2011) explained two ways in which activating the touch sensory channel can have an impact on learning through science experimentation. First, they (2011) say that if the same type of information that travels through the visual or the auditory channels is transferred through the sensory channel of touch, the cognitive load on the visual and auditory storage systems is reduced (p. 119), which leaves idle capacity in central working memory to sustain processing for complex understanding. The second approach offered by Zacharia and Olympiou (2011) is that if different types of complementary information are carried via the visual or auditory channels to the touch sensory channel, then learning would be enhanced, since the amount of information received by the learner's working memory increases without augmenting the cognitive load for each individual channel.

2.5 Conceptual Change

Children's concept knowledge based on their observations or other information sources is alterable due to their biological growth and their learning (Vosniadou & Ioannides, 1998). Many studies have concluded that children start their education with concept knowledge, which are usually not aligned with scientific knowledge (Duit & Treagust, 2003; Duit, Treagust, & Widodo, 2008). Such concept knowledge is stored for a long time by students and is resistant to change (Duit & Treagust, 1998; 2003). Furthermore, in some cases, students develop new knowledge based on their existing knowledge that contradicts scientific knowledge (Palmer, 1999; Tsai, 2000). This type of knowledge is known as: *intuitional concepts* (McCloskey, 1983), *misunderstanding* (Zoller, 1990), *naive beliefs* (Caramazza, McCloskey, & Green, 1981) *conceptual misunderstanding* (Picciarelli, Stella, Di Gennaro, & De Leonardis, 1990), *child science* (Gilbert, Osborne, & Fensham, 1982), *pseudo-science beliefs* (Impey, Buxner, & Antonellis, 2012), *alternative conceptual framework* (Taber, 1998), *pre-concept* (Clement, 1982) *alternative concept* (González, 1997) and *misconception* (Bradley & Mosimege, 1998).

In a general sense, conceptual change in science denotes the learning pathways from students' pre-instructional conceptions to the science concepts to be learned (Treagust & Duit, 2009, p. 91). Studies about conceptual change (e.g., Chi, Slotta, & De Leeuw, 1994; Pintrich, Marx, & Boyle, 1993; Posner, Strike, Hewson, & Gertzog, 1982) have used three different viewpoints: epistemological, ontological and affective (Duit & Treagust, 2003). The epistemological perspective, which is also known as the classical conceptual change model, was mainly developed by Posner et al. (1982). They suggested that a student's dissatisfaction with prior concept(s) initiates the conceptual change process, and then if a replacement concept is advisable, accommodation of the new concept may occur (Treagust & Duit, 2009). Posner et al. (1982) suggested four conditions that must be fulfilled for the conceptual change process to occur. These are "dissatisfaction with the existing concepts, the new concept should be intelligible, and it should seem plausible and should be fruitful to be extended" (p. 214). In other words, the new concept must be clear, useful and understandable for successful conceptual change.

In terms of the ontological perspective, Chi (1992) and Chi, Slotta and Leeuw (1994) claimed that all entities can be defined according to three different ontological categories. Chi et al. (1994) claimed that when a student's initial representation of the concept is incompatible with the concept's veridical ontological status, then learning the concept requires conceptual change, meaning that the concept's categorical membership has to be re-assigned (p. 34). Figure 2.2 shows the ontological categorization of all entities in the world from Chi et al. (1994).

Chi (1992) defined conceptual change on two different levels. One is hierarchical conceptual change, which happens in the same ontological category. The other is called as radical conceptual change, which takes place across ontological categories. The second type of conceptual change is harder than the first.

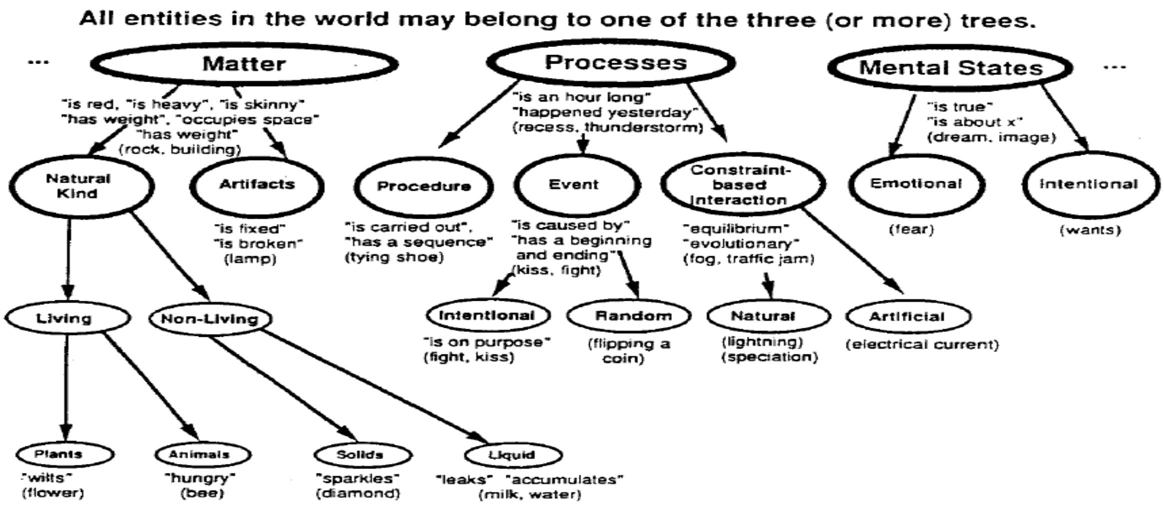


Figure 2.2 Ontological categorization scheme for all the entities in the world (Chi et al., 1994)

Third, Pintrich, Marx and Boyle (1993) explained that social and affective dimensions should be considered during the conceptual change process. They emphasized that students' self-efficacy, the social environment in classroom, students' intrinsic motivation, goals, expectations and needs are crucial components of the conceptual change process as much as cognitive strategies.

As a consequence, conceptual change might be a challenging process for students. In order to help them to deal with the process, the four conditions defined by Posner et al.

(1982) should be followed carefully and students' affect also should be taken into consideration.

2.6 Attitude towards Science and Laboratory

Students' attitude towards science is an important factor to motivate them during the learning process. Although many studies have investigated students' attitudes towards science, there is no common definition of 'attitude' (Kind, Jones, & Barmby, 2007; Osborne, Simon, & Collins, 2003) because of its complicated nature, which includes various properties from different domains (Zhang & Campbell, 2011). One common definition of attitudes towards science developed by Osborne and colleagues (2003) was feeling, beliefs and values held about an object, which might be the enterprise of science, school science, and the impact of science on society or scientists themselves (p. 1053). Other researchers have stated that attitudes towards something develop based on a person's estimations (Ajzen, 2001; Crano & Prislin, 2006), while others have claimed that attitudes involve judging something along with emotional feelings, having an idea like good or bad, lovely or beastly (Kind et al., 2007). Based on these definitions, Reid (2006) stated that attitudes have cognitive, affective and behavioral constituents and these are related with each other. These three components have strong effects on individuals' attitudes towards something. The cognitive component involves knowledge about an object, event or concept. The affective component includes feelings or emotions (e.g., like or dislike) about an object, event, or concept. The behavioral component is related to a behavior based on a person's attitude toward an object, event or concept.

It is difficult to change or develop a person's attitudes towards something (Reid, 2006) but attitudes can be learned or taught, related to behavior and long-lived (Young, 1998, p. 97). In related literature, researchers developed several criteria in order to determine students' attitudes towards science. For example, Kind and colleagues (2007) advocated that several sub-dimensions such as learning science in school, practical work in science, science out of school, the importance of science, self-concept in science and future participation in science (p. 871) can be used when measuring students' attitudes towards science. In another study done by Osborne and colleagues (2003), they stated that "anxiety toward science, self-esteem for science, motivation toward science, enjoyment of science, attitudes of peers, friends, and parents toward science, achievement in science and fear of failure in a course" (p. 1054) are some cognitive and affective components of students' attitudes toward science. Researchers (e.g., Freedman, 1997; Xu, Villafane, & Lewis, 2013) have also investigated whether achievement influences attitude or vice versa. Yet, there is no certain conclusion about this issue (Zacharia, 2003).

Studies have also shown that an inquiry-based science learning approach has positive impacts on students' attitudes and self-confidence in science education (Chen et al., 2014; Zacharia, 2003). Furthermore, the use of simulations in educational contexts has also been investigated, with the conclusion that simulations are successful tools in order to improve students' attitudes towards science (Zacharia, 2003). In other words, the learning environment is another important factor in students' attitudes towards science. Not only computer simulations but also laboratory environments and experiences are crucial elements students need in order to have positive attitudes towards science. Chen et al. (2014) stated that laboratories might be powerful environments to enable students to develop positive attitudes towards science, if students act as active learners and design and implement experiments in an innovative way. Indeed, not only these factors but also science curricula at schools (Khishfe & BouJaoude, 2016), the social environment, students' needs, interests, characters, personalities and communication skills are some other factors that affect attitudes towards science (Lemke, 2001). For example, there are studies examining effects of gender on attitudes towards science (e.g., Baram-Tsabari & Kaadni, 2009; Çokadar & Külçe, 2008; Haste, Muldoon, Hogan, & Brosnan, 2008; Tal, Geier, & Krajcik, 2000). The results of these studies are contradictory and there is no certain conclusion. Yet, children are exposed to gender- and ethnicity-related messages frequently from different sources such as internet, television, and computer games. These sources might have greater effects on children's attitudes towards science than their own gender does. Besides gender, parents and the school environment are other important factors in the development of attitudes towards science, which were investigated in several studies. For instance, communication and relations with other students and teacher, being an active participant in the learning process, and structure and mode of delivery of the science curriculum are vital elements for students' achievement and attitudes towards science (Khishfe & BouJaoude, 2016;

Mahamood et al., 2012; Perera, 2014; Şentürk & Özdemir, 2014; Sun, Bradley, & Akers, 2012).

In conclusion, there are many cognitive, affective and behavioral factors influencing students' attitudes towards science (Reid, 2006). Therefore, it is not an easy task to change students' attitudes towards science in a short period of time or by a single event (Chen et al., 2014).

2.7 Comparison of Hands-on and Virtual Laboratories

Through developments in educational technology, virtual laboratory environments have become used in educational contexts. Many studies have compared the effects of hands-on and virtual laboratory environments on students' conceptual understanding, inquiry skills and attitudes (e.g., Chen et al., 2014; Gnesdilow et al., 2016; Pyatt & Sims, 2012; Zacharia & de Jong, 2014; Zacharia & Michael, 2016). There are also several meta-analyses (e.g., Brinson, 2015; Potkonjak et al., 2016; Smetana & Bell, 2012) that give detailed information about comparisons of hands-on and virtual laboratory environments.

2.7.1 Achievement and Conceptual Understanding

A meta-analysis done by Brinson (2015) revealed that virtual laboratory environments provide equal or greater opportunity for students' achievement and conceptual understanding. For example, Tatli and Ayas (2013) designed and implemented a study with 90 high school students to examine the effects of hands-on and virtual laboratory environments on students' achievement, for the topic of chemical changes. They found that the virtual laboratory environment was at least as effective as the hands-on lab environment. A similar study was designed by Kollöfel and de Jong (2013) with secondary school students. They found that students in the virtual laboratory outperformed the participants in the hands-on laboratory environment for conceptual understanding of electric circuits. Zacharia and Constantinou (2008) compared both modes of experimentation with regard to undergraduate students' conceptual understanding about heat and temperature, and found that the two modes were equally effective. Tüysüz (2010) also compared the impacts of hands-on and virtual laboratory environments on high school students' achievement, for the topic of matter, and concluded that investigations done in a virtual laboratory increased students' achievement better than those in a hands-on laboratory. In another study, Triona and Klahr (2003) investigated the influence of physical and virtual experimentation on fourth and fifth grade students' conceptual understanding of the behavior of springs. They found no significant difference between the two different laboratory environments.

On the other hand, researchers have also found that hands-on experimentation is more effective than virtual experimentation. For example, Gire et al. (2010) concluded from their study that experiments done in a hands-on laboratory were more beneficial for undergraduate students' understanding of pulleys than those done in a virtual laboratory. Zacharia and Constantinou (2008) explained these contradictory findings as due to the different affordances provided by hands-on and virtual laboratory environments. Hands-on and virtual laboratory environments not only have many common goals for students, but also have unique possibilities. In order to take advantages of the unique opportunities of both types of laboratory environment, researchers investigated the effects of combinations of laboratory environments on students' achievement, when compared to hands-on or virtual laboratories alone. For example, in the study done by Olympiou and Zacharia (2010), they compared a hands-on laboratory, a virtual laboratory and two different combinations of hands-on and virtual laboratory environments. They found that experimenting in a hands-on laboratory, a virtual laboratory or combinations of the laboratory environments were equally effective for teaching concepts about heat and temperature.

However, studies have also found that combinations of hands-on and virtual laboratory environments or using them in a sequence give better results than using them alone. In two studies by Olympiou and Zacharia (2012, 2014), they found that undergraduates who used virtual and physical laboratory environments in a combination developed better conceptual understanding (2012) and content knowledge (2014) about light and color than students in hands-on or virtual laboratory environments alone. Zacharia and Michael (2016) investigated primary school students' understandings about electric circuits in three different laboratory environments, hands-on, virtual and a combination of both types of laboratory environment. They also found that students in the combination condition enhanced their domain knowledge better than in the other two conditions. Wang and Tseng (2018) investigated primary school students' development of knowledge about state changes of water in hands-on, virtual and a combination of both types of laboratory environments. They concluded that the combination of the laboratory environments promoted students’ conceptual understanding much better than the use of either the hands-on or virtual laboratory environment alone.

Another important issue in connection with combinations of two different laboratory environments is the sequence between hands-on and virtual laboratory environments. Some studies (e.g., Zacharia & de Jong, 2014) have found that when the virtual laboratory environment was used first and then followed by the hands-on laboratory environment, students gained better conceptual understanding. The opposite sequence, hands-on laboratory followed by virtual laboratory, was followed in the study by Smith and Puntambekar (2010), who concluded that students should conduct virtual experiments after conducting them in hands-on laboratory environments. Other studies (e.g., Chini, Madsen, Gire, Rebello, & Puntambekar, 2012) have concluded that there is no certain effect of the sequence of laboratory environments on enhancing students’ domain knowledge.

In summary, although hands-on and virtual laboratory environments have common properties, each of them also has unique possibilities. That’s why using both of the laboratory environments in a sequence or a combined form gives better results for students’ achievement. There is no certain conclusion about sequences of laboratory environments, but Olympiou and Zacharia (2012) developed a framework concerning such sequences with respect to their unique advantages for students’ conceptual understanding. This framework was tested by Olympiou and Zacharia (2014), but still needs to be tested with other studies.

2.7.2 Inquiry Skills

A virtual laboratory environment is also appropriate for developing students’ inquiry skills, such as generating hypotheses, gathering and analyzing data, designing experiments and/or drawing conclusions. Although inquiry is at the center of scientific learning (Brinson, 2015), expository laboratories, in which scripted procedures and directions are used (Pyatt & Sims, 2007) to teach and/or validate existing scientific ideas, are common in science education (Lagowski, 2002). Because it is difficult to develop students’ inquiry skills in such expository laboratories, only a few studies have measured development of inquiry skills as outcomes. For example, Yang and Heh (2007) compared the impacts of hands-on and virtual laboratory environments on high school students' inquiry skills and found that students who used a virtual laboratory reached significantly higher scores than their counterparts. In another study, Lee and colleagues (2002) investigated pre-service biology and elementary teachers' views about computer simulations as a learning tool for understanding and using inquiry skills. They found that pre-service teachers mainly thought that the simulation helped them to develop their inquiry skills. A study by Mutlu and Acar-Şeşen (2016) also supported this view. They found that pre-service science teachers developed their inquiry skills significantly better in the virtual laboratory environment when compared to the hands-on laboratory environment.

2.7.3 Attitude towards Science Course and Laboratory

Several studies have investigated the impacts of a virtual laboratory environment on students' attitudes towards science or learning. For instance, Tüysüz (2010) implemented a study with ninth grade students and found that the virtual laboratory environment improved students' attitudes towards science better than the traditional hands-on laboratory environment. In another study done by Akçayır et al. (2016), they concluded that experiments done in the virtual laboratory had more significant effects on pre-service science teachers' attitudes towards laboratories than experiments done in the hands-on laboratory. Similarly, Sarı Ay and Yılmaz (2015) found that a virtual laboratory is an effective tool in order to improve seventh grade students' attitudes towards science. Azar and Aydin-Şengüleç (2011) also found that computer-assisted experiments were more effective than hands-on experiments for improving high school students' attitudes towards science. A study by Kiboss, Ndirangu and Wekesa (2004) revealed that the computer simulation improved high school students' attitudes towards the subject significantly more than their counterparts in the tradition classroom environment. On the other hand, Oser and Fraser (2015) did not find a significant difference between the two laboratory environments in effects on high school students' attitudes towards science. Yang and Heh (2007) also did not detect any significant difference between students' attitudes towards computers in the hands-on and virtual laboratory environments. Similarly, Kim (2006) investigated the effects of 3D simulations on fifth grade students’ attitudes towards science, but he found there were no significant impacts of 3D simulations when compared to traditional 2D visuals.

As a consequence, contradictory results about the effects of virtual laboratory environments on students’ attitudes towards science, laboratories, subjects or computers are contradictory. The reasons behind these differences could be related to teachers, school, age, and even gender.

3
METHOD

3.1 Participants

Seventh grade students from a public school were the participants in the current study. The school was determined by using purposive sampling, since the school had to have an internet connection and a science laboratory that enabled us to implement investigations in both of the laboratory environments. After determination of the school, the students were chosen by convenience sampling. Four different seventh grade classes and a unique science teacher who taught for the same four different seventh grade classes were needed. There was just one science teacher who had this qualification. The science teacher was asked to join the study as a volunteer.

The science teacher had more than 20 years of experience in science teaching. She had no prior experience teaching via virtual laboratories. She mostly uses inquiry-based learning approach in hands-on laboratory environments. The total number of participants was 143 seventh grade students from four different classes; their ages were between 12 and 14 years old. A quasi-experimental research design was used in the study. The classes were coded as HHH, VVV, VHV and HVH, in which H represents ‘hands-on’ and V is for ‘virtual’; the sequences of the letters show the sequence in which the laboratories were offered. Students’ distribution across the conditions is shown in Table 3.1. All of the students had experience with computers or tablets. The study was conducted in the spring term of the 2016-2017 academic year in Turkey.

Table 3.1 Students' distribution across the conditions

Condition	Number of Students
HHH	33
VVV	34
VHV	39
HVH	37

3.2 Instruments

Five different quantitative and qualitative data-gathering tools were used in the study. Quantitative data collection instruments are introduced first, then the qualitative data-gathering tool.

3.2.1 Multiple-Choice Conceptual Knowledge Test

The multiple-choice conceptual knowledge test was developed by Sencar Tokgöz (2007). The test involves 28 questions (Appendix A). Twenty-two of the questions are multiple choice questions (each question has four choices), three are true/false questions and the last three are matching questions. The questions in the test are about parts of electric circuits, serial and parallel circuits and measuring potential difference, current and resistance and asked for students' conceptual knowledge of the domain. Each correct answer was given one point. Possible scores ranged from 0 to 28. A higher score show higher understanding. Cronbach's alpha coefficient was found 0.80 for the multiple-choice conceptual understanding posttest.

3.2.2 Open-Ended Conceptual Knowledge Test

The open-ended conceptual knowledge test (Appendix B) was developed for this study in order to diagnose middle school students' misconceptions about the topic of electricity. The difference between the multiple-choice conceptual knowledge test and open-ended conceptual knowledge test is that the latter was intended to measure students' deeper understandings by having them make drawings themselves. Objectives from the unit on electricity in the seventh-grade science curriculum were considered in the process of developing the test, in order to ensure content validity. A researcher, who has a bachelor's and a master's degree in physics education, and a science teacher examined and reviewed the test in terms of content validity. The adapted form of the test was piloted with 24 seventh grade students. Terms that could cause misunderstandings were revised with respect to students' views. Table 3.2 shows a number of questions from the final version of the test and the corresponding objectives and their topics. The test involves six open-ended questions, which require drawing circuits, analyzing graphs, and writing explanations.

Table 3.2 Classification of questions in the open-ended conceptual knowledge test

Objective	**Topic**	**Questions**
Students are able to explore and to draw serial and parallel circuits.	Differences in bulbs' brightness in serial and parallel circuits Batteries provide electrical energy to the circuits.	Q1a, Q1b, Q4
Students are able to connect an ammeter to a circuit and can read its measurements and know its units.	Function of ammeter in a circuit	Q2, Q5
Students are able to connect an ohmmeter to a circuit and can read its measurements and know its units.	Function of ohmmeter in a circuit	Q2, Q5
Students are able to explore the relation between voltage and current by designing experiments.	Adding batteries to serial and parallel circuits	Q6
Students are able to correlate the different brightness of bulbs in serial and parallel circuits with the resistance.	Adding or subtracting bulbs to (or from) serial and parallel circuits	Q3

In order to determine inter-rater reliability, two independent coders rated 20% of the open-ended conceptual knowledge test individually. The agreement based on the two raters' coding was 81.3%. The remaining tests were coded by only one rater.

For further analysis of the data from the open-ended conceptual knowledge test, these qualitative data were transformed into quantitative data. Fully correct answers, which involved meaningful explanations and/or correct drawings, were given 2 points (see Figure 3.1). Partial understanding responses, which showed a correct result with a wrong explanation or partial (deficient) drawings, were given 1 point (see Figure 3.2). Misunderstandings, no answers or wrong responses were given 0 points (see Figure 3.3).

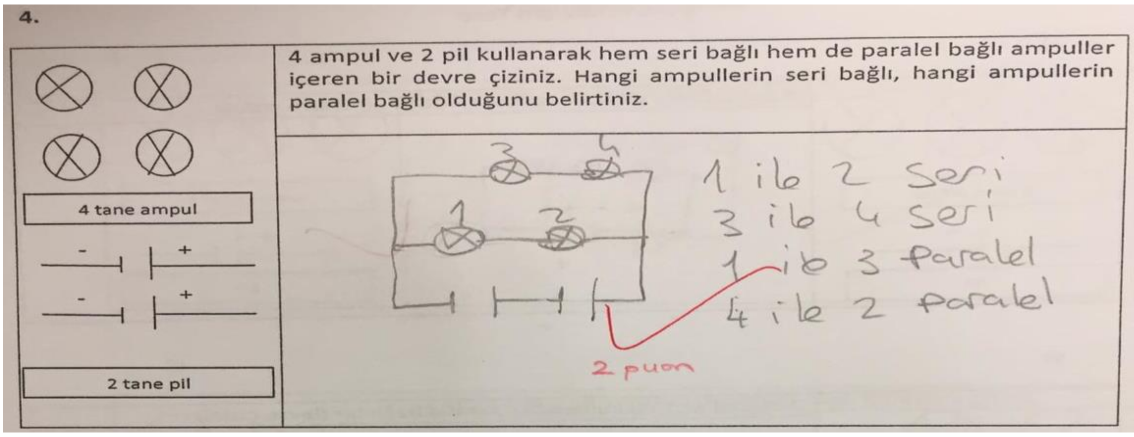


Figure 3.1 A sample figure for a correct drawing

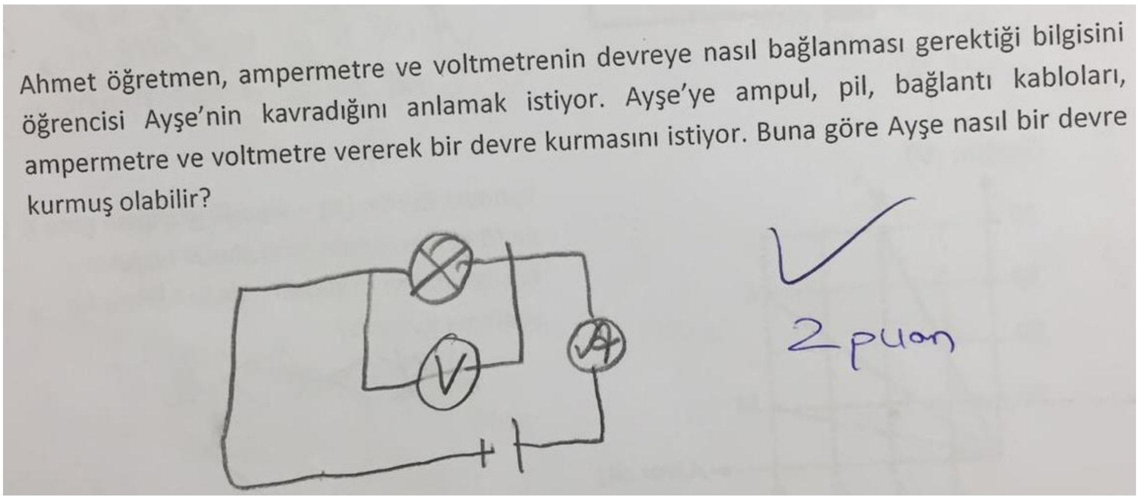


Figure 3.2 A sample figure for a correct drawing

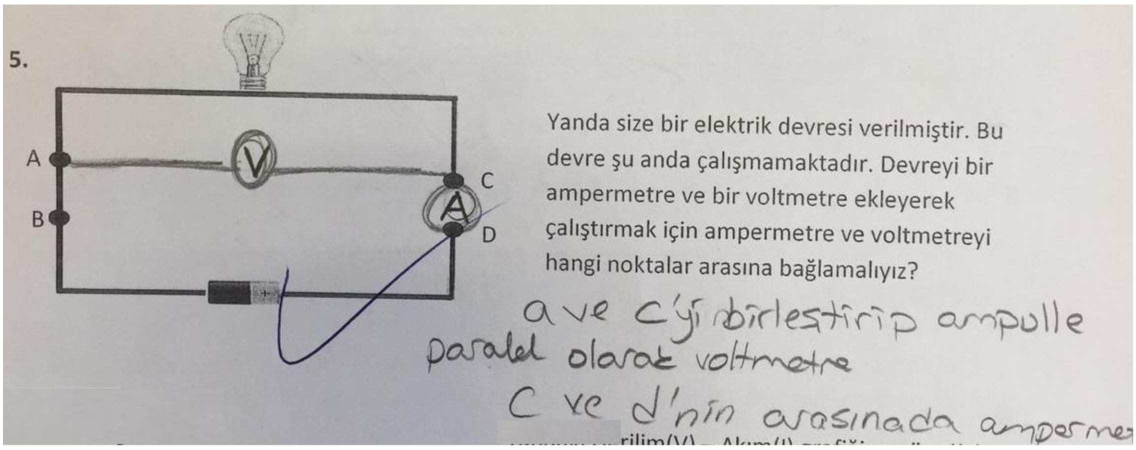


Figure 3.3 A sample figure for a correct drawing

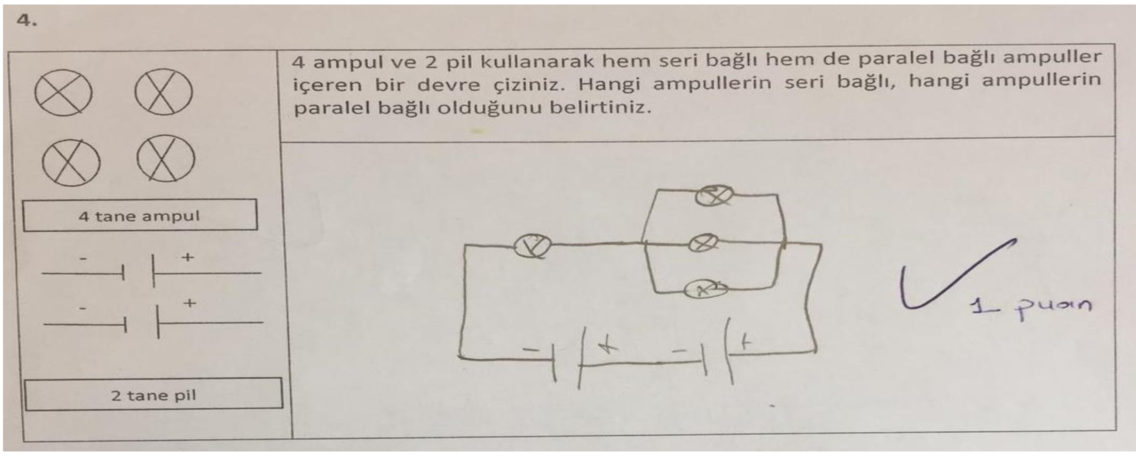


Figure 3.4 A sample figure for a partially correct drawing

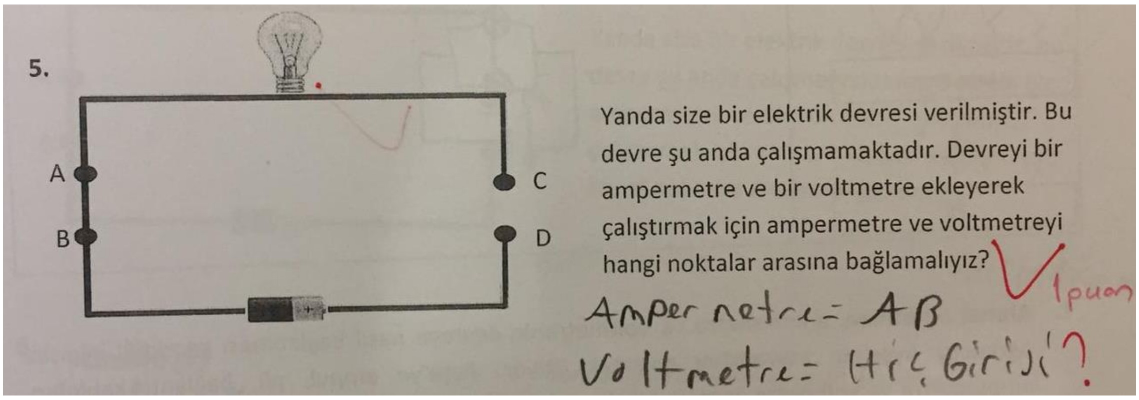


Figure 3.5 A sample figure for a partially correct drawing

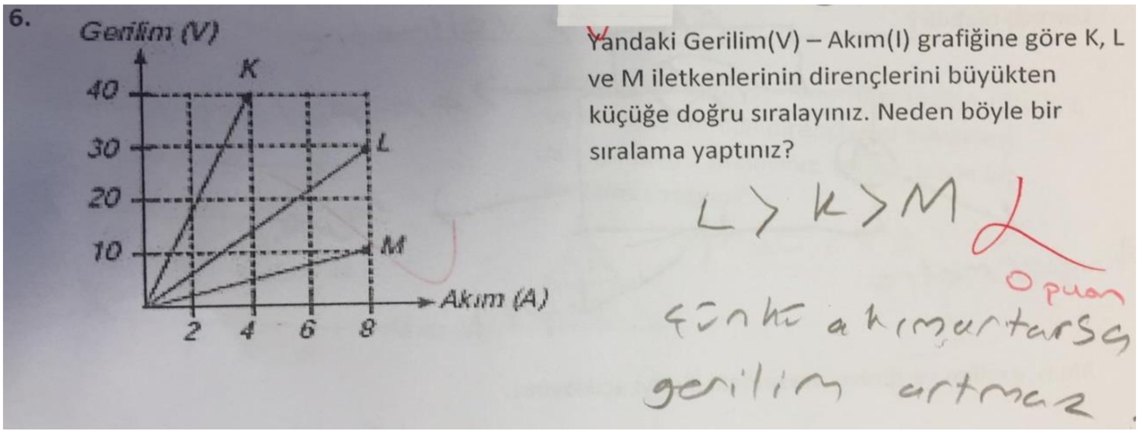


Figure 3.6 A sample figure for a wrong drawing

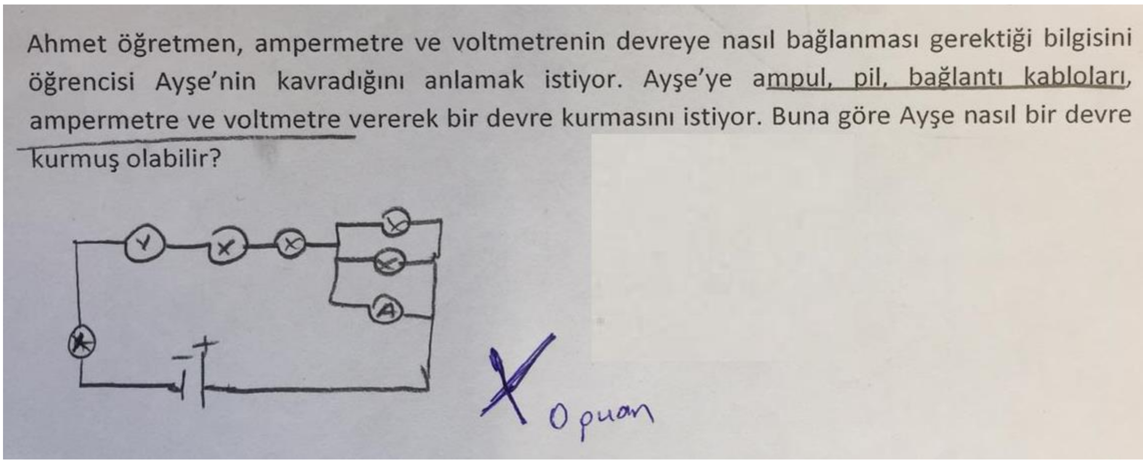


Figure 3.7 A sample figure for a wrong drawing

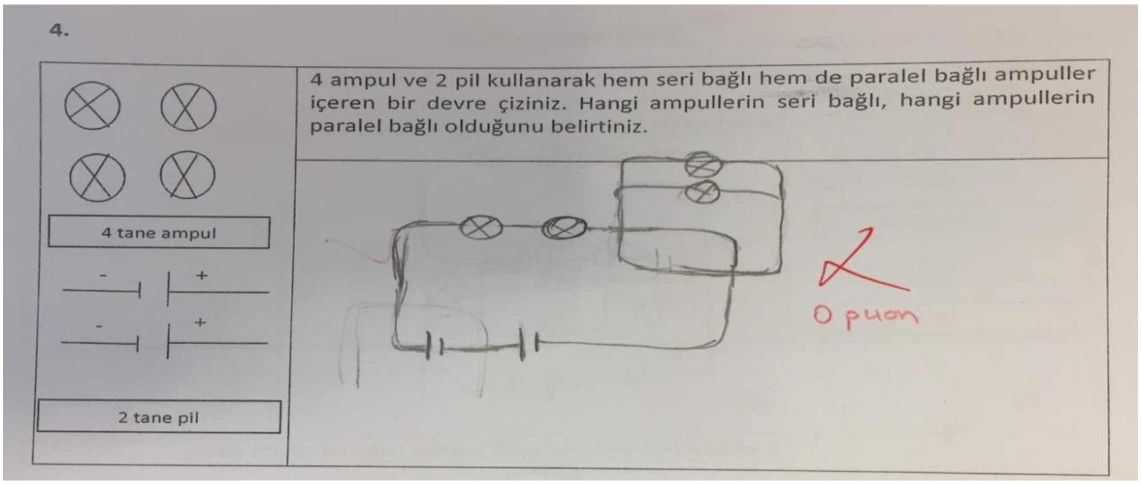


Figure 3.8 A sample figure for a wrong drawing

3.2.3 Inquiry Skills Test

The inquiry skills test was developed by Aydoğdu (2009). The test includes 28 questions and is intended to measure students' basic inquiry skills (e.g., observation, classification, prediction) and higher-order inquiry skills (e.g., forming hypothesis, determining variables, and designing experiments) through multiple-choice questions related to topic of electricity (Appendix C). Each correct answer was given one point. Table 3.3 shows the number of questions that aimed to measure a corresponding inquiry skill. Cronbach's alpha coefficient was 0.96 for the inquiry skills posttest.

Table 3.3 The inquiry skills tested

Inquiry skill	**Number of questions on the test**
Observation	1
Classification	2
Prediction	2
Measurement	2
Inferring	4
Forming hypothesis	2
Determining variables	1
Checking and changing variables	3
Designing experiment	3
Gathering data	1
Data analysis	2
Conclusion and reflection	5

3.2.4 Attitude towards Science Course and Laboratory Questionnaire

The attitude questionnaire developed by Barmby, Kind, Jones and Bush (2005) was used in the current study. The questionnaire was translated into Turkish by Kaya and Böyük (2011). The attitude questionnaire involves 21 items (Appendix D) and aims to measure middle school students' attitudes towards science courses and laboratories. The questionnaire consists of three sub-dimensions: learning science in school (6 items), practical work in science (8 items), and self-concept in science (7 items). The first two sub-dimensions aimed to measure middle school students' attitudes towards science learning in different environments (in the classroom and in the laboratory). The third sub-dimension aimed to measure the learner's perception of their own ability to have comprehensive knowledge of school science. The questionnaire uses a 5-point Likert-type scale. The response choices for the items are *strongly disagree* = 1, *disagree* = 2, *neither agree nor disagree* = 3, *agree* = 4 and *strongly agree* = 5. In the data analysis process, the responses were reverse-coded for negatively phrased items.

Kind, Jones, and Barmby (2007) found a Cronbach's α of 0.89 on a pretest and 0.92 on a posttest for the learning science in school sub-dimension of the questionnaire. For practical work in science, Cronbach's α was found to be 0.85 and 0.89 for the pretest and posttest measures, respectively. Lastly, for self-concept in science, Cronbach's α was found to be 0.85 in the pretest and posttest measures. In the current study, Cronbach's α based on the posttest scores was 0.77 for learning science in school, 0.70 for practical work in science, and 0.73 for self-concept in science.

3.2.5 Interview

Interviews were done with nine students (three students each from the VVV, HVH, and VHV classes) and the science teacher. The science teacher chose these students based on their achievement in science class (high-medium-low) and being able to express their thoughts clearly. The purpose of the interview was to reveal middle school students' and the teacher's views about virtual and hands-on laboratory environments. Besides students in the combined HVH and VHV conditions, students from the VVV condition were also included, because it was assumed that they could compare hands-on and virtual laboratories, having done all their experiments in hands-on laboratories until this study. Students from the HHH condition were not included, since they did not have any experience with the virtual laboratory. Each interview was done one-on-one and lasted approximately 20 minutes. A semi-structured interview form was used. The students were asked six major questions. The original forms of the questions were adapted from a study by Chen et al. (2014). Among the six interview questions, two questions explored students' perceptions of learning throughout the laboratory activities. Three questions focused on their appreciation of laboratory environments, and one question addressed the effectiveness of the scaffolding tools in the virtual laboratory. Similarly, the topics of the interview questions for the teacher were advantages and drawbacks of the virtual laboratory environment, the scaffolding tools used during the learning process and the teacher's choice between hands-on and virtual laboratory environments.

3.3 Research Design and Implementation

First, a unit about electricity was chosen for the topic because of its appropriateness for designing and implementing experiments in both hands-on and virtual laboratories. To organize the study, the unit on electricity was divided into three sections, based on the science curriculum. The first section consisted of a basic closed circuit and serial and parallel circuits. The next section involved how to add an ammeter and voltmeter to the serial and parallel circuits. The last section of the unit included Ohm's law. The lesson plans for the students that involved the topic of electricity, how to use a virtual laboratory in a classroom environment, some basic technical issues about the virtual laboratory platform and the laboratory worksheets that were used in the hands-on laboratory environment were all discussed and planned with the science teacher.

The four classes were assigned randomly to one of the conditions from the study. The class coded as HHH was fully taught in the science laboratory and did all experiments within the hands-on laboratory. The class coded as VVV was totally taught in a computer laboratory and students from this class performed all experiments with a virtual laboratory. The class coded as VHV was taught in the virtual laboratory environment for the first and the last sections of the unit and was instructed in a hands-on laboratory for the second section of the unit. The class coded as HVH was taught in a hands-on laboratory environment for the first and the last sections of the unit and used a virtual laboratory environment for the second section of the unit.

After the classes had each been assigned to a condition, the three different tests (the multiple-choice conceptual understanding test, the open-ended conceptual understanding test, and the inquiry skills test) and the attitude questionnaire were taken as pretests. Exercises with a virtual laboratory were also done for the classes coded as VVV, VHV and HVH. The aim was to introduce the virtual laboratory environment to the students in these classes. The students worked with a similar laboratory and learning environment as in the real laboratory. Their questions about the virtual laboratory environment were answered and some basic technical information was provided. The virtual laboratory platform was not introduced to the students in the HHH condition. The students in all four classes were divided into groups of three, using the alphabetic ordering of the students. After this, students worked in their groups with the combination of laboratories designated for their class's assigned condition. At the end of the study, the same tests and the attitude questionnaire were taken as the posttests. Then, three students each from the VVV, VHV, and HVH conditions were asked to be interviewed; all selected students agreed to be interviewed. Students from the HHH condition were not interviewed because they were not able to experience the virtual laboratory environment, and therefore, they could not compare the two environments. The tests were taken on an individual basis and did not count for the students' official results. The study lasted for six weeks. The first and second sections of the unit each took one week and the third section of the unit lasted for two weeks. Science classes were four hours per week. The interviews were done one week later, after the study had been completed. The tests were administered in the first and last weeks of the study; it was assumed that the duration of the study (6 weeks) and the total number of questions on the tests prevented students from memorizing the questions. Table 3.4 shows the research deign of the study.

The same science teacher instructed each class. The researcher observed all the classes and only interfered when technological problems occurred. Paper-based laboratory worksheets were used for the classes that were taught in the hands-on learning environment; online scaffolding tools were used for the classes that were instructed in the virtual laboratory environment.

Table 3.4 Research design of the study

Pretests for all groups	**Groups**	**Stage 1 (Serial and Parallel Circuits)**	**Stage 2 (Ammeter and Voltmeter)**	**Stage 3 (Ohm's Law)**	**Posttests for all groups**
Multiple-Choice Conceptual Knowledge Test Open-Ended Conceptual Knowledge Test Inquiry Skills Test Attitude towards Science Course and Laboratories Questionnaire	HHH	Hands-on Laboratory	Hands-on Laboratory	Hands-on Laboratory	Multiple-Choice Conceptual Knowledge Test Open-Ended Conceptual Knowledge Test Inquiry Skills Test Attitude towards Science Course and Laboratories Questionnaire Interviews*
	VVV	Virtual Laboratory	Virtual Laboratory	Virtual Laboratory	
	VHV	Virtual Laboratory	Hands-on Laboratory	Virtual Laboratory	
	HVH	Hands-on Laboratory	Virtual Laboratory	Hands-on Laboratory	

* Interviews were done with the students from VVV, VHV, and HVH groups.

Guided inquiry-based learning was used in the study. All classes were taught with the same teaching approach. The inquiry cycle involved orientation, hypothesis generation, experimentation, conclusion and evaluation (de Jong, 2006). In the hands-on laboratory environment, the science teacher acted as the main source of guidance supporting the students; a laboratory worksheet also provided scaffolding for the students. In the virtual laboratory environment, three online scaffolding tools were used in the inquiry cycle (see the Go-Lab Sharing and Authoring Platform, 2015; Pedaste et al., 2015). Students in all classes received scaffolds for the hypothesis generation process, according to their assigned condition. If they were assigned to be in the virtual laboratory environment, an online hypothesis scratchpad was provided for them. For the students in the hands-on laboratory environment, a paper worksheet was provided for generating hypotheses. For the experimentation phase, a brief demonstration video that showed how to design an experiment was provided to the students in the virtual laboratory environment. In the hands-on laboratory environment, the science teacher guided students in how to create circuits. And lastly, a conclusion tool that enables learners to see the group's hypotheses and result of their experiment(s) and gives a space to write their conclusion was provided for students in the virtual laboratory environment. For the students in hands-on laboratory environment, the laboratory worksheet contained a separate space for the students to write what they concluded about their hypothesis in relation to the findings from their experimentation.

Laboratory worksheets were distributed at the beginning of the study for the students in the HHH, VHV, and HVH classes. Similarly, each group in the VVV, VHV, and HVH classes had an account in the virtual laboratory environment platform. The students in the groups in VHV and HVH classes used both the worksheet and online tools, according to the type of laboratory they were currently using.

At the end of the study, the worksheets were gathered from the groups. The virtual laboratory platform allowed the teacher and/or researcher to access the students' learning analytics. For the students who used the virtual laboratory environment, the science teacher and the researcher accessed the groups' online course materials. After all that, the same tests were implemented as posttests. Each student did the pretests and posttests individually, neither as a member of a group nor collaboratively. Then three students from each of the VVV, VHV and HVH conditions were selected randomly to be interviewed about the comparison of hands-on and virtual laboratory environments. No interview was not done with students from the HHH condition because they were not able to experience the virtual laboratory environment, so they could not compare the two environments.

3.4 Data Analysis

The same approach was used for the analysis of the quantitative data from the multiple-choice conceptual understanding test, inquiry skills test, and the attitude questionnaire.

First, a one-way ANOVA was used for comparing the pretest scores of the four classes. Test of homogeneity of variances (Levene test) was checked before each ANOVA test. Other assumptions (normality, independent observations and sample independence) were also controlled. After that, paired samples *t*-tests were used for comparing the pretest and posttest scores of each of the four classes. This procedure was followed to determine whether a class improved their conceptual knowledge (measured by the multiple-choice conceptual test), inquiry skills, and attitudes towards science course and laboratories significantly. And last, an ANCOVA was used for comparing the posttest scores of all classes, taking the relevant pretest scores as covariate. ANCOVA assumptions (normality, homogeneity, homogeneity of regression slopes, linearity and independent observations) were checked before each ANCOVA test.

Because the open-ended conceptual understanding test scores were not normally distributed, non-parametric tests were used for comparing those scores. First, a Kruskal-Wallis test was used for comparing the pretest scores of the four classes. Then, Wilcoxon tests were implemented for comparing the pretest and posttest scores of each of the four classes. Finally, an ANCOVA was used for comparing the posttest scores of all classes, with the relevant pretest scores as covariate.

The interviews were transcribed and analyzed. Each student’s explanations were evaluated individually. Their thoughts about the virtual laboratory environment, their choices between hands-on and virtual laboratory environment, and the reasons behind their views were some of the basic topics of the interviews. Students’ expressions were coded in two main categories: positive views about the virtual laboratory environment and negative views about the virtual laboratories. The quotes from the interviews used as examples have been translated from Turkish.

3.5 The Virtual Laboratory Platform: Go-Lab

Go-Lab (Global Online Science Labs for Inquiry Learning at Schools) is a project funded by the European Commission and provides online science laboratories for inquiry learning. The Go-Lab platform consists of three main parts: online laboratories, scaffolding applications, and inquiry learning spaces.

The first main part of the platform is online laboratories. There are two types of online laboratories in the platform: remote laboratories and virtual laboratories. In remote laboratories, students are able to reach real laboratory setups, real locations and materials from their own location. In the virtual laboratories, laboratories are simulated versions of real laboratories. There are more than 750 remote and virtual laboratories in the platform, about physics, chemistry, biology, astronomy, technology, engineering, environmental education, astronomy and mathematics.

The second main part of the platform is web-based scaffolding applications. These applications can be added into the inquiry learning spaces, together with virtual laboratories, in order to help students in their inquiry learning tasks. Some examples of the applications are hypothesis scratchpad, experiment design tool, reflection tool, conclusion tool, concept mapper and data viewer. These applications act as scaffolding tools in computer-supported inquiry-based learning environments. There are also applications in the platform such as a quiz tool for teachers to assess their students through multiple choice, open-ended, matching, and true/false questions, and a learning analytics app that enables teachers to access an overview of students' progress in the inquiry learning space.

The third main part of the platform is inquiry learning spaces, which are learning environments that can contain online laboratories, web-based (scaffolding) applications and other learning sources such as photos, texts or videos. An inquiry learning space follows the inquiry cycle, and involves the phases of orientation, conceptualization, investigation, conclusion and discussion. It is also possible to develop inquiry learning spaces in which teachers can use a jigsaw approach, 5Es, or learning by critiquing. Teachers create inquiry learning spaces for their students and are able to share them with other teachers using the system. A teacher can share the inquiry learning space with their students, so students can study individually or in groups, going through all steps of a research process and conducting virtual/remote experiments. Teachers are also able to monitor the progress of students and can provide support, if needed. It is also possible to for both teachers and students communicate and collaborate via the web-based applications in the inquiry learning space. In the current study, an electrical circuit laboratory was used as a virtual laboratory. Students are able to create their own circuits and can do measurements on. The virtual laboratory involves resistors, bulbs, power supplies, ammeters, voltmeters, watt meters, ohmmeters, batteries, and switches. Figure 3.1 shows some views of the virtual laboratory used in the current study.

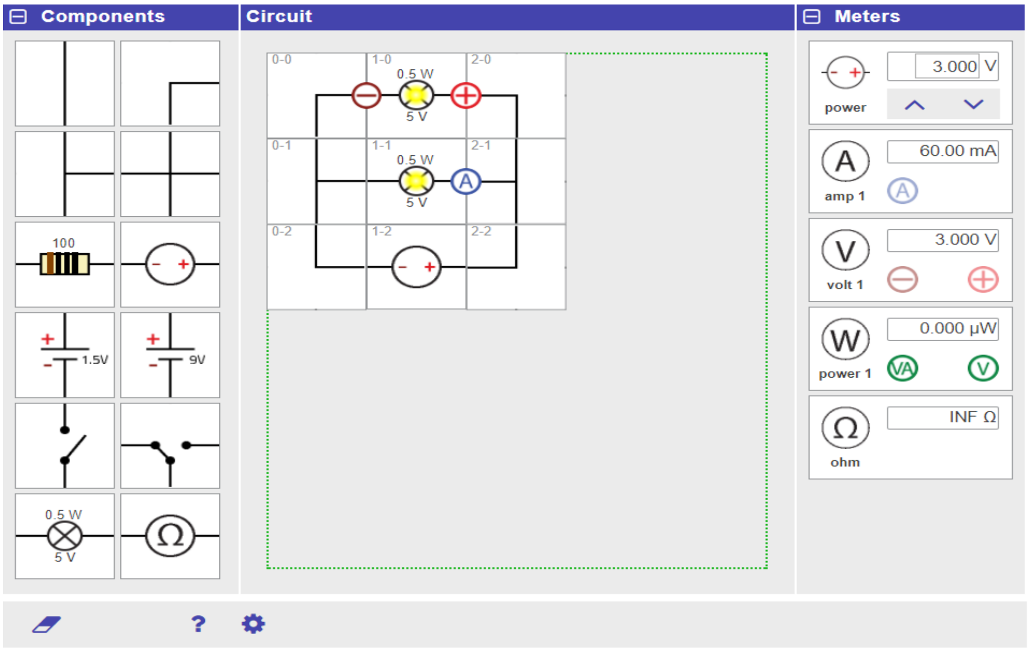


Figure 3.1 A view of the virtual electrical circuit laboratory

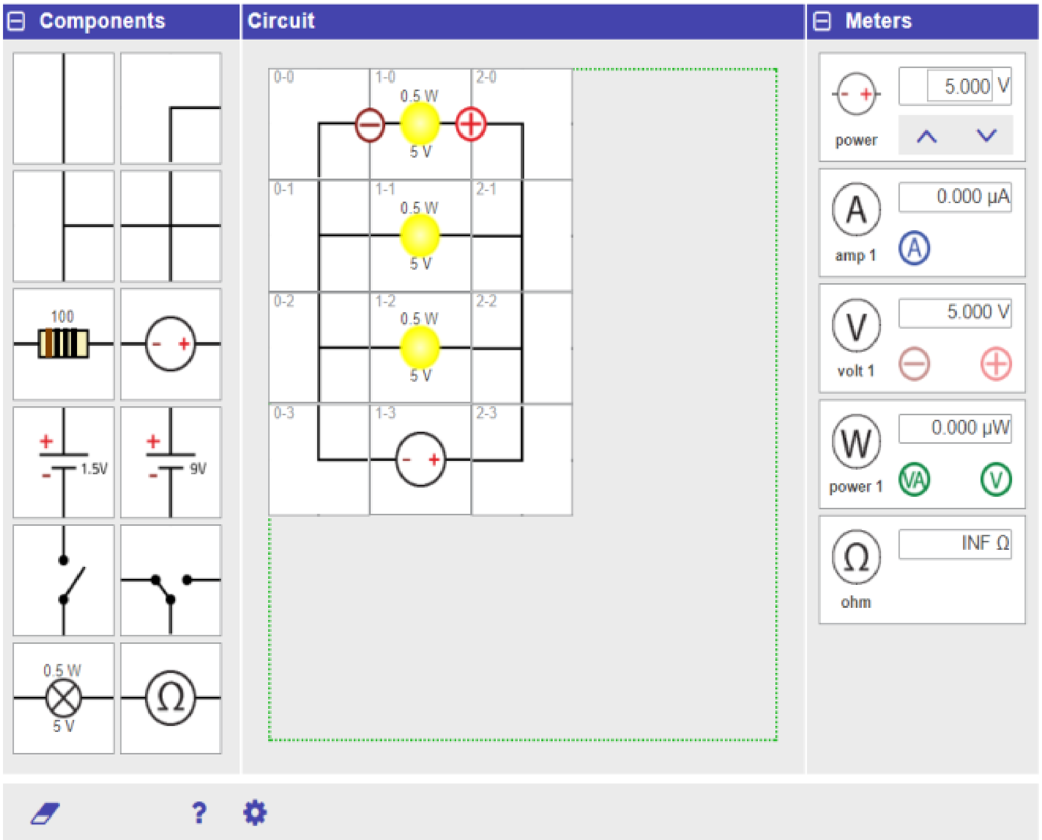


Figure 3.2 A view of the virtual electrical circuit laboratory

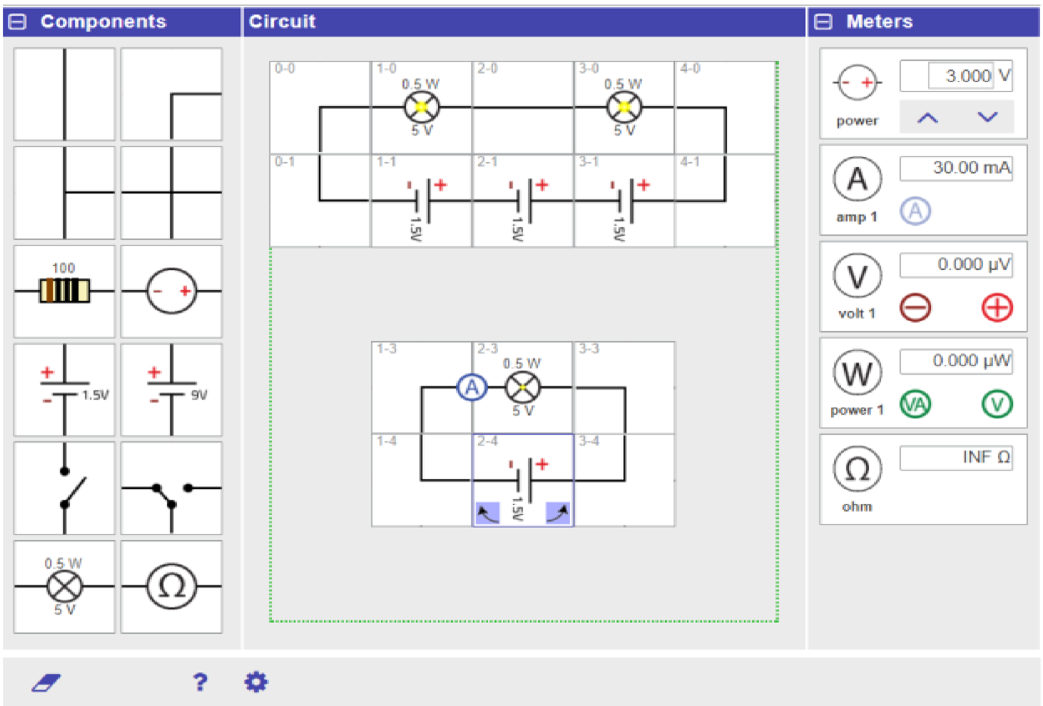


Figure 3.3 A view of the virtual electrical circuit laboratory

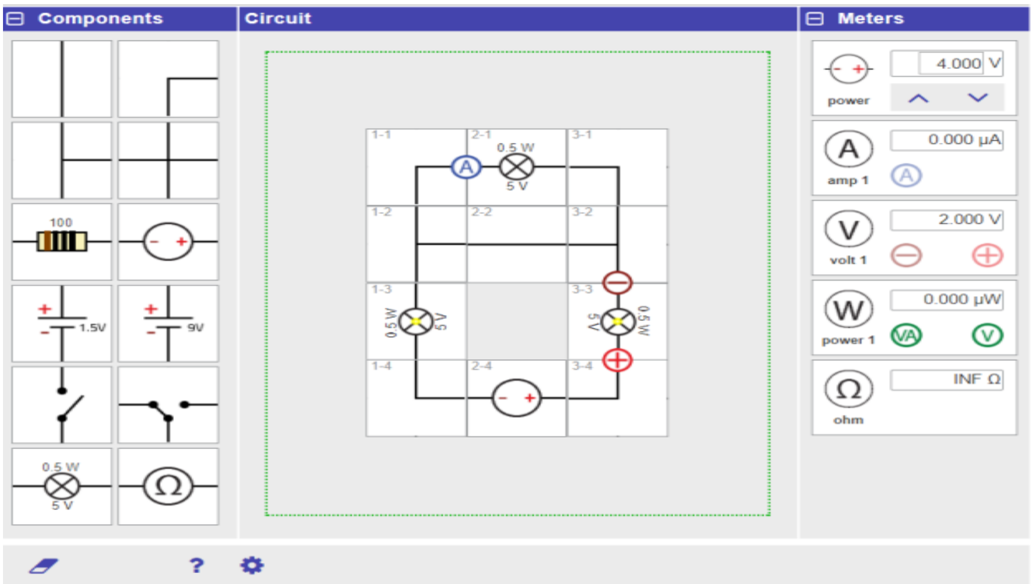


Figure 3.4 A view of the virtual electrical circuit laboratory

Some applications, which can be also called scaffolding tools, were used in the study. One was the hypothesis scratchpad, which helps students to formulate hypotheses. In the tool, predefined concepts are presented to students and then students compose a hypothesis through drag and drop. They can also add their own concepts by using a 'type your own' box. Teachers can add, remove or adjust the predefined terms with respect to the domain and also can offer partially ready-made hypotheses to their students. Figure 3.2 shows an example of the hypothesis scratchpad.

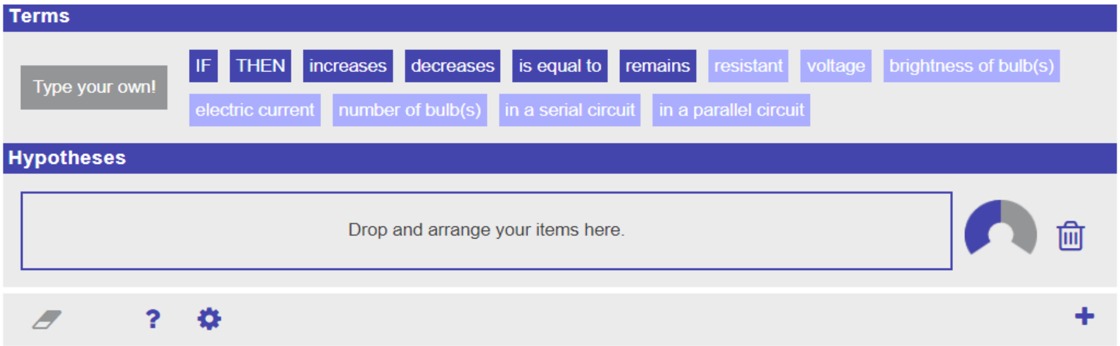


Figure 3.5 Hypothesis scratchpad

In addition to the hypothesis scratchpad, an observation tool also was used in the study. The tool enables students to take notes based on their observations while preparing, conducting and analyzing experiments. Figure 3.3 shows the observation tool used in the study.

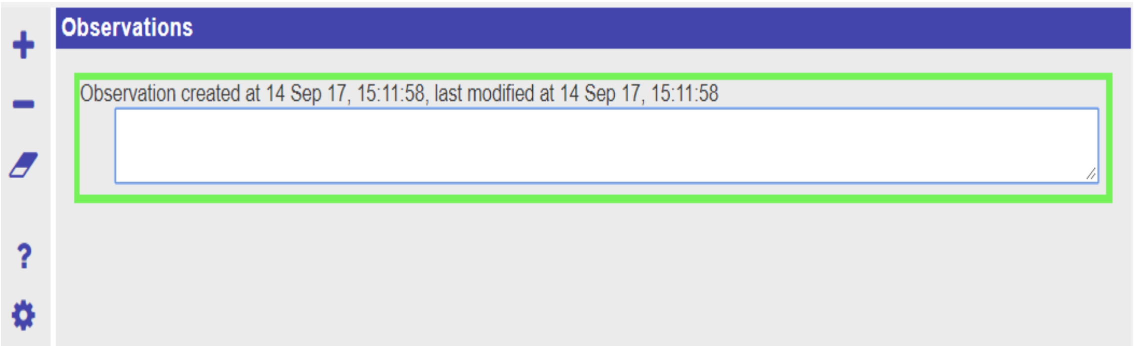


Figure 3.6 Observation tool

A conclusion tool was also used in the study. This tool allows students to check whether the results of experiments are compatible with the hypothesis created at the beginning of investigation. It is possible to access the hypothesis and observation notes via the tool. Figure 3.4 (showing the hypothesis as available) and 3.5 (showing access to observation notes) show examples of the conclusion tool.

Figure 3.7 Conclusion tool (showing students' hypothesis)

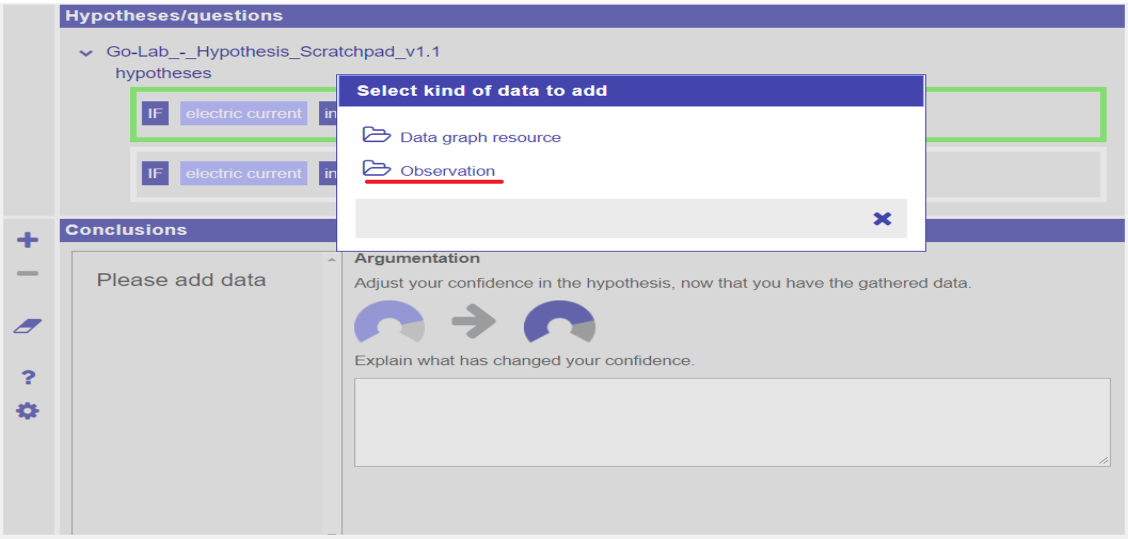


Figure 3.8 Conclusion tool (showing access to students' observation notes)

Three main inquiry learning spaces were used in the study. In the first one, serial and parallel electrical circuits were introduced and students were able to create their own hypothesis and design and implement their own experiments related to the topic. In the second learning space, adding an ammeter and voltmeter to the electrical circuits was introduced. Similarly, students designed and implemented their own experiments with the help of scaffolding tools and the science teacher. In the third inquiry learning space, Ohm's law was taught and students followed a similar approach as in the previous inquiry learning spaces (forming hypothesis, making experiments and drawing conclusions). Figure 3.6 shows the hypothesis formation stage for the first inquiry learning space. Figure 3.7 shows the exploration stage from the second inquiry learning space used in the study. Figure 3.8 shows the drawing a conclusion phase from the third inquiry learning space. The same procedure was followed for the students who used the hands-on laboratory environment. The main difference between students in the hands-on and virtual laboratory environments was the way of presenting scaffolding tools. Whereas students in the hands-on laboratory environment used a paper-based laboratory worksheet, students in the virtual laboratory environment used web-based scaffolding applications. For example, Figure 3.9 shows the developing hypotheses stage as presented in the hands-on laboratory worksheet.

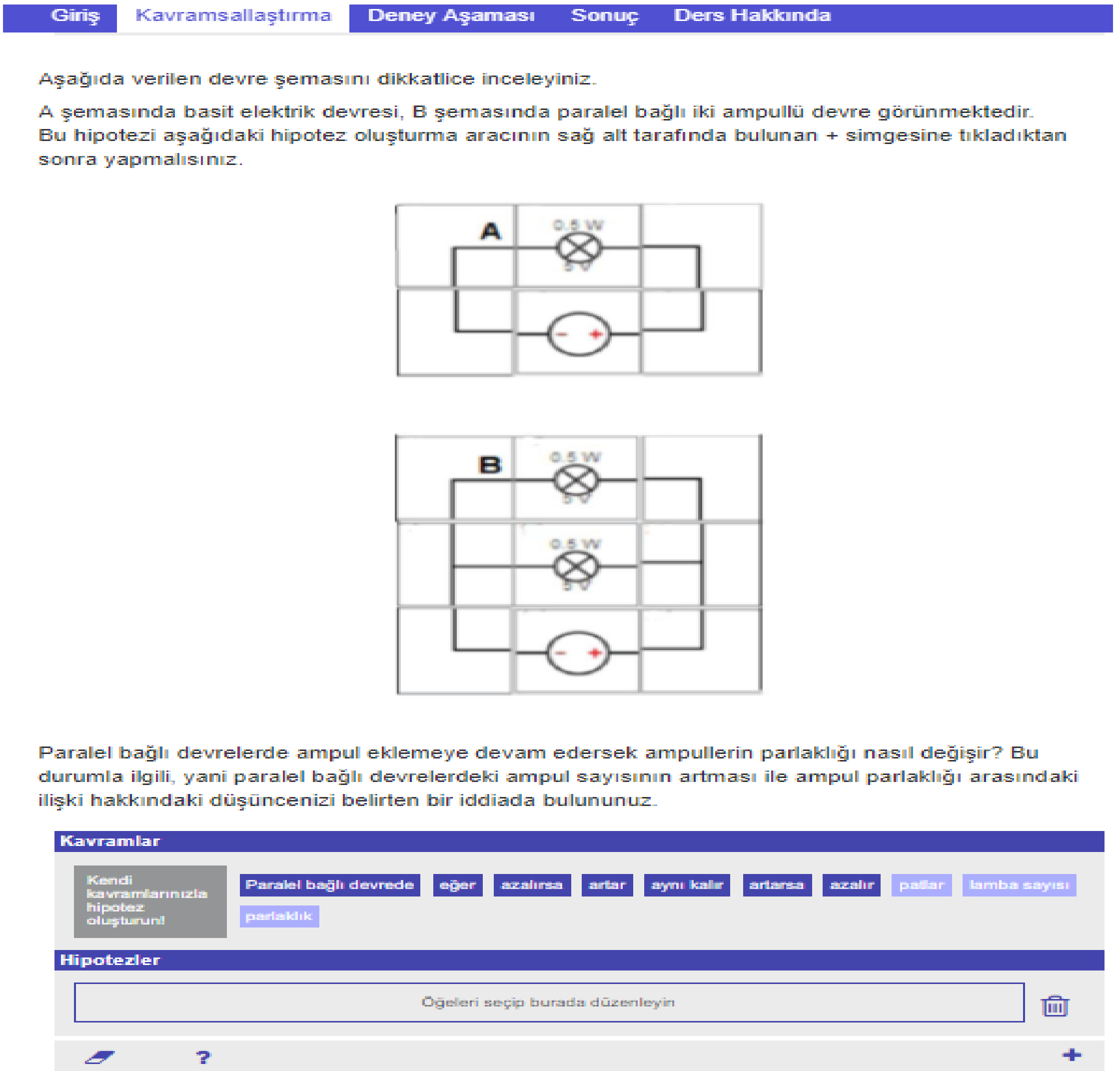


Figure 3.9 Hypothesis forming stage in the first inquiry learning space

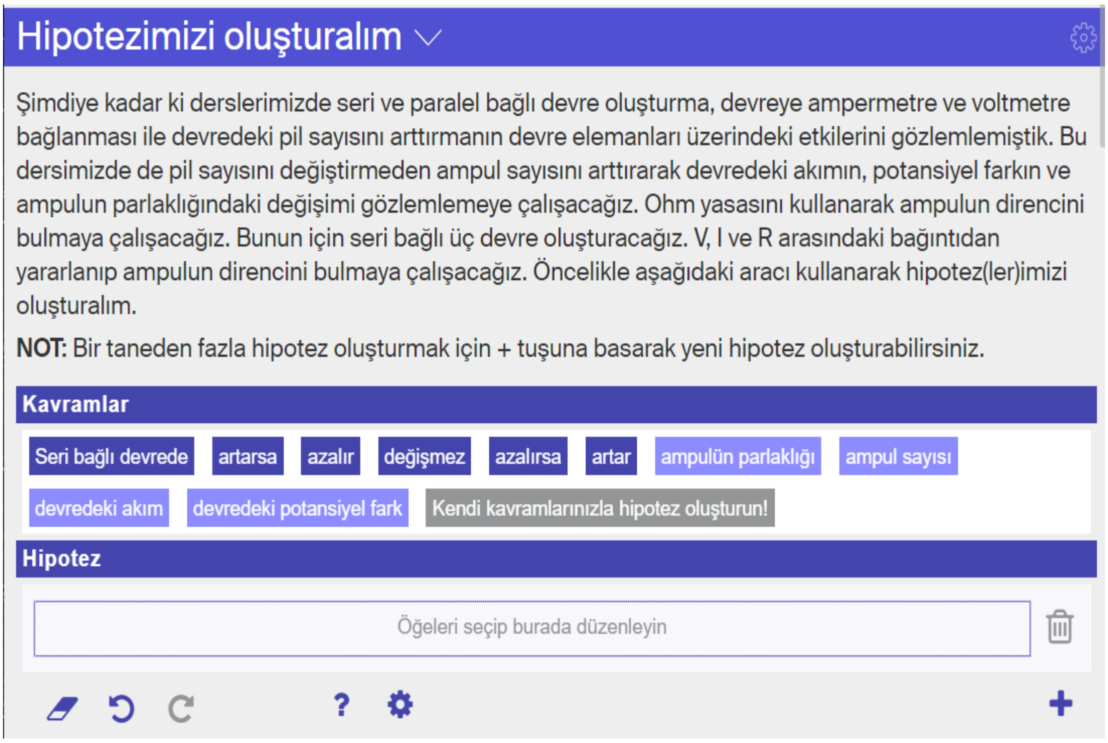


Figure 3.10 Hypothesis forming stage in the first inquiry learning space

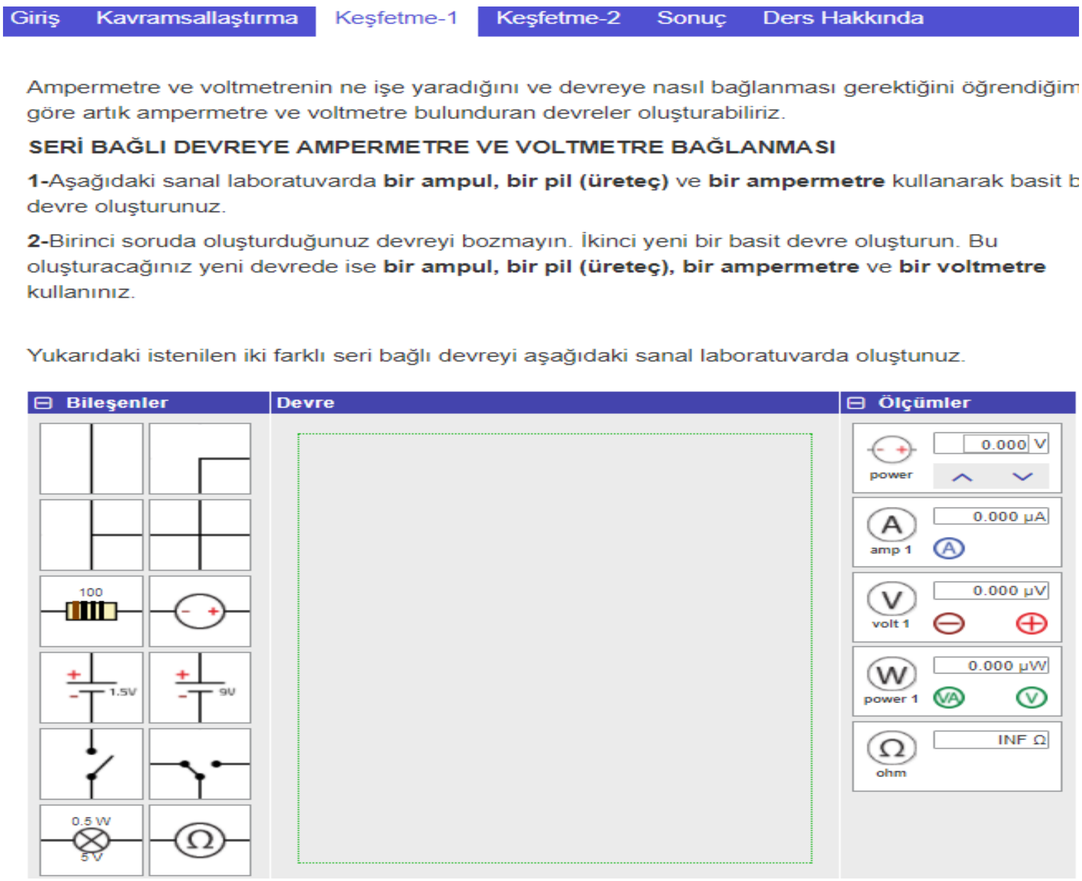


Figure 3.11 Exploration stage for the second lesson plan used in the current study

Giriş | Kavramsallaştırma | Keşfetme-1 | Keşfetme-2 | Sonuç | Değerlendirme | Ders Hakkında

Önceki kısımlarda seri ve paralel bağlı devrelerdeki ampul sayılarını değiştirerek devreden geçen akım ve gerilimi ölçtük. Ohm yasasının elektrik devrelerindeki uygulamalarını yaptık. Buna göre aşağıdaki soruları cevaplayalım.

Önceki aşamalarda yaptığınız deneyleri göz önüne alarak ulaştığınız sonuçları aşağıdaki tabloya yazınız. Akım, potansiyel fark ve devredeki toplam direnç seri ve paralel bağlı devrelerde nasıl değişmektedir?

Tablo

	Seri Bağlı Devrede	Paralel Bağlı Devrede
Potansiyel fark (Gerilim)		
Akım		
Direnç		

Figure 3.12 Conclusion stage for the third lesson plan used in the current study

Seri Bağlı Devre ile İlgili Hipotezimizi (İddiamızı) Oluşturalım

Seri bağlı devrelerde ampul sayısını artırırsak ampullerin parlaklığı nasıl değişir? Bu durumla ilgili düşüncenizi belirten bir hipotez yazınız. Aşağıdaki kavramlar size yardımcı olabilmesi için verilmiştir.

- Seri bağlı devrede - ampul sayısı - eğer - azalırsa - parlaklık
- patlar - artar - azalır - artarsa - aynı kalır

Hipotezini aşağıdaki kutucuğa yazabilirsiniz.

Paralel Bağlı Devre ile İlgili Hipotezimizi (İddiamızı) Oluşturalım

Paralel bağlı devrelerde ampul sayısını artırırsak ampullerin parlaklığı nasıl değişir? Bu durumla ilgili düşüncenizi belirten bir hipotez yazınız. Aşağıdaki kavramlar size yardımcı olabilmesi için verilmiştir.

- Paralel bağlı devrede - ampul sayısı - eğer - azalırsa - parlaklık
- patlar - artar - azalır - artarsa - aynı kalır

Hipotezini aşağıdaki kutucuğa yazabilirsiniz.

Figure 3.13 Hypothesis forming stage for the lesson plan used for the hands-on laboratory group

4
RESULTS AND DISCUSSION

To determine the effects of the different laboratory environments on middle school students' science learning and attitudes towards science courses and laboratories, the data gathered through the tests, the attitude questionnaire, and interviews were analyzed.

First, the results for the multiple-choice conceptual knowledge test are presented. Then, the results for the open-ended conceptual knowledge test are given. Subsequently, the results for the inquiry skills test are presented. After that, the results for the attitudes questionnaire are given. Finally, the interviews done with the students are presented.

4.1 Results for the Multiple-Choice Conceptual Knowledge Test

The multiple-choice conceptual knowledge test was administered as both pretest and posttest. Table 4.1 and Figure 4.10 display the outcomes of this test, by condition.

Table 4.1 Descriptive results for the multiple-choice conceptual knowledge test by condition (max = 28)

	HHH (n = 33) Mean (SD)	VVV (n = 34) Mean (SD)	VHV (n = 39) Mean (SD)	HVH (n = 37) Mean (SD)
Pretest	9.60 (2.70)	9.32 (2.22)	10.53 (2.95)	9.21 (2.21)
Posttest	14.42 (3.37)	12.76 (2.89)	16.10 (4.08)	15.18 (2.67)
Difference	4.82 (3.86)	3.44 (3.37)	5.56 (5.27)	5.97 (3.10)

All classes' pretest scores were compared in a univariate analysis of variance (ANOVA). Two main assumptions were checked before using an ANOVA. One is that the distribution of each sample was normal and the other is homogeneity of variances, tested using the Levene test.

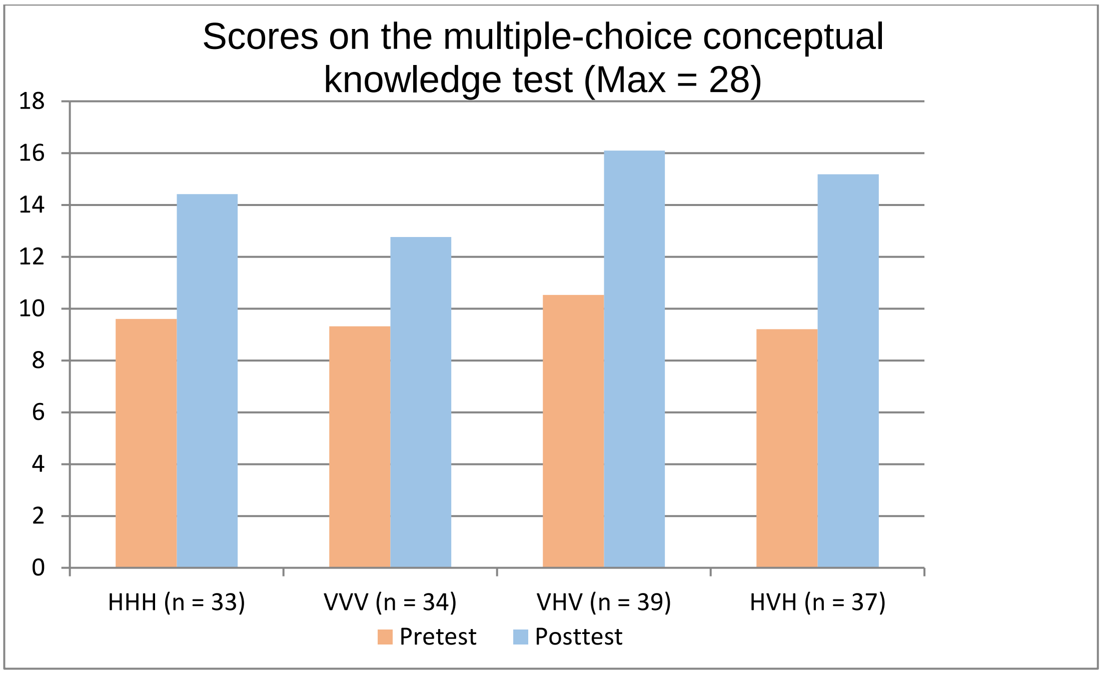


Figure 4.14 Pretest and posttest multiple-choice conceptual knowledge test scores by condition

The ANOVA results showed that there were no differences among the conditions on the pretest [$F(3, 138) = 2.108$; $p = .102$]. Separate paired samples *t*-tests showed that each class increased its mean score on the multiple-choice conceptual knowledge test significantly. Table 4.2 shows each condition's paired samples *t*-test result.

Table 4.2 Paired samples *t*-test results for the multiple-choice conceptual knowledge test by condition

Condition	*t*	*df*	Sig. (2-tailed)
HHH	7.17	32	.000
VVV	5.94	33	.000
VHV	6.58	38	.000
HVH	11.70	36	.000

An ANCOVA using the pretest score as a covariate indicated that the classes differed on their posttest scores [$F(3, 138) = 6.024$; $p = .001$, partial $\eta^2 = 0.12$] (see Table 4.3). In order to understand which classes' posttest scores were reliably different from the other(s), post-hoc tests were performed. Post-hoc analysis revealed that posttest scores of the classes in which hands-on and virtual laboratories alternated (VHV and HVH) were higher than for the class that followed only virtual laboratories (VVV); for the comparison between VHV and VVV, p = 0.000, d = 0.94, and for the comparison between HVH and VVV, p = 0.015, d = 0.87.

Table 4.3 Effect sizes for the post hoc pairwise comparisons for the multiple-choice conceptual knowledge test

Pairwise Comparisons	Cohen's *d*
HHH-VVV	0.53
HHH-VHV	0.45
HHH-HVH	0.25
VVV-VHV*	0.94
VVV-HVH*	0.87
VHV-HVH	0.27

To sum up, all conditions improved their conceptual knowledge (measured with multiple-choice questions) about the topic of electricity significantly. Furthermore, the overall picture suggested by these comparisons is that using hands-on and virtual laboratory environments in a combination provides a better learning opportunity than using virtual laboratories alone for teaching electricity. And that replacing some of the traditional hands-on laboratories with ones using virtual components resulted in similar results as using hands-on laboratories alone.

4.2 Results for the Open-Ended Conceptual Knowledge Test

The open-ended conceptual knowledge test was also implemented as a pretest and posttest. The correlation between the open-ended and multiple-choice conceptual knowledge posttest was 0.128. This non-significant correlation means that the two tests generally measured something different. Table 4.4 and Figure 4.11 show descriptive results for the open-ended conceptual knowledge test, by condition.

Table 4.4 Descriptive results for the open-ended conceptual knowledge test by condition (max = 12)

	HHH (n = 33) Mean (SD)	VVV (n = 34) Mean (SD)	VHV (n = 39) Mean (SD)	HVH (n = 37) Mean (SD)
Pretest	4.73 (4.30)	3.62 (2.59)	3.87 (2.60)	3.05 (2.03)
Posttest	8.94 (4.00)	7.71 (4.48)	10.28 (4.04)	8.11 (3.81)
Difference	4.21 (3.28)	4.09 (3.92)	6.41 (3.85)	5.06 (3.26)

Due to non-normal distribution of the data for the pretest scores, non-parametric tests were used for analysis in which the pretest scores were involved, and parametric tests for the posttest.

Kruskal-Wallis test results showed that there were no differences between the classes at the pretest (H = 6.075; p = 0.108). In the following step, Wilcoxon tests showed that each class increased its score on the open-ended conceptual knowledge test significantly (HHH, Z = -4.552, p = 0.000; VVV, Z = -4.403, p = 0.000; VHV, Z = -5.200, p = 0.000; HVH, Z = -5.112, p = 0.000). For the posttest scores, an ANCOVA was performed using the pretest score as a covariate. ANCOVA results showed that the classes differed on the posttest scores [F(3, 138) = 3.291; p = .023, partial η^2=0.06]. In order to understand which classes' posttest scores differed significantly from the other(s), post-hoc tests were performed (see Table 4.5).

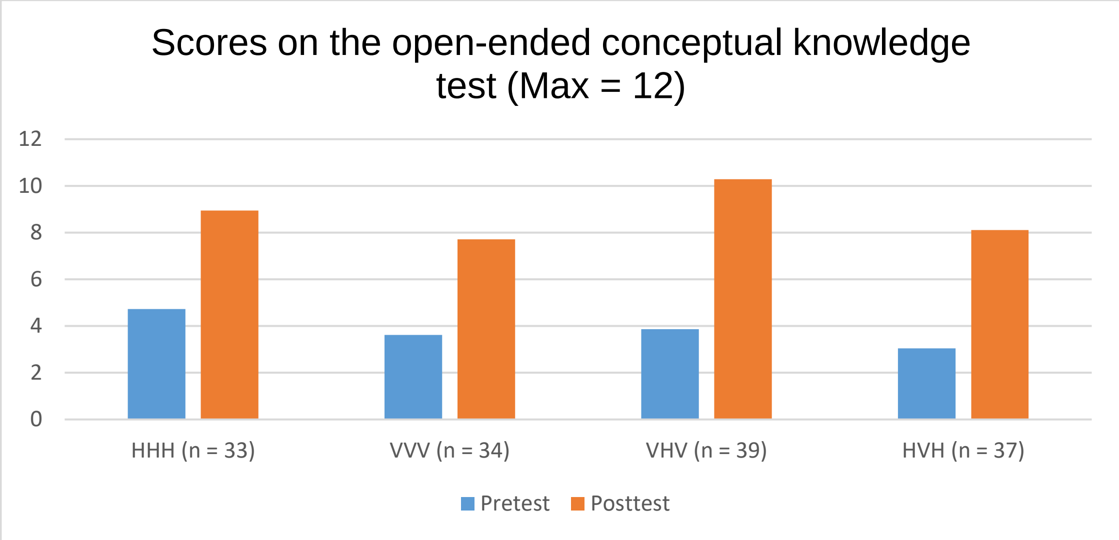


Figure 4.15 Pretest and posttest open-ended conceptual knowledge test scores by condition

Post-hoc analyses revealed a significant difference between the posttest scores for the VHV class and the VVV class (p = 0.000, d = 0.60; the VHV class had a higher score for the open-ended conceptual knowledge questions.

Table 4.5 Effect sizes for the post hoc pairwise comparisons for the open-ended conceptual knowledge test

Pairwise Comparisons	Cohen's *d*
HHH-VVV	0.29
HHH-VHV	0.33
HHH-HVH	0.21
VVV-VHV	0.60
VVV-HVH	0.10
VHV-HVH	0.55

This finding supports the view that using virtual laboratories alone does not yield as successful outcomes as using different laboratory environments in combination. Students' pretest and posttest scores were further compared using Wilcoxon tests, with respect to the three major topic categories (serial and parallel circuits, ammeter and voltmeter, and Ohm's law). For the first topic, serial and parallel circuits, the findings were as follows: for HHH, $Z = -3.904$, $p = 0.000$; for VVV, $Z = -4.522$, $p = 0.000$; for VHV, $Z = -4.920$, $p = 0.000$; for HVH, $Z = -4.740$, $p = 0.000$. For the second topic, adding ammeters and voltmeters to circuits, the results were as follows: for HHH, $Z = -4.448$, $p = 0.000$; for VVV, $Z = -3.888$, $p = 0.000$; for VHV, $Z = -5.358$, $p = 0.000$; for HVH, $Z = -4.651$, $p = 0.000$. Lastly, for the third topic, Ohm's law, the results were as follows: for HHH, $Z = -2.460$, $p = 0.014$; for VVV, $Z = -2.055$, $p = 0.040$; for VHV, $Z = -3.883$, $p = 0.000$; for HVH, $Z = -3.206$, $p = 0.001$. Findings based on the analysis by topic category revealed that students in all conditions developed their conceptual knowledge for all three topics.

Students' misconceptions about electricity were also investigated. Table 4.6 shows students' misconceptions about electricity from pretest to posttest. The number in the table shows the number of students with the corresponding misconception in that class. The percentage in parentheses shows the corresponding percentage of students in that class.

Table 4.6 Students' misconceptions about electricity at pretest and posttest

Misconceptions	**Pretest**				**Posttest**			
	HHH	**VVV**	**VHV**	**HVH**	**HHH**	**VVV**	**VHV**	**HVH**
	(*n* = 33)	(*n* = 34)	(*n* = 39)	(*n* = 37)	(*n* = 33)	(*n* = 34)	(*n* = 39)	(*n* = 37)
Adding light bulbs incorrectly to create parallel circuit (Q1b, Q4)	12 (36%)	11 (32%)	13 (33%)	23 (62%)	6 (18%)	5 (15%)	3 (7%)	3 (9%)
Incomplete electrical circuit (Q1b, Q4)	1 (3%)	1 (3%)	2 (5%)	4 (%11)	-	-	-	-
Adding batteries in the wrong direction to electrical circuit (Q4)	1 (3%)	-	1 (3%)	2 (5%)	-	-	-	-
Adding voltmeter in serial or adding ammeter in parallel in electrical circuit (Q2, Q5)	6 (18%)	7 (21%)	5 (15%)	11 (30%)	2 (6%)	4 (12%)	2 (5%)	1 (3%)
Voltage, resistance and electrical current are directly proportional with each other (Q3)	1 (3%)	4 (12%)	3 (9%)	1 (3%)	1 (3%)	2 (6%)	1 (3%)	1 (3%)
Ohm's law is R= I x V or I = V x R. (Q3, Q6)	2 (6%)	-	-	2 (6%)	1 (3%)	-	-	-

Electrical current is intensity in an electrical circuit. (Q3)	5 (15%)	-	-	-	-	-	-	-
Increased resistance in a circuit causes burning out of the bulbs in the circuit. (Q3)	-	1 (3%)	-	-	-	-	-	-
If resistance in a circuit is high, then the potential energy of that circuit is high. (Q3)	-	1 (3%)	-	-	-	-	-	-

Table 4.6 shows that students' misconceptions about closed electrical circuits and connecting batteries to each other were removed over the course of the study. In addition, students' misconceptions about drawings of parallel circuits and adding ammeters and voltmeters to circuits diminished. Nevertheless, Ohm's law still seemed to be a difficult topic for students. The number of students who answered the questions about Ohm's law correctly was not as high as for other questions. This might be because questions about Ohm's law required higher-order thinking skills such as analyzing the correlations among variables or interpreting a graph.

For the misconception involving adding light bulbs incorrectly to create parallel circuits, students in the HVH and VHV conditions improved their understanding more than those in the other two classes. Similarly, for the other misconception about adding a voltmeter in serial or adding an ammeter in parallel in an electrical circuit, students in the HVH condition showed greater improvement than those in the other classes. The number of students who held a misconception about the relations among voltage, resistance and electric current decreased more in the VVV and VHV conditions than in the other two classes. Furthermore, two students in the VVV condition had other misconceptions about electricity at the beginning of the study, which were both corrected during the study.

4.3 Results for the Inquiry Skills Test

A similar procedure was followed for the inquiry skills test as for the multiple-choice conceptual knowledge test. The test was implemented as both pretest and posttest. Table 4.7 and Figure 4.12 display the outcomes for this test.

Table 4.7 Descriptive results for the inquiry skills test by condition (max = 28)

	HHH (n = 33) Mean (SD)	VVV (n = 34) Mean (SD)	VHV (n = 39) Mean (SD)	HVH (n = 37) Mean (SD)
Pretest	8.96 (2.68)	6.82 (2.85)	7.35 (3.10)	7.72 (2.51)
Posttest	10.33 (3.53)	8.55 (3.53)	10.58 (3.71)	10.64 (2.96)
Difference	1.36 (4.14)	1.73 (4.09)	3.23 (4.94)	2.91 (4.03)

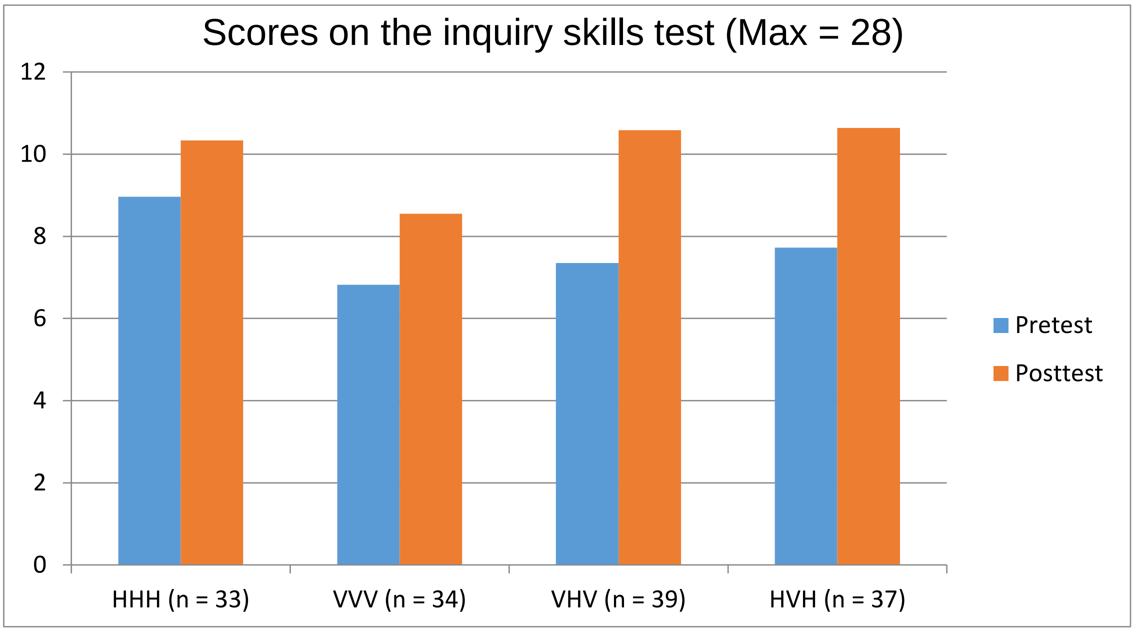


Figure 4.16 Pretest and posttest inquiry skills test scores by condition

All classes' pretest scores were compared with each other through an ANOVA after checking the assumptions (normal distribution for each sample and homogeneity of variances).

The ANOVA results showed that there were no differences among the conditions at the pretest [$F(3, 138) = 2.118$; $p = 0.101$]. Separate paired samples t-tests showed that students in the VVV, VHV, and HVH conditions increased their scores on the inquiry skills test significantly, but those in the HHH condition did not. Table 4.8 shows the paired samples t-test results for each condition.

Table 4.8 Paired samples *t*-test results for the inquiry skills test by condition

Condition	*t*	*df*	Sig. (2-tailed)
HHH	1.89	32	.068
VVV	2.46	33	.019
VHV	4.07	38	.000
HVH	4.40	36	.000

An ANCOVA was done to compare students' inquiry skills posttest scores per condition, using the pretest score as a covariate. The finding indicated that the classes did not differ on the posttest scores [$F(3, 138) = 2{,}390$; $p = .071$, partial $\eta^2=.05$]. This finding showed that the use of either a hands-on or a virtual laboratory environment was equally effective in developing students' inquiry skills across all conditions.

Table 4.9 Effect sizes for the post hoc pairwise comparisons for the inquiry skills test

Pairwise Comparisons	Cohen's *d*
HHH-VVV	0.50
HHH-VHV	0.07
HHH-HVH	0.09
VVV-VHV	0.56
VVV-HVH	0.64
VHV-HVH	0.01

As a consequence, although there was no statistically significant difference between conditions in improvement of inquiry skills scores, students in the VHV and HVH conditions descriptively increased their scores more than those in the other two classes, HHH and VVV (see Table 4.9 for post hoc pairwise comparisons). Although there was no statistically significant result, it seems that using hands-on and virtual laboratory environments in a combination have the potential to support students better in developing their inquiry skills.

4.4 Results for the Attitudes towards Science Course and Laboratory Questionnaire

The attitude questionnaire was administered as both pretest and posttest. Table 4.10 and Figure 4.13 display the outcomes for the test.

Table 4.10 Descriptive results for the attitude questionnaire for all conditions (max = 5)

	HHH (*n* = 33) Mean (SD)	VVV (*n* = 34) Mean (SD)	VHV (*n* = 39) Mean (SD)	HVH (*n* = 37) Mean (SD)
Pretest	3.95 (0.38)	3.59 (0.43)	3.68 (0.37)	3.70 (0.40)
Posttest	4.19 (0.30)	4.05 (0.44)	4.21 (0.35)	4.08 (0.33)
Difference	0.24 (0.43)	0.46 (0.51)	0.53 (0.48)	0.38 (0.44)

At the beginning of the study, students' attitudes towards the science course and laboratories were at the upper intermediate level (3.73 out of 5). After the study, the attitudes of students from each condition became mostly positive (4.14 out of 5). The biggest gains between pretest and posttest were seen for students in the VVV and VHV conditions.

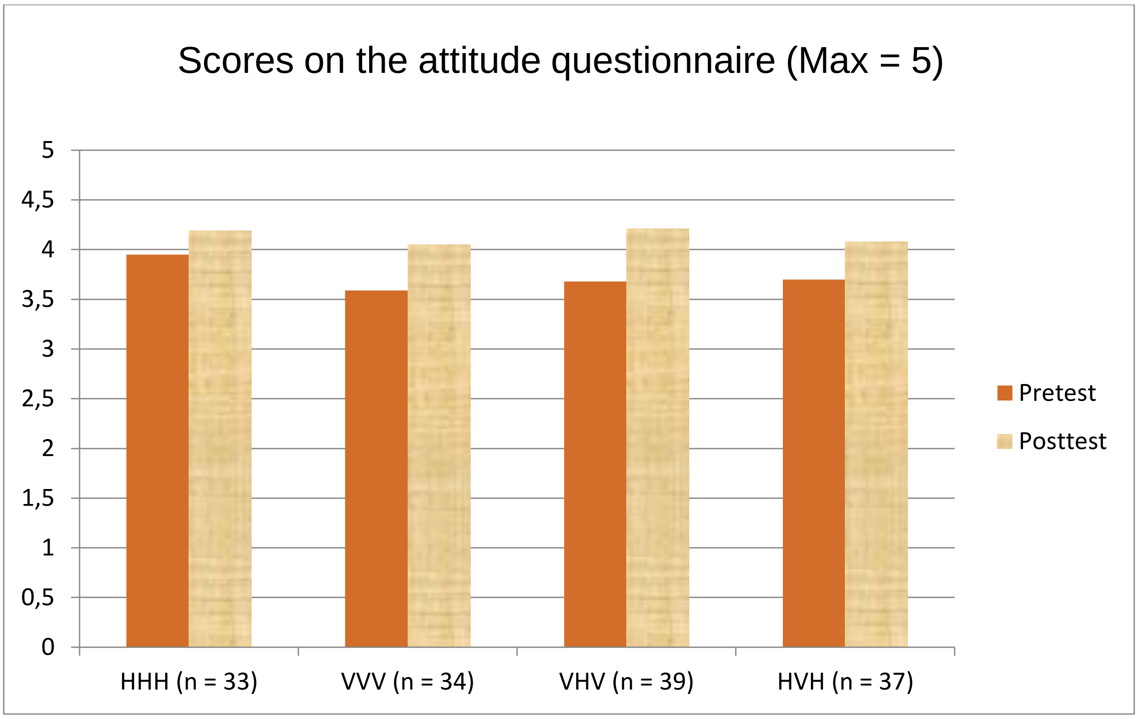


Figure 4.17 Pretest and posttest attitude questionnaire scores by condition

An ANOVA was used to compare the pretest scores of the classes. The ANOVA showed that there were no differences between the conditions at the pretest [$F(3, 138) = 1.602$; $p = .192$]. Separate paired samples *t*-tests showed that each class increased their mean score on the attitude questionnaire significantly. Table 4.11 shows the paired samples *t*-test result for each condition.

Table 4.11 Paired samples *t*-test results for the attitude questionnaire by condition

Condition	*t*	*df*	Sig. (2-tailed)
HHH	3.13	32	.004
VVV	5.32	33	.000
VHV	6.89	38	.000
HVH	5.20	36	.000

An ANCOVA was done to compare students' attitudes towards science course and laboratory questionnaire posttest scores, using the pretest score as a covariate. The finding indicated that the conditions did not differ on the posttest scores [$F(3, 138) = 1.187$; $p = .317$, partial $\eta^2 = .025$). This finding suggests that using a hands-on or a virtual laboratory environment was equally effective for improving middle school students' attitudes towards science courses and laboratories.

Table 4.12 Effect sizes for the post hoc pairwise comparisons for the attitude questionnaire

Pairwise Comparisons	Cohen's *d*
HHH-VVV	0.04
HHH-VHV	0.01
HHH-HVH	0.03
VVV-VHV	0.04
VVV-HVH	0.01
VHV-HVH	0.04

To sum up, the overall picture shows that although there was no significant difference among the posttest scores of the conditions (see Table 4.12 for post hoc pairwise comparisons), students in the VVV and VHV conditions descriptively increased their mean scores more than the other two conditions, HVH and HHH. Furthermore, the students in the HHH class increased their mean scores the least. These findings may indicate that students who used virtual laboratory environments developed slightly better positive attitudes toward science courses and laboratories.

The attitude questionnaire involves three sub-dimensions: learning science in school, self-concept in science, and practical work in science. A similar analysis was followed for each sub-dimension of the questionnaire. Table 4.13 shows the descriptive statistics for the sub-dimensions of attitude questionnaire.

Table 4.13 Descriptive results for the sub-dimensions of the attitude questionnaire by condition (max = 5)

	Learning Science in School		Self-Concept in Science		Practical Work in Science	
	Pretest Mean (SD)	Posttest Mean (SD)	Pretest Mean (SD)	Posttest Mean (SD)	Pretest Mean (SD)	Posttest Mean (SD)
HHH (*n* = 33)	3.89 (0.62)	4.15 (0.48)	3.55 (0.51)	3.80 (0.52)	4.43 (0.44)	4.63 (0.45)
VVV (*n* = 34)	3.53 (0.80)	4.06 (0.57)	3.12 (0.60)	3.62 (0.62)	4.12 (0.58)	4.50 (0.41)
VHV (*n* = 39)	3.44 (0.65)	4.09 (0.53)	3.25 (0.63)	3.84 (0.61)	4.36 (0.49)	4.71 (0.44)
HVH (*n* =37)	3.62 (0.56)	4.09 (0.40)	3.27 (0.50)	3.59 (0.68)	4.22 (0.59)	4.56 (0.37)

The results of ANOVAs for the first sub-dimension [$F(3, 138) = 1.669$; $p = .176$], the second sub-dimension [$F(3, 138) = 2.120$; $p = .100$] and the third sub-dimension [$F(3, 138) = 1.607$; $p = .191$] indicated that there were no differences between the conditions at the pretest. Table 4.14 shows the results of comparisons of each condition's pretest and posttest scores with respect to each sub-dimension of the attitude questionnaire.

Table 4.14 Paired samples *t*-test results for each sub-dimension of the attitudes questionnaire by condition

	Learning Science in School		Self-Concept in Science		Practical Work in Science	
	t	Sig. (2-tailed)	t	Sig. (2-tailed)	t	Sig. (2-tailed)
HHH (n = 33)	2.420	.021	2.206	.035	1.760	.088
VVV (n = 34)	3.308	.002	3.605	.001	3.012	.005
VHV (n = 39)	5.947	.000	4.122	.000	3.409	.002
HVH (n = 37)	5.105	.000	2.578	.014	3.481	.001

The analysis with respect to the sub-dimensions showed that on average, students in all classes improved their attitudes towards the science course and laboratories, except in the HHH condition for the laboratory work in science sub-dimension.

Classes' posttest scores with respect to the sub-dimensions were also compared by ANCOVA, taking the relevant pretest scores as covariate. For the first sub-dimension, learning science in school, there was no statistically meaningful effect of condition on students' attitudes towards learning science in school [$F(3,138) = .04$, $p = .978$, partial $\eta^2 = .001$]. For the second sub-dimension, self-concept in science, there was also no statistically significant impact of laboratory environment on students' attitudes related to self-concept in science [$F(3,138) = 1.493$, $p = .261$, partial $\eta^2 = .029$]. For the third sub-dimension as well, practical work in science, there was no statistically meaningful effect of laboratory environment on students' attitudes towards practical work in science [F(3,138) = .706, p = .270, partial η^2 = .028].

Hence, the analysis of the sub-dimension scores for each class indicated that the students in the VVV, VHV, and HVH conditions developed a more positive attitude towards learning science in school, self-concept in science, and practical work in science. Although students in the HHH condition developed more positive attitudes towards learning science in school and self-concept in science, this was not the case for practical work in science.

4.5 Results of the Interviews

Interviews were done with nine students and the science teacher. The aim of the interviews with the students was to reveal middle school students' views about the virtual laboratory environment. The questions in the interview protocol were about comparison of hands-on and virtual laboratory environments, advantages and drawbacks of virtual laboratory environments, and the scaffolding tools used in the virtual laboratory environment. At the end of the study, a semi-structured interview was done with the science teacher in order to reveal the opportunities and disadvantages of virtual laboratories and the difficulties faced by the teacher while using a virtual laboratory in the classroom.

At the beginning of the interviews, students' preferences as far as laboratory environments were discussed. Two main views about choosing lab environments became apparent based on the interview findings. Slightly more than half of the students (five out of nine) preferred virtual laboratory environments over hands-on laboratory environments. Students who would like to use virtual laboratory environments more argued that virtual laboratory environments are attractive and help them to be more motivated, because using tablets and PCs in the courses is enjoyable and does not commonly happen in public schools. For example, Student 2 from the VVV condition said:

> I think virtual laboratory environments attract our attention more than hands-on laboratory environments. Willingness to study increases in these learning environments. You do experiments on PCs and follow the whole course from the screen. It was enjoyable.

The other view preferred hands-on laboratories rather than virtual laboratories. This view had slightly under half of the students as supporters (four out of nine). Students who preferred to use hands-on lab environments in science courses mostly stated that hands-on lab environments enable them to touch materials. In addition, they emphasized that hands-on laboratory environments provide the opportunity to be more active during the learning process. For instance, Student 5 from the HVH condition stated:

> Although virtual laboratory environments are simple and easy to use, I would prefer to do experiments in hands-on laboratories because you have to deal with a design procedure, have to endeavor to reach the goal in such laboratories. I like to engage with materials in the laboratory.

After that, students' views about virtual laboratory environments' advantages and drawbacks were discussed. Most of the students (six out of nine) emphasized that designing and implementing experiments in virtual laboratory environments is easier than in hands-on laboratory environments. Furthermore, a few students (two out of nine) mentioned that virtual laboratory environments have advantages in terms of time efficiency and materials. For example, Student 1 from the VHV condition said:

> It's easy to see your mistakes in virtual laboratory environments. You can do many experiments in limited time and there is no restriction about materials.

On the other hand, students (three out of nine) sometimes had trouble while writing in virtual laboratory environments. One student also expressed that he had difficulty with using some tools in virtual laboratory environments. He was from the HVH condition (Student 9) and stated:

> It was difficult to use some tools in virtual laboratories. I didn't understand well about how to use them. This might be because it's my first time to experience them.

The third topic in the interviews was the scaffolding tools used in the hypothesis generation, experimentation, and conclusion phases of the inquiry cycle. For instance, students were asked whether the hypothesis scratchpad was useful for their learning or not. Only two students (Student 4 from the VHV and Student 8 the VVV) did not find it a useful tool. These two students thought that the tool hindered them in thinking about creating a hypothesis. They just tried to form meaningful sentence(s) by using the given concepts in the scratchpad. For instance, Student 4 from the VHV class said:

> It would be better if no concepts were given in the scratchpad since this would urge us to think deeply and then understand better.

On the other hand, the other students emphasized that it was good for them to have concepts in the scratchpad. They felt that the scratchpad helped them remember the other related concepts and create hypothesis deliberately, and that it reduced the time needed to create hypothesis. As an example, Student 3 from the VVV class stated:

> Having concepts enabled us to focus on our experiments much more. If we didn’t have the concepts, then it would be difficult for us to create a hypothesis and also we would have worried about our hypothesis in terms of its structure.

As a result, the interview findings show that most of the students preferred virtual laboratory environments to hands-on environments, because they think that it is enjoyable to use technological equipment while learning. Although they generally emphasized the virtual laboratory’s advantages, such as enabling them to design more experiments in a limited time, they also mentioned that it was difficult to understand some tools’ functions in the virtual laboratory and to write using PCs. This might be because they were inexperienced with virtual laboratory environments. Having more experience with virtual laboratory environments might help them understand the tools and write more easily and faster. And they mainly found the scaffolding tools, such as the hypothesis scratchpad, beneficial for their learning.

An interview was also done with the science teacher. This was her first time using virtual laboratory environments. Before the implementation of the virtual laboratory environments in the study, she was taught how to use and integrate the virtual laboratory into learning environments. In the interview, first the advantages and drawbacks of virtual laboratory environments were discussed. The teacher emphasized that she mainly liked the virtual laboratory environment due to providing safer environment for students and its time efficiency. She said:

> Although students have opportunities to touch materials physically in hands-on laboratory environments, they are mostly afraid of touching the apparatus. They don't feel comfortable due to possibility of making mistakes and breaking materials. Yet, in the virtual laboratories, they are able to design and implement experiments in safer environment, feel free to try more experiments in the given time and have opportunities to learn by trial and error.

On the other hand, she also addressed the negative sides of virtual laboratory environments. She stated:

> It seemed to me that student had fun while learning in the class. They were all doing experiments on their tablets excitedly. Virtual laboratories attracted their attention. It was a different experience for them. On the other hand, virtual laboratories also have possible negative sides. For example, it is difficult to follow all students. Students have tablets or PCs and internet connections. It is open to misuse. I tried to check all groups' screens carefully. In addition, it is also open to technical problems. It would be horrible if we had such problems during the learning process.

Indeed, the drawbacks of virtual laboratory environments mentioned by the teacher were not directly related to virtual laboratories. That is why the science teacher was asked to give specific explanations of virtual laboratories' possibilities and disadvantages in learning process. The teacher thought that the experimentation phases of the inquiry cycle were much more enjoyable than other phases of the inquiry cycle for students. She said:

> Students expressed that they had difficulty while writing on tablets, especially on the conclusion tool. They were also not much eager to read the long texts on the screen. Yet, they tried to design a lot of experiments based

on their hypothesis. It was the most attractive section of the virtual laboratories for them, I think.

Then the science teacher was asked about the effects of scaffolding tools. She considered that the scaffolding tools, especially the hypothesis scratchpad, had important roles in the learning process. She stated:

> I believe that, for example, if we didn't use the hypothesis scratchpad, it was almost impossible to create a hypothesis because my students are not very familiar with hypotheses. Although the conclusion tool wasn't attractive for students due to writing difficulties, it was also a very useful tool, I think, because students were able to see their hypothesis, observation notes and findings simultaneously. The tool enabled them to associate all their activities, from creating a hypothesis to reaching a conclusion through the course. It seems to me that these tools were effective and helped students learn better and easily.

The science teacher was asked about her choice between using hands-on and virtual laboratory environments. She emphasized that she would prefer to use both types of laboratory environments in combination. Then she was asked about the order of the laboratories. The teacher would prefer to use the virtual laboratory environment first and then hands-on laboratories. She explained:

> I would prefer to use both of the laboratory environments because each type has its own benefits. In the first stages of the unit or topic, I would like to use virtual laboratory environments. It seems to me that virtual laboratories are proper tools to teach the main basis of the topic and to experience inquiry skills in a certain way. After gaining fundamental knowledge and principles about the topic through virtual laboratories, then hands-on laboratory environments can be used to see the practical form of the theoretical knowledge, and to develop psychomotor skills and to experience as a 'real' scientist. Besides, some topics are much more appropriate for virtual laboratories, such as acid-base, astronomy topics and some biology topics. Students have limited chances to design and implement experiments

> about such topics. On the other hand, it is an indisputable fact that hands-on laboratory activities have certain advantages for students, so they should also be used sometimes in the learning process.

The interview findings show that the science teacher had positive views about virtual laboratories. She considered that virtual laboratories attracted students' attention and enabled them to learn in an enjoyable way. She also thought that scaffolding tools are necessary for effective teaching in an inquiry-based learning environment. She mentioned that virtual laboratories should be a part of the science learning process and should be used in combination with hands-on laboratories.

4.6 Discussion

In the current study, we investigated the effects of different laboratory environments for development of middle school students' conceptual knowledge, inquiry skills, and improved attitudes toward science courses and laboratories. The results for the multiple-choice conceptual knowledge test showed that the students who followed alternating combinations of different laboratory environments (VHV and HVH conditions) increased their conceptual knowledge more than those in the VVV condition. Similarly, findings based on the open-ended conceptual knowledge test demonstrated that students in the VHV condition enhanced their conceptual knowledge better than those in the VVV condition. These results indicate that using hands-on and virtual laboratory environments in combination should be preferred over using the virtual laboratory alone. As students in the VHV condition spent 12 hours in the virtual laboratory and 4 hours in the hands-on laboratory, and for HVH, this was the other way around, it seems that it is not the number of hours that mainly counts, but the combination per se. These findings are in line with other studies, for instance, Olympiou and Zacharia (2012) and Zacharia and Michael (2016), but also differ with results from other studies, such as Zacharia and Olympiou (2011), in which combinations of different laboratory environments were found to be equally as effective as a single laboratory environment.

These different results are puzzling, and an explanation may be found in differences in the domain and/or students involved. For example, in terms of participants and domain, in the study done by Olympiou and Zacharia (2012), undergraduate students were involved and the subject was light and color. These authors found that combinations of hands-on and virtual laboratory environments enhanced students' conceptual knowledge more than the use of a single laboratory environment. On the other hand, Zacharia and Olympiou (2011) implemented another study with undergraduate students based on the topic of heat and temperature, and they did not find a significant difference in effects among hands-on, virtual, hands-on then virtual, and virtual then hands-on conditions in their study. How different combinations of students and domain characteristics may influence the results should be the subject of further research. An additional explanation may possibly be found in the level of experience that students have with virtual laboratories, which may have an impact on their ability to learn from virtual learning environments (Chini et al., 2012). In our case, for example, students had no prior experience with learning from virtual laboratories. All in all, many studies have suggested that combining hands-on and virtual laboratories enables students to gain more conceptual knowledge because students are able to take advantage of the strong sides of both laboratory environments in such learning environments (de Jong et al., 2013).

Another important topic concerning combinations of different laboratory environments is the sequencing of hands-on and virtual laboratories. In the current study, in order to investigate whether different combinations of the laboratory environments work better, two different sequences of the laboratory environments were presented. Based on the findings, there were no statistically significant differences between the different combinations in terms of middle school students' learning about the topic of electricity. Although some studies have found that a hands-on then virtual sequence led to better results than a virtual then hands-on sequence (e.g., Smith & Puntambekar, 2010), most studies, as in the current study, have not found differences in effects between different combinations of hands-on and virtual laboratory environments (e.g., Chini et al., 2012). Zacharia and de Jong (2014) also investigated different combinations of the types of laboratory environment for teaching concepts about topic of electricity and concluded that not all hands-on and virtual laboratory environment combinations have the same impact on students' conceptual knowledge. They suggested that using virtual laboratory environments first might be more beneficial, especially for teaching complex concepts.

In the current study, the scores for the open-ended conceptual knowledge test for students in the VHV condition were descriptively, but not significantly, higher than the scores for those in the HVH condition. Based on these data, we can very cautiously conclude that using a virtual laboratory first has the potential to yield better results in terms of students' conceptual knowledge. The two types of laboratories differ insofar as there is the possibility of making better observations and using less time to set up experiments in the virtual laboratories versus the physicality that is present in hands-on laboratories. One could argue that using virtual laboratories before hands-on laboratories could help learners to act more effectively in the hands-on laboratory, but the other combination obviously works; in the current study, students in the HVH condition could have benefited in the final hands-on part from using the virtual laboratory in the middle phase. As in the comparison between combinations versus a single laboratory environment, more studies are also needed to identify the best combination, so that any underlying mechanisms can be identified.

Although the results for the two types of knowledge test were mainly coherent with each other, there was no significant correlation between scores on these two tests. This non-significant value means that the two tests measured different aspects of the domain. Still, results from both tests generally pointed in the same direction. Students in the two conditions that combined types of laboratories (especially in the VHV condition) showed better performance than the students who used the virtual laboratory exclusively (those in the VVV condition). Concerning students' misconceptions, it can be very tentatively concluded, based on descriptive data, that when students were exposed to both hands-on and virtual laboratory environments in combination, their scientific knowledge increased and misconceptions faded more than when exposed to virtual laboratories or hands-on laboratories alone. Some studies have emphasized the opportunities provided by virtual laboratory environments, such as the ease of changing variables, as being beneficial for handling misconceptions (Crawford, Zembal-Saul, Munford, & Friedrichsen, 2005; Perry, Meir, Herron, Maruca, & Stal, 2008), whereas other studies (e.g., Lazonder & Ehrenhard, 2014; Zacharia, Loizou, & Papaevripidou, 2012) have concluded that physical experiments are a prerequisite for conceptual change. The main difference between this study and the studies that claimed physicality as a prerequisite for conceptual change is the participants' age. Participants in the current study are older than the students in the studies done by Lazonder and Ehrenhard (2014) and Zacharia et al. (2012). The participants' age is important in terms of Piaget's theory of cognitive development (Piaget, 1936). Students in this study are most probably in their formal operational stage, which mean that they have abstract reasoning skills that might help them to achieve conceptual change without physicality. Students in the studies by Zacharia et al. (2012) and Lazonder and Ehrenhard (2014) were likely to be in the pre-operational or concrete operational stage, which meant that they might not be able to deal very well with abstract concepts, so they might need to see and touch the materials for conceptual understanding. In this respect, it is important to note that in the current study, students in the VVV condition also corrected their misconceptions by the end of the study (going on average from 25 to 11 misconceptions). This result can be related to the students' prior sensory experience of manipulating the experimental objects, which might have an impact on their learning in virtual laboratory environments (Chen et al., 2014).

The learning environments were also designed to support students with their inquiry processes in the current study. Scaffolding supports (in an online form for students in the virtual laboratory environments, and as paper-based worksheets for the ones in the hands-on laboratory environments) were provided to overcome a lack of inquiry skills. Overall, it was found that there were no significant differences between the conditions in terms of the effects of the laboratory environment on middle school students' inquiry skills. Similarly, Mustafa and Trudel (2013) found that hands-on and virtual laboratories were equally effective for acquiring inquiry skills when a guided inquiry approach was used. However, interestingly enough, students in conditions in which virtual laboratories and the online tools were used (VVV, VHV, and HVH) all showed significant development of inquiry skills, whereas this was not the case for the students in the HHH condition. This may be a cautious indication that the paper-based worksheets used in the hands-on laboratory environments might have been less effective than the online interactive tools used in the virtual laboratory environments. In other words, the online scaffolding tools could be easier for students to use. For example, Hovardas, Xenofontos, and Zacharia (2017) used a hypothesis formulating tool similar to the one used in the current study, and they concluded that using the tool helped students to develop their inquiry skills better than the condition with no tool. However, as a general conclusion, it can be said that students' inquiry skills were and remained fairly low. This could mean that the scaffolding tools helped the students to perform in the learning environment, but that these tools (or the duration and frequency of their use) were insufficient to elicit a large change in students' inquiry skills.

Because there were no sub-scales in the inquiry skills test used in the current study, no conclusions can be drawn about differences between types of inquiry skills. Yet, based on further analysis of the results of the open-ended conceptual knowledge test and the inquiry skills test, it can be tentatively concluded that using higher-order skills was difficult for students. For example, the questions that required analyzing graphs or correlating concepts with each other were answered correctly by fewer students than the other questions. Furthermore, students' scores on the inquiry skills test were relatively low even on the posttest. This may be because Turkish students' inquiry skills are generally at a low level. For example, PISA 2015 results showed that Turkey ranked 55th out of 73 countries for the scientific literacy level of its students (Taş, Arıcı, Ozarkan, & Özgürlük, 2016). Similarly, TIMMS 2015 results also showed that Turkey ranked 35th out of 47 countries for the performance of its fourth grade students, and 21st out of 39 countries for the performance of its eighth grade students (Yıldırım, Özgürlük, Parlak, Gönen, & Polat, 2016). Students' limited inquiry skills might be difficult to develop through just one intervention, such as the one applied in this study.

Middle school students' attitudes towards science courses and laboratories were also investigated, because the learning environment in which the instruction occurs is important not only for students' achievement and conceptual learning (Pyatt & Sims, 2012; Zacharia, 2003) but also for their attitudes towards science (Lawrenz, 1976). In the current study, all conditions had a positive and statistically meaningful impact on students' attitudes towards the science course and laboratories. The attitude questionnaire involves three sub-dimensions, and similar conclusions were reached for each sub-dimension for nearly all conditions. The exception was for the students in HHH condition, for the sub-dimension of laboratory work in science. Although students in the HHH condition developed a more positive attitude towards laboratory work in science, the increase was not statistically significant. This result could imply that using hands-on laboratory environments may not be as effective as using virtual laboratory environments for improving middle school students' attitudes towards science laboratory work. Interviews done with the students also supported this conclusion, because students who used the virtual laboratory environments mentioned that the virtual laboratory environment was more attractive and motivating for them. A similar result was reached by Soyibo and Hudson (2000), who found that students who were instructed by computer-assisted instruction (CAI) developed significantly more positive attitudes towards biology. In the current study, it is also possible that the virtual laboratory environment could be effective for improving students' attitudes towards practical work, because more than half of the interviewed students stated that they would prefer to design and implement investigations in science classes through virtual laboratories rather than hands-on laboratories. Park, Khan, and Petrina (2009) also found that middle school students' attitudes towards science were affected positively after experience with CAI. They suggested that CAI enabled students to link the topic with their daily lives, which resulted in increasing students' achievement and improving their attitudes towards science.

There were no significant differences in middle school students' attitudes towards laboratory work between the HHH, VVV, VHV, and HVH conditions. Oser and Fraser (2015) also did not find a significant impact of virtual laboratories on students' attitudes when compared to hands-on laboratories. They concluded that virtual laboratories are equally effective for improving students' attitudes as hands-on laboratories, so they can be used confidently, especially in schools without adequate resources. Yet, Chen et al. (2014) concluded that students who were exposed to combined physical and virtual laboratory environments developed slightly better attitudes towards laboratories than the students who used solely hands-on or virtual laboratory environments. In terms of attitude towards learning science in school and self-concept in science, both types of laboratory environments were equally effective. The finding is consistent with the literature (e.g., Pyatt & Sims, 2012).

Interviews were done with students in order to reveal their views about virtual laboratory environments and their preferences for hands-on and virtual laboratory environments. The students' positive attitudes towards science course and laboratories were also revealed by the interviews. More than half of the interviewed students stated that they would opt to use a virtual laboratory rather than a hands-on laboratory. The main reasons behind their choice were that they could follow the course easily, were able to use technological apparatus actively throughout the learning process and could use the time efficiently. The students also mentioned that the scaffolding tools in the virtual laboratory were beneficial and helpful for their learning. The interview done with the science teacher also supported most of these results. The teacher also emphasized that virtual laboratory environments enabled students to learn in an enjoyable way. Similarly, she also emphasized the importance of the scaffolding tools. Furthermore, the science teacher stated that her preference as far as hands-on and virtual laboratory environments was using them in combination. She would like to use virtual laboratories at the beginning of the course while teaching the main concepts and principles related to the topic or unit. And then she would prefer to use hands-on laboratory environments to transform the theoretical data into an applicable form. The teacher also emphasized the problems faced by the students in the virtual laboratories, such as writing and/or reading in the virtual laboratory environment. Nevertheless, the problems students faced in virtual laboratory environments might be due to the use of tablets, since it is difficult to write and read on tablets. Using PC would be a better choice to decrease such problems.

All in all, students revealed their positive thoughts about virtual laboratories. They found this type of laboratory useful and mentioned that they would like to use it more regularly. These findings are mostly contrary to the ones found by Chen et al. (2014). They concluded that virtual manipulation did not impress students and was not as much fun as a hands-on laboratory, perhaps due to the tactile input provided by hands-on laboratories (Chen et al., 2014).

4.7 Conclusion and Implications

In conclusion, the findings of this study revealed that using hands-on and virtual laboratory environments together in a combination such as VHV and HVH gives significantly better outcomes for students' achievement than using virtual laboratories alone. Although students in the VVV condition only experienced the virtual laboratory environment, there were no significant differences between this condition and the HHH condition in terms of enhancing knowledge and improving inquiry skills. This result shows that virtual laboratory environments are as effective as hands-on laboratory environments for increasing middle school students' domain knowledge and developing their inquiry skills. This conclusion also proves that touching materials physically is not a prerequisite for conceptual understanding or for developing students' inquiry skills at the middle grade levels. In other words, it can be said that learning and gaining skills occurs through cognitive activities, so providing guidance (scaffolding tools in computer-supported environments; teachers and/or worksheets in classroom environments) for students to deal with cognitive load during the learning process might be a better solution. In addition, it was also found that manipulation could be done either physically or virtually. Both were effective for increasing domain knowledge and developing students' inquiry skills.

In terms of attitudes towards science course and laboratory, it was concluded that although all classes developed more positive attitudes towards science courses and laboratories, students in an exclusively hands-on laboratory environment, unlike their counterparts who used virtual laboratories, did not show a statistically significant increase in their positive attitudes towards practical work in science. Students' statements during interviews also emphasized that virtual laboratory environments encourage and motivate them to study science. It can be concluded that virtual and hands-on laboratory environments mostly have an equal effect on students' attitudes towards science courses and laboratories. Although a virtual laboratory environment provides time and cost efficiency, transforms invisible entities into concrete forms and is suitable for inserting online scaffolding tools efficiently, hands-on laboratories also attract students' attention and provide tactile input, which is an important property for meaningful learning. Science teachers can prefer one of the laboratories depending on the objective(s) of the course. Furthermore, a good combination of hands-on and virtual laboratories may be another efficient solution to enhance students' attitudes towards science, because students in VHV condition in the current study showed the greatest improvement in attitudes towards science.

Overall, the findings of this study offer several practical implications for science teachers as far as deciding which type of laboratory environment is more beneficial to use for learning science through experimentation. First, this study shows that when virtual laboratories are considered as an alternative for hands-on laboratories (for example, for reasons of easier experimental setup), they can be regarded as being as effective as hands-on laboratories. Second, if possible, providing students with alternating hands-on and virtual laboratories should be preferred over single laboratory formats, especially single virtual laboratories.

A
MULTIPLE CHOICE CONCEPTUAL KNOWLEDGE TEST

ELEKTRİK ENERJİSİ BAŞARI TESTİ

İSİM-SOYİSİM: **SINIF:**

1. Aşağıda bir lamba, bir pil ve bir iletken telden oluşan iki şekil görüyorsunuz. Verilen şekillere göre, aşağıdaki seçeneklerden doğru olanı işaretleyiniz.

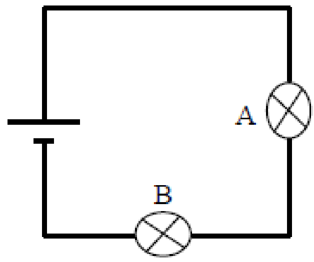
A) Şekil 2’deki lamba yanmaz fakat Şekil 1’deki lamba yanar, çünkü pilin (+) ucundan çıkan elektrik akımı lambaya ulaşır.

B) İki şekilde de lamba yanmaz. Çünkü devrelerden akım geçmez.

C) Şekil 1’deki lamba yanmaz fakat Şekil 2’deki lamba yanar, çünkü pilin (-) ucundan çıkan elektrik akımı lambaya ulaşır.

D) Her iki şekilde de lamba yanar çünkü lamba ve pil arasındaki tek bir tel bağlantısı, lambanın yanması için yeterlidir.

2. Şekilde verilen devrede birbirine seri olarak bağlanmış A ve B lambalarını görüyorsunuz. Bu lambaların parlaklıkları ile ilgili aşağıdaki yargılardan hangisi doğrudur?



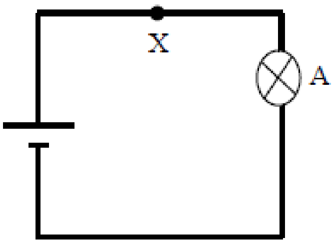
A) B lambası A lambasından daha az parlak yanar çünkü A lambası akımın bir kısmını kullanmıştır ve B lambasına ulaşan akım şiddeti azalmıştır.

B) A ve B lambalarının parlaklıkları aynıdır, çünkü pilin (+) kutbundan gelen akım A lambasına ulaşır, pilin (-) kutbundan gelen akım B lambasına ulaşır ve bu iki akımın şiddeti birbirine eşittir.

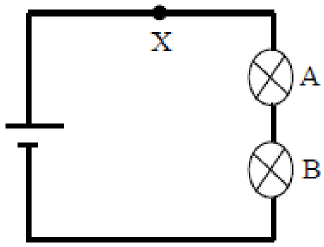
C) A ve B lambalarının parlaklıkları aynıdır, çünkü devrede oluşan akım pilin iki kutbu arasında tek yönde hareket etmektedir ve iki lambadan eşit miktarda akım geçmektedir.

D) A lambası B lambasından daha az parlak yanar çünkü A lambası B lambasına göre pilden daha uzakta bulunmaktadır.

3. B lambası şekil 1'de görülen devreye seri olarak bağlandığında Şekil 2'de görülen devre elde edilmektedir. Buna göre aşağıdaki bilgilerden doğru olanı işaretleyiniz. (A ve B lambaları özdeştir.)



Şekil 1



Şekil 2

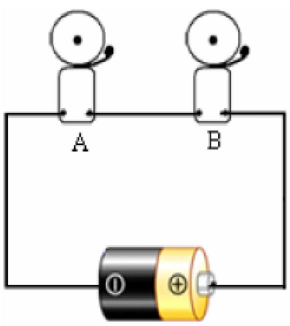
A) Her iki devrede de X noktasından geçen akım aynıdır çünkü devrede X noktasından önce akım kullanabilecek bir lamba yoktur ve bu nedenle lamba sayısı bu noktadaki akım miktarını değiştirmez.

B) Şekil 1'de verilen devreye B lambası Şekil 2'deki gibi bağlandığında A lambasının parlaklığı azalır çünkü B lambası devrede sabit olan akımın bir kısmını harcar.

C) Şekil 2'de verilen devrede A ve B lambaları eşit parlaklığa sahiptirler fakat ikisi de Şekil 1'de verilen devredeki A lambasından daha az parlak yanarlar.

D) Şekil 2'de verilen devrede B lambasının parlaklığı A lambasının parlaklığından daha azdır çünkü A lambası akımın bir kısmını kullanır ve B lambasına daha az akım ulaşır.

4. Şekilde görülen devre için aşağıdakilerden hangisi doğrudur?



(Ziller aynı özelliklere sahiptir.)

A) Şekilde görülen iki zil de çalar, fakat B zili pilin (+) kutbuna daha yakın olduğu için daha güçlü çalar.

B) Şekilde görülen iki zil de çalar, fakat A zili pilin (-) kutbuna daha yakın olduğu için daha güçlü çalar.

C) Şekilde görülen iki zil de eşit şiddette çalar çünkü devreden geçen akım, pilin iki kutbu arasında tek yönde hareket etmekte ve iki zilden de eşit miktarda akım geçmektedir.

D) Şekilde görülen iki zil de eşit şiddette çalar çünkü devreden geçen akım ziller tarafından paylaşılır ve azalarak pile geri döner.

5. Aşağıdaki seçeneklerden doğru olanı işaretleyiniz.

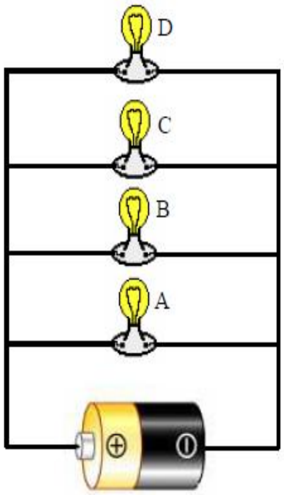
A) Devre nasıl olursa olsun bir pil bütün devrelerde aynı akımı oluşturur.

B) Tek direnci olan bir devreye yeni bir direnç paralel bağlandığında eşdeğer direnç artar.

C) Pil, bütün devrelerde aynı potansiyel farkına sebep olur.

D) Pil, devredeki akımı oluşturan elektronların kaynağıdır.

6. Aşağıda verilen cümleleri dikkatlice okuyup, verilen şekil için doğru olan seçeneği işaretleyiniz. (Lambalar özdeştir.)



A) Şekilde görülen lambaların hepsi yanar çünkü pilin (+) kutbundan gelen elektrik akımı ile pilin (-) kutbundan gelen elektrik akımı lambalarda karşılaşır ve lambaların yanmasını sağlar.

B) Şekilde görülen lambaların hepsi yanar fakat A lambası pile en yakın lamba olduğu için en parlak yanarken, D lambası pile en uzak lamba olduğu için en az parlak yanar.

C) Şekilde görülen lambaların hepsi yanar çünkü pilin bir kutbundan A, B, C, D lambalarına doğru hareket edip daha sonra pilin diğer kutbuna geri dönen akım, lambaların yanmasını sağlar.

D) Şekilde görülen bütün lambaların parlaklıkları aynıdır. Devredeki akım lambalar tarafından eşit olarak paylaşılır ve harcanır.

7. Bir lambanın bir pile iletken teller ile bağlanıp kapalı bir devre oluşturulması sonucunda lamba ışık vermektedir. Bu durumda aşağıda verilen cümlelerden doğru olanını işaretleyiniz.

A) Lamba devredeki elektrik akımının bir kısmını harcar.

B) Aynı pil kullanılarak devreye başka lambalar eklendiğinde, devreden geçen toplam akım miktarı değişmez.

C) Lambanın parlaklığı devreye başka lambaların eklenmesinden sonra değişmez çünkü lambalardan geçen akım şiddeti iki durumda da aynıdır.

D) Lamba devredeki elektrik potansiyel enerjisinin bir kısmını harcar.

8. Aşağıda verilen seçeneklerden doğru olanını işaretleyiniz.

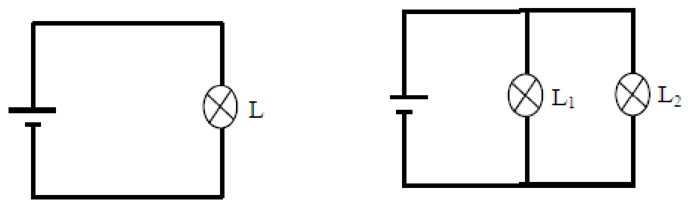
A) Birbirlerine paralel ve seri olarak bağlanmış lambaların olduğu bir devrede pil, devredeki her lambaya aynı miktarda akı verir.

B) Akım, devrede sadece bir yönde ve her bir devre elemanında azalarak akar.

C) Akım, devre elemanları arasında eşit olarak paylaşılır.

D) Pilden çıkan akımla pile geri dönen akım aynıdır ve akım bir yönde akar.

9. Aşağıdaki elektrik devrelerinde piller ve lambalar özdeştir. Buna göre aşağıda verilen seçeneklerden doğru olanını işaretleyiniz.



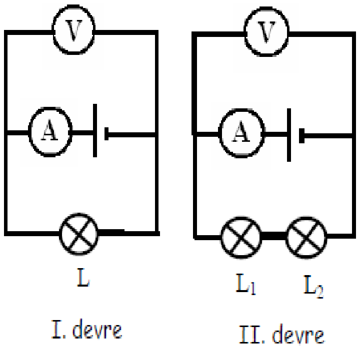
A) L_1 ve L_2 lambalarının uçlarındaki potansiyel fark L lambasının sahip olduğu potansiyel farktan daha azdır.

B) L_1 ve L_2 lambalarının uçlarındaki potansiyel fark birbirine eşittir.

C) L_1 ve L_2 lambaları, L'ye göre daha az parlak yanarlar.

D) İkinci devredeki eş değer direnç daha büyük olduğu için devreden geçen toplam akım miktarı daha azdır.

10. Aşağıda verilen elektrik devreleri ile ilgili olarak aşağıda verilen bilgilerden doğru olanı işaretleyiniz. (Piller ve lambalar özdeştir.)



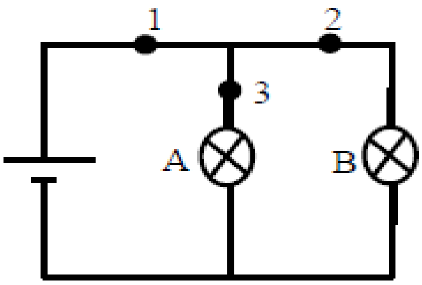
A) İkinci devredeki voltmetre birinci devredeki voltmetreye göre daha düşük bir potansiyel fark gösterir.

B) L_2 lambası L_1 lambasına göre daha parlak yanar çünkü pile daha yakındır.

C) L_1 ve L_2 lambaları, L'ye göre daha az parlak yanarlar.

D) Birinci devredeki ampermetrenin ölçtüğü toplam akım şiddeti, ikinci devredeki ampermetrenin ölçtüğü toplam akım şiddetinden daha azdır.

11. Yandaki devrede 1, 2, 3 noktalarındaki akım miktarlarını karşılaştırınız. (A ve B lambaları özdeştir.)



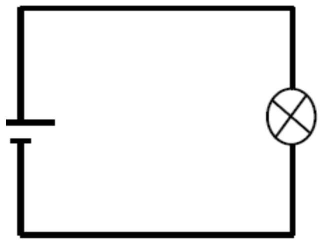
A) 1, 2, ve 3 noktalarındaki akımlar birbirine eşittir çünkü akım henüz lambalara ulaşmamıştır.

B) 2 ve 3 noktalarındaki akım miktarları birbirine eşittir. 1 noktasındaki akım, 2 ve 3 noktalarındaki akım miktarlarının toplamına eşittir.

C) 2 noktasındaki akım en büyüktür çünkü pilin (-) kutbuna en yakındır.

D) 1 noktasındaki akım en küçüktür çünkü akım A ve B lambalarından geçerken azalmıştır.

12. Şekilde görülen devreden geçen akım ile ilgili olarak aşağıda verilen bilgilerden hangisi doğrudur?



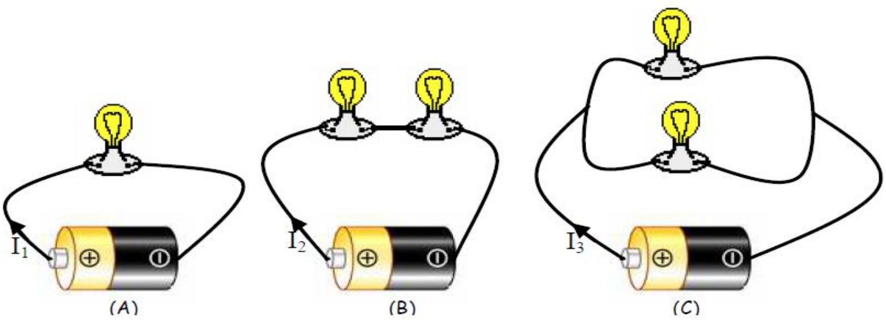
A) Akım, devrenin her yerinde aynıdır.

B) Akım devrenin her iki kutbundan çıkar ve lamba tarafından kullanılır.

C) Pilden uzaklaştıkça akım miktarı azalır.

D) Akım, lambada kullanıldıktan sonra azalır ve böylece pile geri döner.

13. Şekilde görülen üç devreden geçen akım miktarları ile ilgili doğru seçeneği işaretleyiniz. (Lambalar özdeştir.)



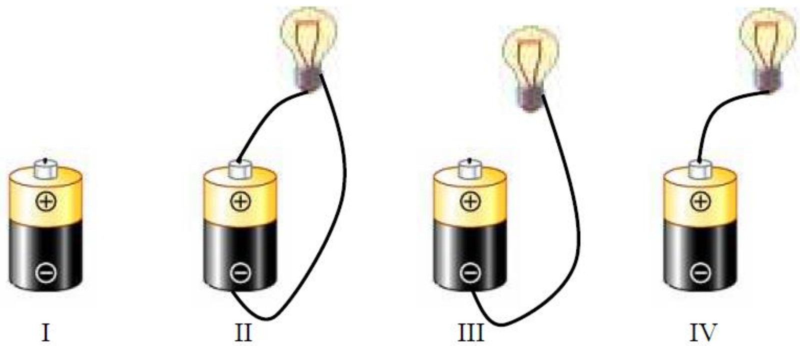
A) Üç devrenin ana kollarından geçen akım miktarı birbirine eşittir. (I_1=I_2=I_3)

B) B ve C devrelerindeki toplam lamba (direnç) sayısı aynı olduğu için akımlar da birbirine eşittir. A devresindeki akım farklıdır. (I_2=$I_3 \neq I_1$)

C) En fazla akım A devresinden geçer çünkü devredeki akım sadece bir lamba tarafından kullanılır.

D) Ana koldan geçen toplam akım miktarı üç devrede de farklıdır.

14., **15.**, **16.** ve **17.**soruları aşağıdaki şekillere göre cevaplayınız.



14. Yukarıdaki şekillerin hangisinde ya da hangilerinde lamba ışık verir?

A) Yalnız III B) Yalnız II C) Yalnız IV D) II, III ve IV

15. Yukarıdaki şekillerin hangisi ya da hangileri kapalı bir devredir?

A) Yalnız IV B) Yalnız III C) Yalnız II D) II ve III

16. Yukarıdaki şekillerin hangisinde ya da hangilerinde potansiyel fark vardır?

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

17. Yukarıdaki şekillerin hangisinde ya da hangilerinde akım vardır?

A) Yalnız II B) Yalnız III C) Yalnız IV D) II ve III

18. Aşağıda verilen ifadelerden hangisi bir elektrik devresindeki direncin görevini doğru olarak açıklar?

A) Elektrik devrelerinin enerji ihtiyacını karşılar.

B) Devreden geçen akım miktarını sınırlar.

C) Devre elemanlarının uçları arasındaki potansiyel farkı ölçer.

D) Devreden geçen akımı kesmeye ve devreye akım verilmesini sağlar.

19. R_1 ve R_2 dirençleri bir üretecin uçları arasına paralel olarak bağlanmıştır. R_2'nin büyüklüğü azaltılacak olursa, aşağıdakilerden hangisi doğru olur?

A) R_1'den geçen akım şiddeti sabit kalır.

B) R_1'den geçen akım şiddeti artar.

C) Devreden geçen akım şiddeti azalır.

D) R_1'in uçları arasındaki potansiyel fark azalır.

20. Bir iletken telin üzerinden geçen akım şiddeti arttırılmak isteniyor. Bunun için telle ilgili aşağıdaki değişikliklerden hangisi veya hangileri yapılabilir?

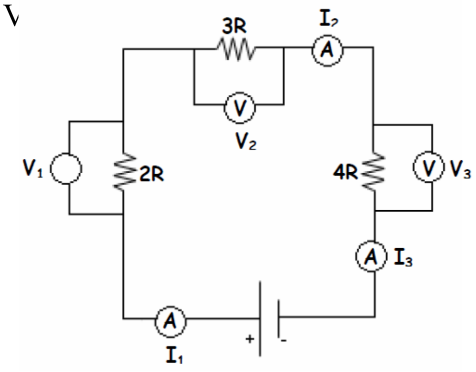
I- Telin boyu uzatılmalı

II-Telin kesiti büyütülmeli

III-Telin uçları arasındaki potansiyel fark düşürülmeli

A) I ve II B) Yalnız II C) II ve III D) I, II, III

21. Şekilde gösterilen devrede ampermetrenin okuduğu değerler I_1, I_2, I_3 ve voltmetrenin okuduğu değerler V V_2, V_3'tür. Bu değerler arasındaki ilişki nedir?



A) $V_3 > V_2 > V_1$ $I_1 = I_2 = I_3$

B) $V_1 = V_3 < V_2$ $I_1 = I_2 > I_3$

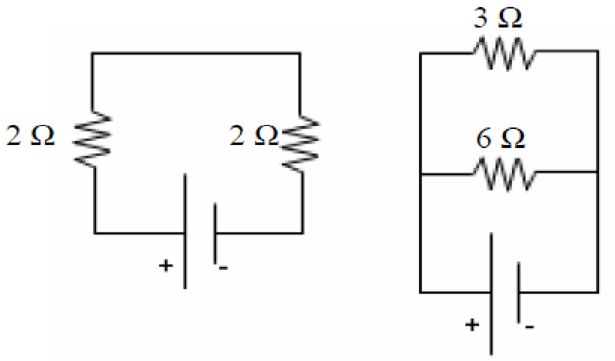
C) $V_2 > V_1 = V_3$ $I_1 = I_2 = I_3$

D) $V_2 > V_1 > V_3$ $I_3 > I_1 > I_2$

22. Şekildeki özdeş üreteçlerden kurulmuş I. ve II. devrelerin eşdeğer dirençleri R_1 ve R_2'dir. Buna göre R_1 / R_2 oranı kaçtır?

A) 2 B) 8/3

C) 4 D) ½



<u>Açıklama:</u> Aşağıdaki cümleleri okuduktan sonra doğru olduğunu düşündüğünüz cümlelerin önündeki "D" harfini, yanlış olduğunu düşündüğünüz cümlelerin önündeki "Y" harfini yuvarlak içine alınız.

D **Y** **23.** Paralel bağlı devrelerde, her bir kolun uçları arasındaki potansiyel fark, üretecin uçları arasındaki potansiyel farka eşittir.

D **Y** **24.** Ampermetre devreye paralel, voltmetre ise devreye seri bağlanır.

D **Y** **25.** Seri bağlı devrelerdeki lamba sayısı arttıkça devrenin eşdeğer direnci azalır.

<u>Açıklama:</u> Aşağıdaki "A" sütununda devre elemanları, "B" sütununda ise devre elemanlarının tanımları yer almaktadır. Her bir elemanın solundaki boşluğa o elemanın tanımının önündeki harfi yazınız.

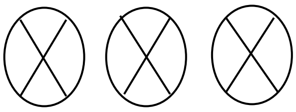
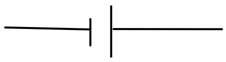
	"A" Sütunu	"B" Sütunu
……………	**26.** Üreteç	A. Devredeki akımı kesmeye ve tekrar açmaya yarayan devre elemanıdır.

…………...	**27.** Ampermetre	B. Bir devre elemanının uçları arasında oluşan potansiyel farkını ölçmeye yarayan, devreye paralel bağlanan araçtır.
……………	**28.** Anahtar	C. İletken içinden geçmek isteyen yüklü parçacıklara iletkenin temel parçacıklarının karşı koymalarının ölçüsüdür.
		D. Bir elektrik devresinden geçen akım şiddetini ölçmeye yarayan, devreye seri bağlanan iki uçlu araçtır.
		E. Elektrik devrelerinin enerji ihtiyacını karşılayan, devrenin ana elemanıdır.

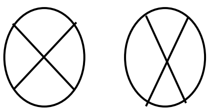
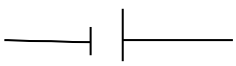
B
OPEN-ENDED CONCEPTUAL KNOWLEDGE TEST

Elektrik Kavram Testi

1. a)

 3 tane ampul  Pil	3 ampul ve 1 pil kullanarak seri bağlı bir devre çiziniz.

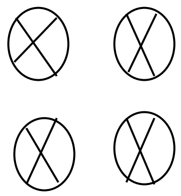
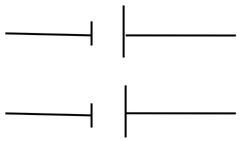
b)

 2 tane ampul  Pil	2 ampul ve 1 pil kullanarak paralel bağlı bir devre çiziniz.

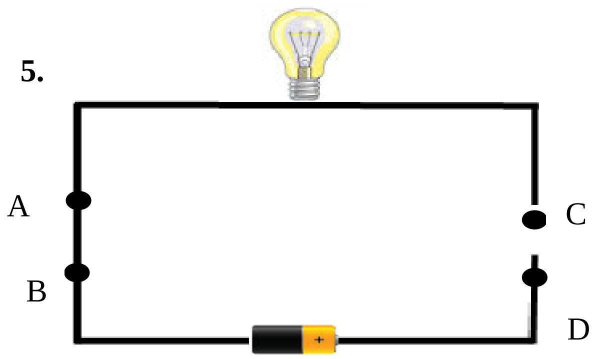
2. Ahmet öğretmen, ampermetre ve voltmetrenin devreye nasıl bağlanması gerektiği bilgisini öğrencisi Ayşe'nin kavradığını anlamak istiyor. Ayşe'ye ampul, pil, bağlantı kabloları, ampermetre ve voltmetre vererek bir devre kurmasını istiyor. Buna göre Ayşe nasıl bir devre kurmuş olabilir?

3. Akım, gerilim ve direnç arasındaki ilişkiyi açıklayınız.

4.

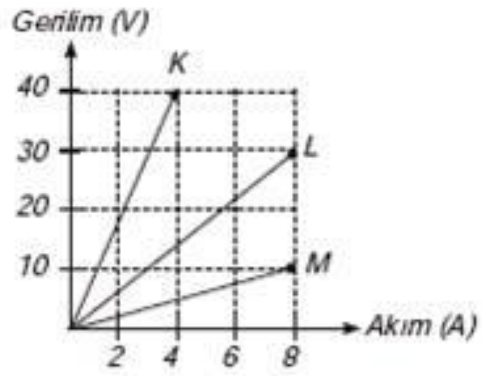
 4 tane ampul  2 tane pil	4 ampul ve 2 pil kullanarak hem seri bağlı hem de paralel bağlı ampuller içeren bir devre çiziniz. Hangi ampullerin seri bağlı, hangi ampullerin paralel bağlı olduğunu belirtiniz.

5.



Yanda size bir elektrik devresi verilmiştir. Bu devre şu anda çalışmamaktadır. Devreyi bir ampermetre ve bir voltmetre ekleyerek çalıştırmak için ampermetre ve voltmetreyi hangi noktalar arasına bağlamalıyız?

6.



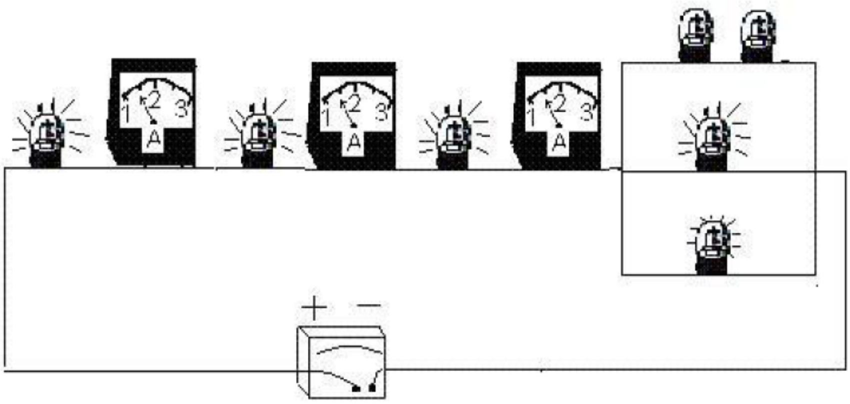
Yandaki Gerilim(V) – Akım(I) grafiğine göre K, L ve M iletkenlerinin dirençlerini büyükten küçüğe doğru sıralayınız. Neden böyle bir sıralama yaptınız?

C
INQUIRY SKILLS TEST

BİLİMSEL SÜREÇ BECERİ ÖLÇEĞİ

İSİM-SOYİSİM: **SINIF:**

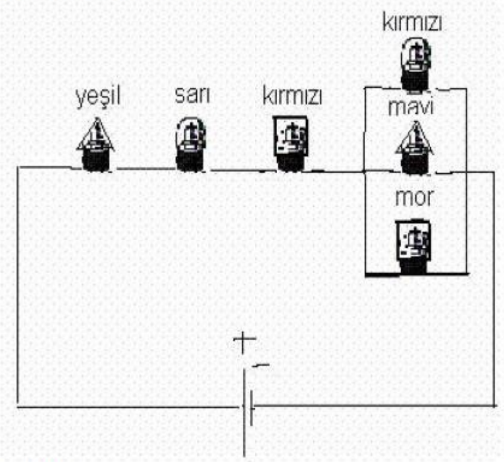
1) Öğretmen aşağıdaki şekilde görülen bir elektrik devresini kurmuş ve öğrencilerin bu devreyi incelemelerini istemiştir.



Öğrenciler yukarıdaki elektrik devresini incelerken aşağıdaki şıklarda verilen bazı açıklamaları yapmıştır. Bu açıklamalardan hangisi sadece bir <u>gözlemdir</u>.

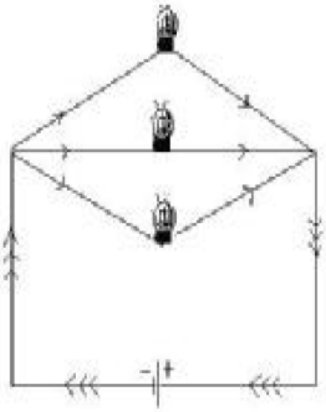
A) Devredeki bazı ampuller yanmıyor, öyleyse yüksek gerilimle patlamış (bozulmuş) olmalı.
B) Devredeki yanan ampuller yeterince aydınlatmıyor, öyleyse devreye verilen gerilim düşük olmalı.
C) Devredeki ampuller kalitesiz malzemeden yapılmışa benziyor.
D) Seri bağlı devre elemanlarının hepsinden aynı akım geçmektedir.

2) Aşağıda farklı şekil ve renkte ampullerden oluşan bir elektrik devresi verilmektedir. Ampulleri hangi özelliklerine göre sadece <u>iki grupta</u> sınıflayabiliriz?



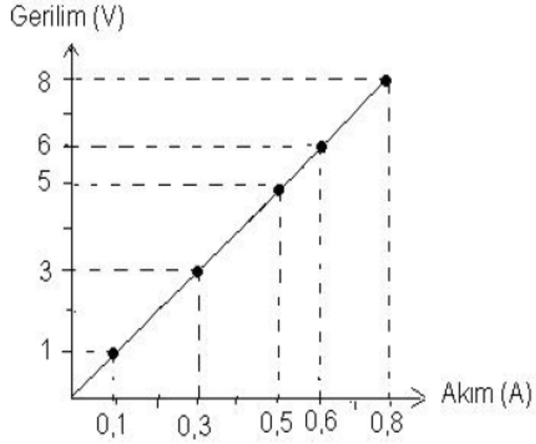
A) Sarı ve yeşil renkli ampuller
B) Seri ve paralel bağlı ampuller
C) Üçgen ve kare şeklinde ampuller
D) Yuvarlak ve kare şeklinde ampuller

3) Öğretmen aşağıdaki şekilde görüldüğü gibi, bir devredeki akımın doğrultusu ayrıca ana kol ve ara koldan geçen akımın nasıl dağıldığı ampermetre yardımıyla göstermiştir. Siz devredeki akımın hangi özelliğine göre sadece <u>iki grupta</u> sınıflama yapabilirsiniz?



A) Doğu-batı ve güney-kuzey doğrultusunda geçen akıma göre
B) Kuzeybatı-güneydoğu ve kuzeydoğu-güneybatı doğrultusunda geçen akıma göre
C) Doğu-batı ve kuzeybatı-güneydoğu doğrultusunda geçen akıma göre
D) Ana koldan ve ara koldan geçen akıma göre

4) Ahmet, bir elektrik devresi kurmuş ve devredeki gerilim ve akım değerlerini kaydetmiştir. Yapılan çalışma sonucunda elde edilen bulgular aşağıdaki grafikte gösterilmiştir.



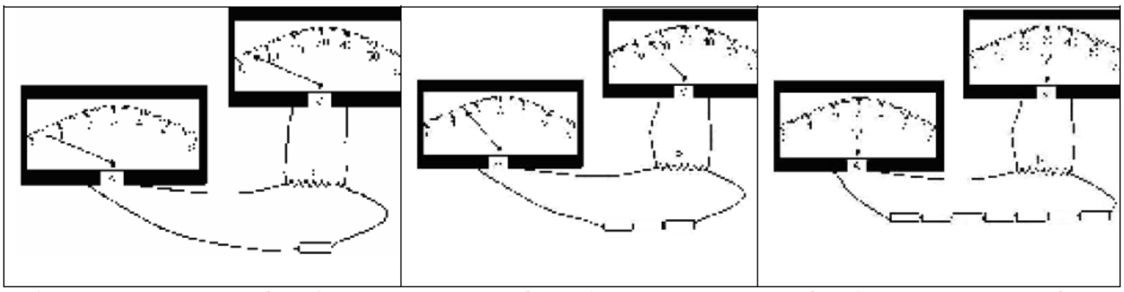
Size göre aşağıdakilerden hangisi değişkenler arasındaki ilişkiyi açıklamaktadır?

A) Gerilim artarsa akım artar
B) Akım artarsa daha çok enerji harcanır
C) Gerilim artarsa direnç artar
D) Akım artarsa direnç azalır

5) Hüseyin, sürtünmeyle elektriklenme deneyine başlamadan önce şu hipotezi test etmek ister: Plastik çubuk kumaşa ne kadar hızlı sürtülürse o kadar çok elektriklenir. Sizce Hüseyin plastik çubuğun ne kadar çok elektriklendiğini nasıl ölçebilir?

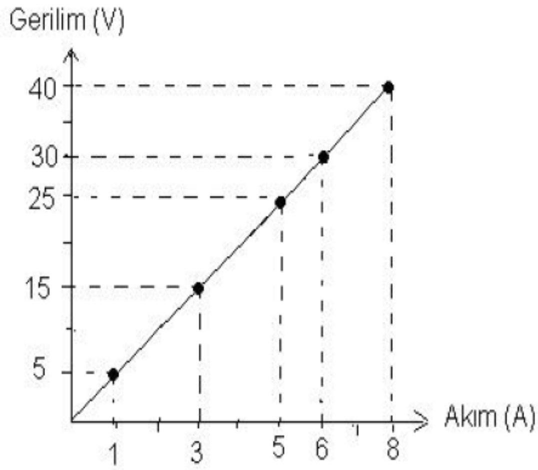
A) Plastik çubuğun boyunu ölçer
B) Plastik çubuğun kumaşa sürtülme hızını ölçer.
C) Plastik çubuğun kumaşa sürtüldüğü alanı ölçer.
D) Plastik çubuğun çektiği kâğıt parçalarının sayısını ölçer.

6) Ali, aşağıdaki şekilde görüldüğü gibi seri bağlı pillerden oluşan bir devre üzerindeki akım ve gerilim değerlerini, voltmetre ve ampermetre yardımıyla ölçmektedir. Ölçtüğü akım ve gerilim değerleri, aşağıda ampermetre ve voltmetre üzerinde görülmektedir. Sizce Ali, 7 pili seri bağladığında devredeki ampermetre ve voltmetre hangi değerleri gösterir?



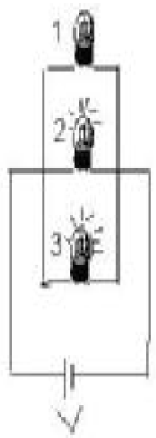
A) 2,5 Amper —25 Volt B) 3 Amper— 30 Volt C) 3,5 Amper—35 Volt D) 4 Amper—40 Volt

7) Aşağıdaki grafik bir iletken üzerinden geçen akım ve buna karşılık gelen gerilim değerlerini göstermektedir. Bu grafiğe göre iletkenin üzerinden 11 A'lik akım geçerse, iletkenin uçları arasındaki gerilim kaç V olmalıdır?



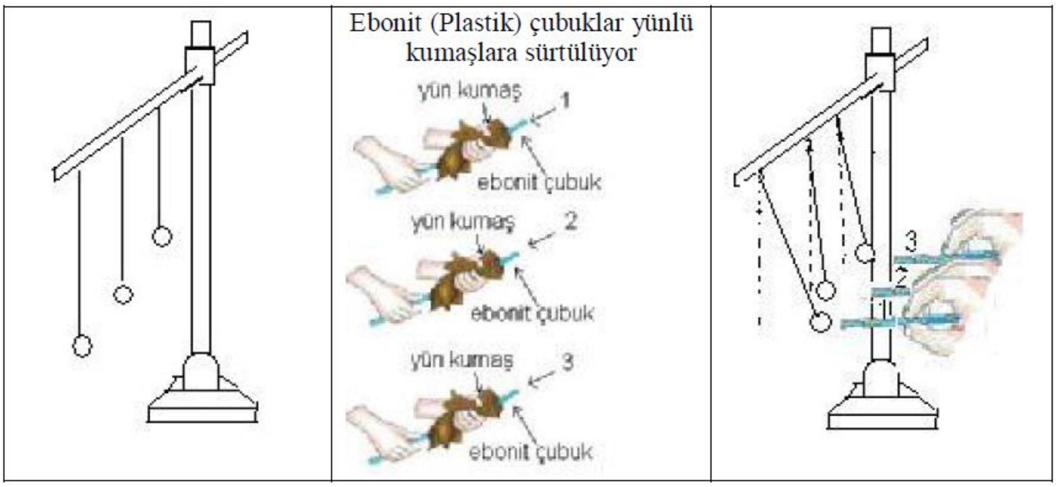
A) 45 V B) 50 V C) 55 V D) 60 V

8) Aşağıdaki şekilde, paralel bağlı yeni üretilmiş üç lamba görülmektedir. Bu lambalara gerilim verildiğinde 1 nolu ampul patlarken (bozulurken), 2 ve 3 nolu ampuller yanmaya devam ediyor. Bu sonuçlara bakarak hangi çıkarımda bulunursunuz?



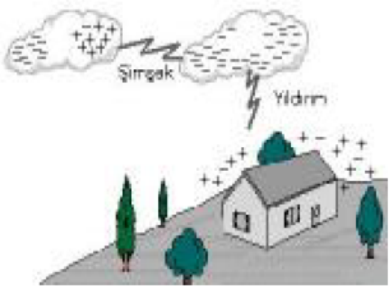
A) 1 ve 2 nolu ampuller özdeştir çünkü ampullerin patlaması (bozulması) önemli değildir.
B) 1 ve 3 nolu ampuller özdeş değildir. Çünkü 1 nolu ampul verilen gerilimle patlamıştır.
C) 2 ve 3 nolu ampuller özdeştir. Çünkü yanmaya devam ediyorlar.
D) Ampullerin üçü de özdeştir. Çünkü ampullerin patlaması ya da yanması önemli değildir.

9) Alüminyum folyodan üç küçük top ince naylon iplikle aşağıdaki şekilde görüldüğü gibi bir düzeneğe asılmıştır. Özdeş üç ebonit (plastik) çubuk, kumaşlara sürtülmüş ve alüminyum folyodan yapılan toplara aynı mesafeden yaklaştırılmış ve topların hareketi şekildeki gibi olmuştur. Bu sonuçlara göre hangi çıkarımı yapabiliriz?



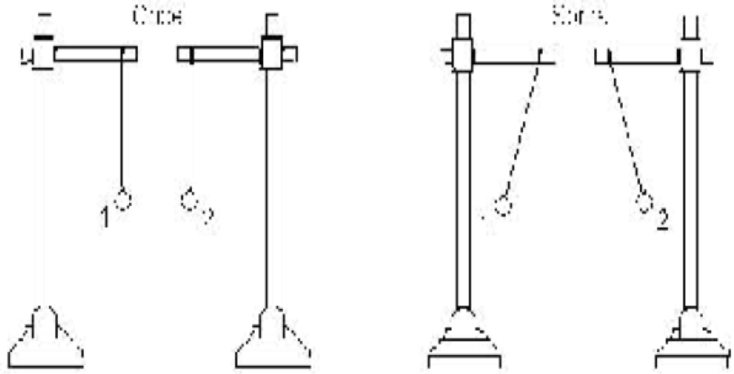
A) 1, 2 ve 3 nolu çubuklar aynı cins ve aynı miktar elektrik yüküyle yüklenmiştir.
B) 1, 2 ve 3 nolu çubuklar farklı cins elektrik yüküyle yüklenmiştir.
C) 1, 2 ve 3 nolu çubuklar alüminyum topları çekmiştir.
D) Yukarıdaki cevapların hiçbiri doğru değildir.

10) Atmosferde rüzgârın etkisiyle sürüklenen bulutlar hem havayla hem de birbirleriyle temas ederler. Bunun sonucunda da elektriklenirler. Elektrik yüklü bulutlar birbirlerine yeterince yaklaşırsa birinden ötekine elektrik yükü boşalması olabilir. Bu olaya şimşek denir. Benzer şekilde elektrik yüklü bulutlar yer küreye yeterince yaklaşırsa buluttan yere ya da yerden buluta elektrik yükü boşalması olabilir. Bu olaya da yıldırım denir. Ancak, yıldırım düşmesi sırasında önce ışık görür, sonra sesini duyarız. Bu sonuçtan nasıl bir çıkarım yapabiliriz?



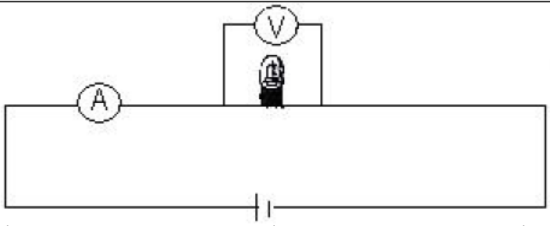
A) Bu sonuç ışığın sese göre daha yavaş yayıldığını gösterir.
B) Bu sonuç ışık ile sesin aynı hızda yayıldığını gösterir.
C) Bu sonuç sesin boşlukta yayılmadığını gösterir.
D) Bu sonuç ışığın sese göre daha hızlı yayıldığını gösterir

11) İki küçük top, iple aşağıdaki şekilde görüldüğü gibi bir düzeneğe asılmıştır. Daha sonra her iki topta elektriklenme yoluyla yüklenmiş ve tekrar serbest bırakıldığında şekilde görülen değişim meydana gelmiştir. Bu sonuçlara göre hangi çıkarımı yapabiliriz?



A) Topların biri pozitif, diğeri negatif yüklenmiştir.
B) 1 ve 2 nolu top pozitif yüklenmiştir.
C) Her iki topta aynı yükle yüklenmiştir.
D) Yukarıdaki cevapların hiçbiri doğru değildir.

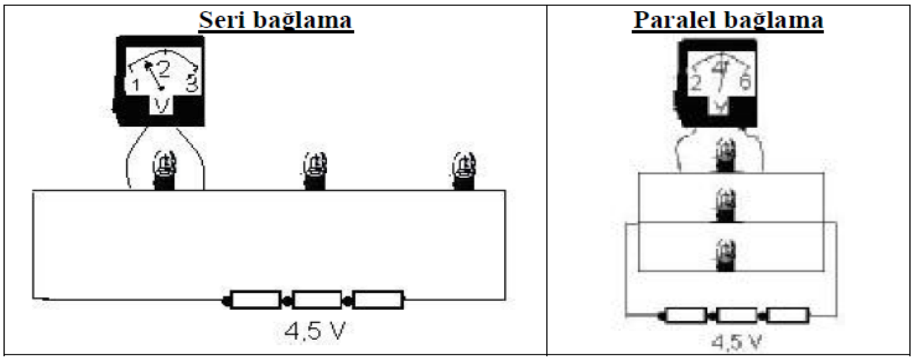
12) Aşağıda bir elektrik devresi verilmektedir. Elektrik devresinde gerilim ölçmek için voltmetre, akımı ölçmek için ampermetre bağlıdır. Tablodaki verilere bakarak nasıl bir sonuç çıkarırsınız?



Devredeki Telin Cinsi	Gerilim	Akım	Direnç
Bakır	10 V	2 Amper	5 Ohm
Bakır	20 V	4 Amper	5 Ohm
Bakır	30 V	6 Amper	5 Ohm

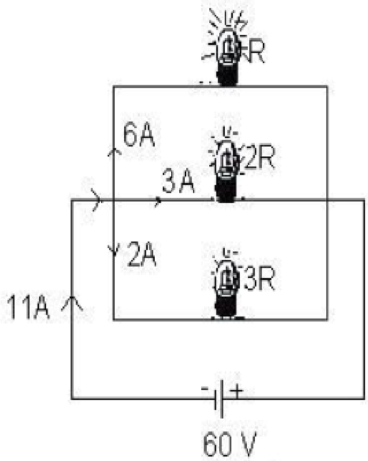
A) Devredeki gerilimin akıma oranı her defasında değişir
B) Devredeki akım azalırsa direnç artar
C) Devredeki akım artarsa direnç azalır
D) Devredeki gerilim artarsa akım artar

13) Bir öğrenci aşağıdaki şekilde görüldüğü gibi, üç özdeş ampulü önce seri, daha sonra ise paralel olarak bağlamıştır. Her iki devreye de 4,5 voltluk gerilim vermesine rağmen seri bağlı devrede voltmetre 1,5 voltu, paralel bağlı devrede ise 4,5 voltu göstermektedir. Bu verilerden nasıl bir sonuç çıkarırsınız?



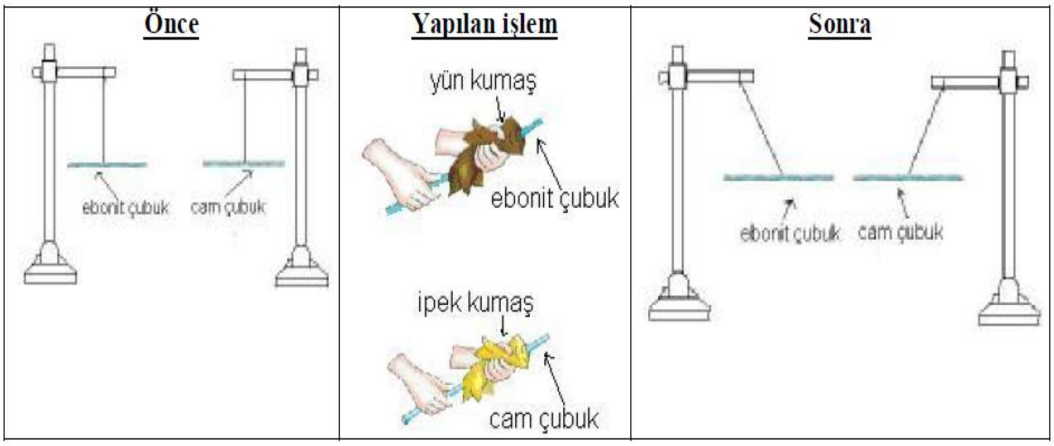
A) Özdeş ampullerden oluşan bir devrede, seri bağlı devrelerde gerilim ampul sayısına bağlı olarak eşit paylaşılırken paralel bağlı devrelerde gerilim paylaşılmadan aynen ampullere dağılır.
B) Farklı dirence sahip ampullerden oluşan bir devrede, seri bağlı devrelerde gerilim ampul sayısına bağlı olarak eşit paylaşılırken paralel bağlı devrelerde gerilim paylaşılmadan aynen ampullere dağılır.
C) Farklı dirence sahip ampullerden oluşan bir devrede, paralel bağlı devrelerde gerilim ampul sayısına bağlı olarak eşit paylaşılırken seri bağlı devrelerde gerilim paylaşılmadan aynen ampullere dağılır.
D) Özdeş ampullerden oluşan bir devrede, paralel bağlı devrelerde gerilim ampul sayısına bağlı olarak eşit paylaşılırken seri bağlı devrelerde gerilim paylaşılmadan aynen ampullere dağılır.

14) Aşağıdaki şekilde, ana koldan geçen akımın devre elemanlarına nasıl paylaştırıldığı görülmektedir. Bu verilerden nasıl bir sonuç çıkarırsınız?



A) Ana koldan geçen akım, dirençlere bağlı olarak ara kollarda paylaşılır.
B) Ana koldan geçen akım, dirençlere bağlı olmaksızın ara kollara eşit paylaşılır
C) Devreye verilen gerilim arttıkça ampullerin parlaklığı azalır
D) Devreye fazla gerilim verilirse ampuller patlar (bozulur)

15) Aşağıdaki deneyde, ebonit çubuğun yün kumaşa, cam çubuğun da ipek kumaşa sürtülerek her iki çubuğunda elektrikle yüklendiği ve yüklü çubukların arasındaki etkileşim görülmektedir. Yapılan bu deneyden nasıl bir sonuç çıkarırsınız?



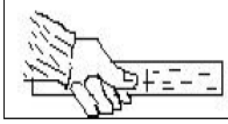
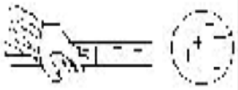
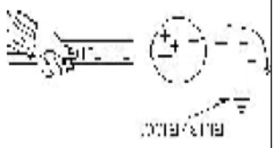
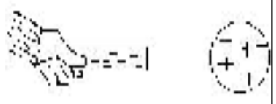
A) Çubuklar birbirini çektiği için iki cins elektrik yükü olduğu sonucu çıkarılır
B) Çubuklar birbirini ittiği için aynı cins elektrik yükü olduğu sonucu çıkarılır
C) Plastik çubuk elektriği iletmez
D) Cam çubuk elektriği iletir

16) Aşağıdaki tabloyu inceledikten sonra, <u>gerilim ve dirençle</u> ilgili en uygun hipotez nasıl kurulabilir?

Devredeki Telin Cinsi	Gerilim	Akım	Direnç
Alüminyum	15 V	1 Amper	15 Ohm
Alüminyum	30 V	2 Amper	15 Ohm
Alüminyum	45 V	3 Amper	15 Ohm

A) Devredeki gerilim azalırsa akım artar.
B) Devredeki akım artarsa gerilim değişmez
C) Devredeki gerilim artarsa direnç değişmez
D) Tabloda verilen bilgilerden bir hipotez kurmak mümkün değildir.

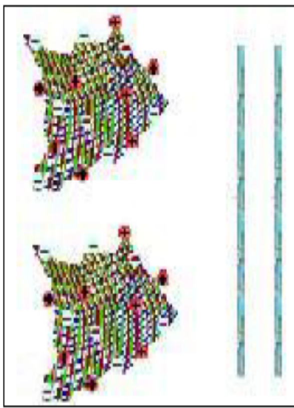
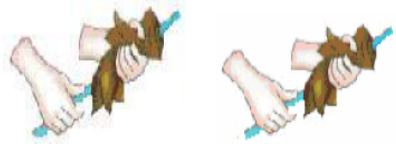
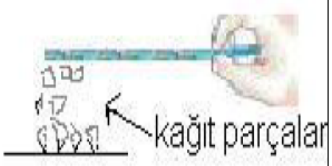
17) Aşağıda gösterilen deneyde, negatif yüklü bir çubuk, nötr bir küreye yaklaştırılmış daha sonra nötr küre bir iletkenle toprağa bağlanmış ve nötr küreden toprağa negatif yük akışı olmuştur

Birbirinden uzakta negatif yüklü çubuk ve nötr küre	Negatif çubuk, nötr küreye yaklaştırılıyor	Nötr küre iletkenle toprağa bağlanıyor	Küreden topraklama çekiliyor
			

Bu deneyden nasıl bir sonuç çıkarılabilir?

A) Nötr küre büyürse daha fazla yük alış verişi olur
B) Yüklü çubuk küçülürse daha az yük alış verişi olur
C) Küredeki negatif yükler çubuğa geçmiştir.
D) Cisimler birbirine dokundurulmadan etkiyle elektriklenerek zıt yükle yüklenebilirler

Senaryo: Burhan, sürtünmeyle elektriklenmede, sürtünme süresinin etkili olup olmadığını merak etmektedir. Bir deney yapmaya karar verir ve özdeş iki kumaş ve iki plastik çubuk alır. Plastik çubukları, birini kısa süre sürterken diğerini de uzun süre kumaşa sürter ve elektriklenme sayesinde kâğıt parçalarını çeker.

	**Kısa süre sürtme Uzun süre sürtme** 	

18) Yukarıdaki senaryoya göre, araştırmada aşağıdaki hipotezlerden hangisi sınanmıştır.

A) Plastik çubukların boyu artarsa elektriği iletmezler
B) Plastik çubuk ne kadar hızlı sürtülürse, o kadar az elektriklenir.
C) Plastik çubuğun sürtündüğü yüzey artarsa, elektriklenme artar.
D) Plastik çubuk ne kadar uzun sürtülürse, o kadar çok elektriklenir.

19) Yukarıdaki senaryoya göre, araştırmadaki bağımlı değişken (ölçülen değişken) hangisidir?

A) Plastik çubukların çektiği kâğıt sayısı
B) Sürtünen çubukların cinsi
C) Sürtülen kumaş parçalarının cinsi
D) Plastik çubukların sürtülme süresi

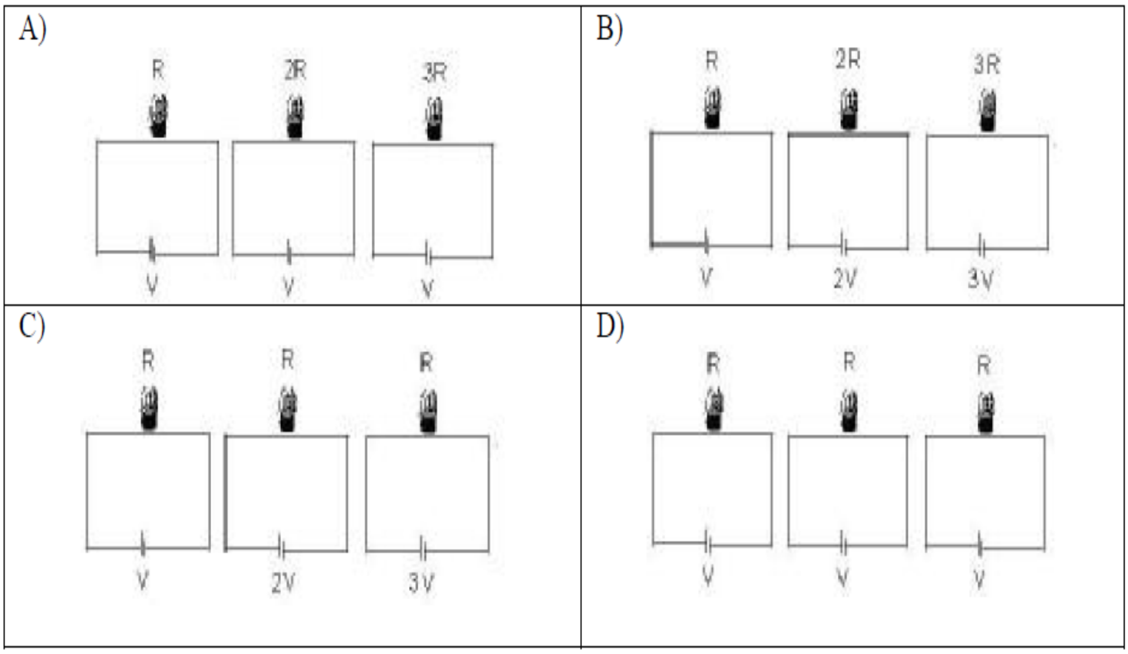
20) Yukarıdaki senaryoya göre, araştırmadaki bağımsız değişken (değiştirilen değişken) hangisidir.

A) Plastik çubukların çektiği kâğıt sayısı
B) Plastik çubukların boyu
C) Sürtülen kumaş parçalarının cinsi
D) Plastik çubukların sürtülme süresi

21) Yukarıdaki senaryoya göre, deneyde aşağıdakilerden hangisi kontrol (sabit tutulan değişken) edilmiştir?

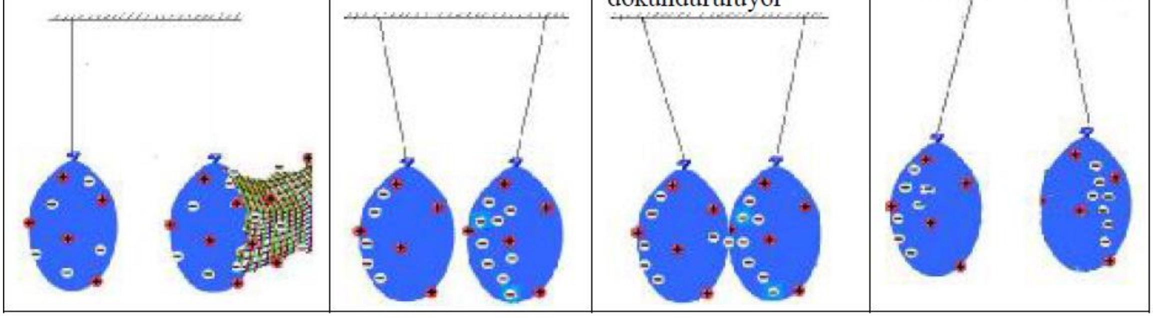
A) Plastik çubukların sürtülme süresi
B) Plastik çubukların sürtülme hızı
C) Çekilen kâğıt parçası sayısı
D) Hiçbiri

22) "Bir devrede ampulün direnci arttıkça, ampulün parlaklığı azalır" hipotezini test etmek için aşağıda verilen deney düzeneklerinden hangisi en uygundur?



23) Aşağıda gösterilen deneyde, iki nötr balon alınmış, biri yünlü kumaşa sürtülerek yüklenirken diğeri yüklenmemiştir. Daha sonra bu iki balon, birbirine dokundurulmadan yaklaştırıldığında balonların birbirini çektiği ayrıca balonları birbirine dokundurarak tekrar ayrıldığında ise balonların birbirini ittiği gözlenmiştir.

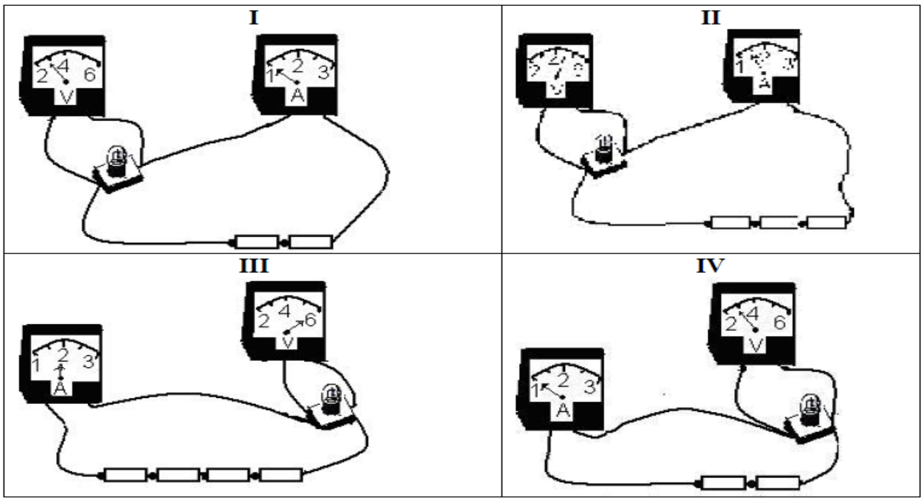
Nötr balonlardan biri yün kumaşla yükleniyor	Yüklü balon, nötr balonu çekiyor	Yüklü ve nötr balon birbirine dokunduruluyor	Balonlar ayrıldıktan sonra birbirini itiyor



Bu deneyden nasıl bir sonuç çıkarılabilir?

A) Yüklü bir cisim başka bir cisme dokunduğunda onu aynı yükle yükleyebildiği ve bu cisimlerin daha sonra birbirini itebildiği
B) Yüklü bir cisim başka bir cisme dokunduğunda onu farklı yükle yükleyebildiği ve bu cisimlerin daha sonra birbirini çekebildiği
C) Yünlü kumaşa sürtülen balonun pozitif yüklenebildiği
D) Yüklü iki cismin birbirini çekebildiği

24) Aşağıdaki tabloda, ampul ve pilden oluşan basit bir elektrik devresi görülmektedir. Devrede ampulün üzerinden geçen akım ampermetreyle, ampulün uçları arasındaki gerilimi de voltmetreyle ölçülmüştür. Bu devrelerdeki akım ve gerilim değerleri hangi tabloda doğru olarak verilmiştir.



A)

Sıra	Akım (Amper)	Gerilim (Volt)
I	1	3
II	1,5	4,5
III	2	6
IV	1	3

B)

Sıra	Akım (Amper)	Gerilim (Volt)
I	3	1
II	4,5	1,5
III	6	2
IV	3	1

C)

Sıra	Akım (Amper)	Gerilim (Volt)
I	1,5	3
II	1	6
III	2	4,5
IV	1	3

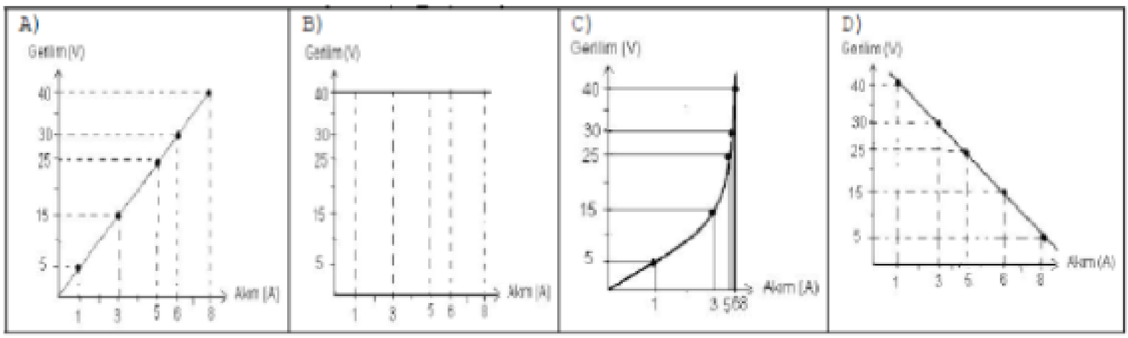
D)

Sıra	Akım (Amper)	Gerilim (Volt)
I	2	6
II	1	4,5
III	1,5	4,5
IV	1	3

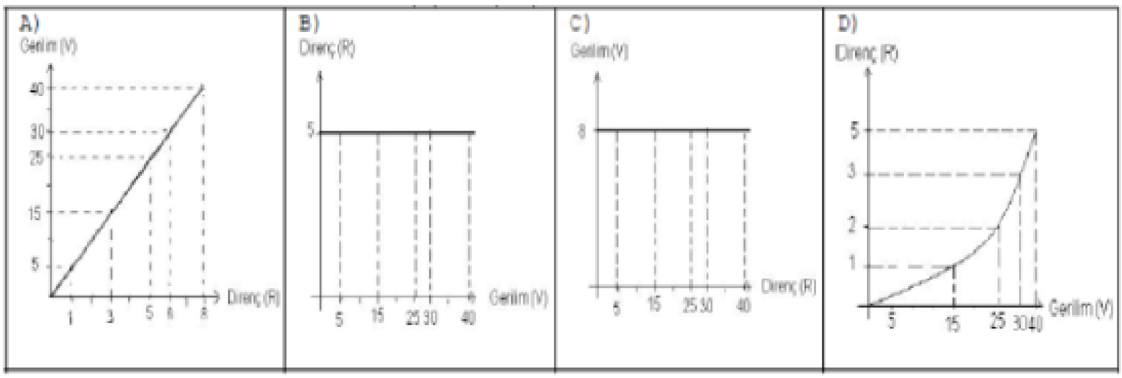
Aşağıdaki tablo, bir devredeki gerilim, akım ve direnç değerlerini göstermektedir. 25 ve 26. soru bu tabloya göre cevaplanacaktır.

Gerilim	Akım	Direnç
5 Volt	1 Amper	5 Ohm
15 Volt	3 Amper	5 Ohm
25 Volt	5 Amper	5 Ohm
30 Volt	6 Amper	5 Ohm
40 Volt	8 Amper	5 Ohm

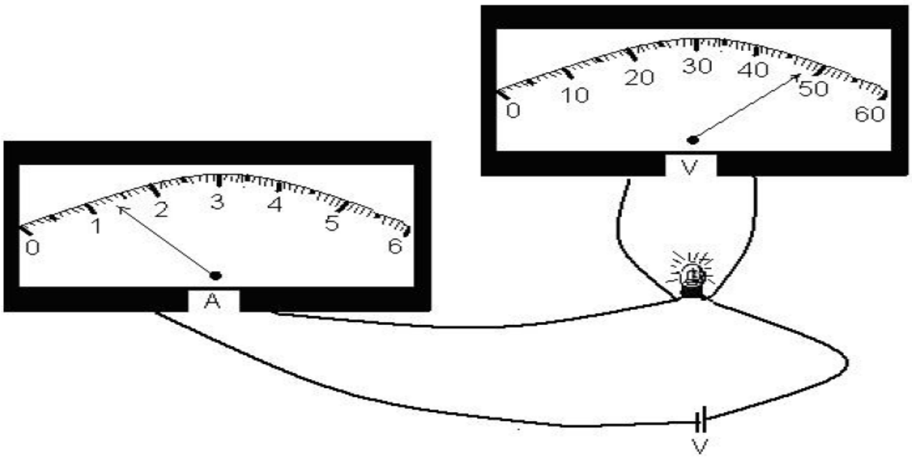
25) Yukarıdaki tablodaki *gerilim ve akım* değerleri grafikte nasıl gösterilir?



26) Yukarıdaki tablodaki *gerilim ve direnç* değerleri grafikte nasıl gösterilir?



27) Aşağıdaki şekilde, bir devre elemanı üzerine bağlanmış ampermetre ve voltmetre görülmektedir. Buna göre, ampermetre ve voltmetredeki okunan değerlerin ne olacağını bulunuz?



A)

Akım	Gerilim
1,6 Amper	54 Volt

B)

Akım	Gerilim
48 Volt	1,8 Amper

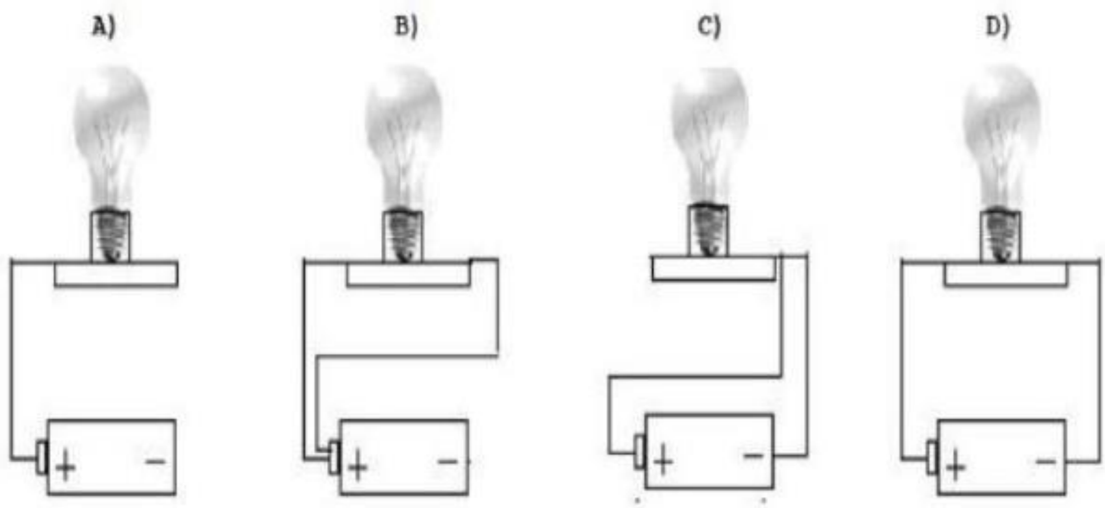
C)

Akım	Gerilim
1,5 Volt	45 Amper

D)

Akım	Gerilim
1,3 Amper	48 Volt

28) Bilindiği gibi, elektrik devrelerinde akımın oluşması için kapalı bir devre olması gerekir. Aşağıdaki resimlerde ampullerin pillere olan bağlantıları görülmektedir. Sizce hangi ampul yanar?



D
ATTITUDES TOWARDS SCIENCE COURSE AND LABORATORIES TEST

Fen Bilimleri Dersi ve Fen Laboratuvarına Yönelik Tutum Ölçeği

<u>Fen bilimleri dersine</u> yönelik görüşler ve katılım ifadeleri	**Kesinlikle katılıyorum**	**Katılıyorum**	**Kararsızım**	**Katılmıyorum**	**Kesinlikle katılmıyorum**
Fen bilimleri dersinde ilginç şeyler öğreniriz.					
Fen bilimleri dersini dört gözle beklerim.					
Fen bilimleri dersi heyecan vericidir.					
Okulda daha fazla fen dersinin olmasını isterim.					
Okulda fen bilimleri dersini diğer derslerden					

daha çok severim.					
Fen bilimleri dersi sıkıcıdır.					
Fen bilimleri dersi zordur.					
Sadece fen dersinde başarısızım.					
Fen bilimleri dersinden yüksek notlar alırım.					
Fen ve teknoloji konularını kolayca anlarım.					
Fen bilimleri dersi benim en başarılı olduğum derslerden biridir.					
Fen bilimleri dersinin ödevlerini yaparken					

kendimi çaresiz hissederim.					
Fen bilimleri dersinde anlatılan her şeyi anlarım.					
Fen Deneylerine Yönelik Görüşleri ve Katılım İfadeleri	**Kesinlikle Katılıyorum**	**Katılıyorum**	**Kararsızım**	**Katılmıyorum**	**Kesinlikle Katılmıyorum**
Fen deneyleri heyecan vericidir.					
Deney sonunda ne olacağını bilemediğimiz için deneyleri severim.					
Deneyler arkadaşlarımla ortak çalışma fırsatı verdiği için faydalıdır.					
Deneyleri kendi kendime karar					

verme olanağı sağladığı için severim.					
Fen bilimleri dersinde daha fazla deney yapılmasını isterim.					
Deney yapıldığı zaman fen dersini daha iyi öğreniyorum.					
Fen bilimleri dersinde deney yapılmasını dört gözle bekliyorum.					
Fen dersindeki deneyler sıkıcıdır.					

E
SOME PARTS OF THE LABORATORY WORKSHEET FOR THE HANDS-ON LABORATORY

SERİ ve PARALEL BAĞLI DEVRELER

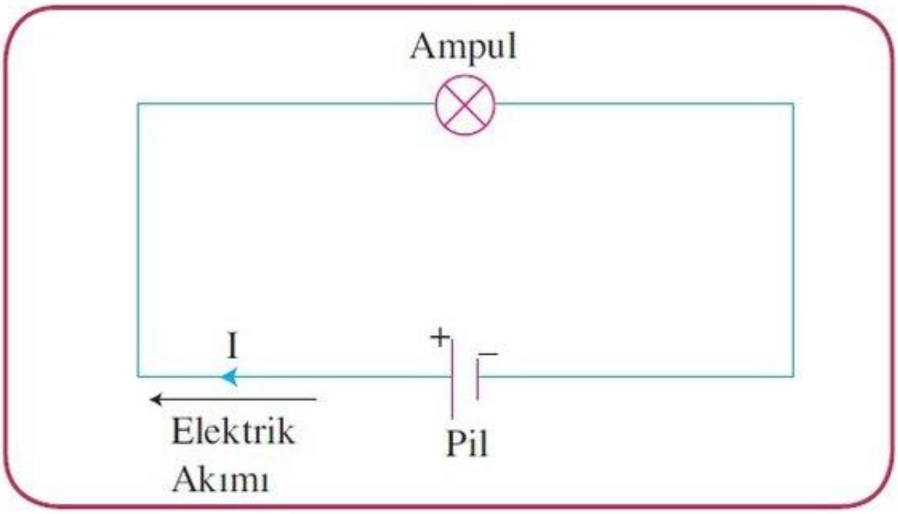
Önemli Kavramlar

Gerilim (Potansiyel Fark): Devrenin iki ucu arasındaki (+ ve – uçları arasındaki) elektron yüklerinin farkını gösterir. Birimi **Vol**t'tur. **V** ile gösterilir.

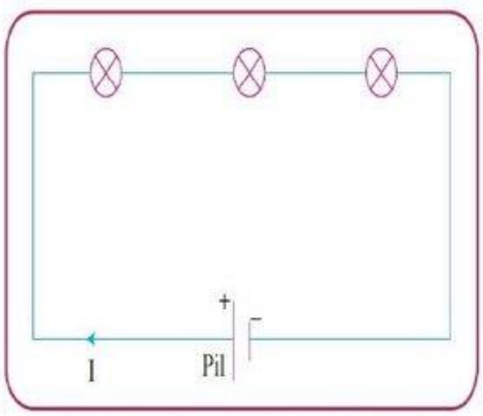
Akım: Devrede elektrik yüklerinin pilin (üretecin) + (pozitif) kutbundan - (negatif) kutbuna doğru iletken kablo üzerinde hareket etmesi **akım**ı oluşturur. Birimi **Amper(A)**'dir. I ile gösterilir.

Direnç: Devrede akımın geçmesini zorlaştıran elemanlardır. Örneğin ampuller. Bu zorluğa **direnç** denir. **R** ile gösterilir. Birimi ise **ohm (Ω)** dur.

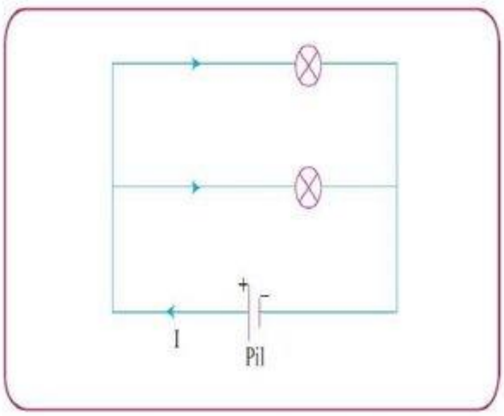
Basit Elektrik Devresi



Seri ve Paralel Bağlı Devreler



Seri bağlı ampullerin bulunduğu elektrik devresi



Paralel bağlı ampullerin bulunduğu elektrik devresi

Seri Bağlı Devre ile İlgili Hipotezimizi (İddiamızı) Oluşturalım

Seri bağlı devrelerde ampul sayısını artırırsak ampullerin parlaklığı nasıl değişir? Bu durumla ilgili düşüncenizi belirten bir hipotez yazınız. Aşağıdaki kavramlar size yardımcı olabilmesi için verilmiştir.

- Seri bağlı devrede	- ampul sayısı	- eğer	- azalırsa	- parlaklık
- patlar	- artar	- azalır	- artarsa	- aynı kalır

Hipotezini aşağıdaki kutucuğa yazabilirsiniz.

Paralel Bağlı Devre ile İlgili Hipotezimizi (İddiamızı) Oluşturalım

Paralel bağlı devrelerde ampul sayısını artırırsak ampullerin parlaklığı nasıl değişir? Bu durumla ilgili düşüncenizi belirten bir hipotez yazınız. Aşağıdaki kavramlar size yardımcı olabilmesi için verilmiştir.

- Paralel bağlı devrede - ampul sayısı - eğer - azalırsa
- patlar - artar - azalır - artarsa - aynı kalır
- parlaklık

Hipotezini aşağıdaki kutucuğa yazabilirsiniz.

1. **Deney**

Seri bağlı devrelerle ilgili oluşturduğunuz hipotezinizi test ediniz.

Araç-Gereçler:

- Pil
- Ampul
- Bağlantı kabloları
- Pil yuvası
- Duy

Deneyin Yapılışı

1- Önce 2 ampulün seri olarak bağlandığı basit bir elektrik devresi oluşturalım. Ampullerin parlaklığına dikkat edelim.

2- Daha sonra devreye bir ampul daha ekleyerek 3 ampullü seri bağlı devre oluşturalım. Ampullerin parlaklığına dikkat edelim

İki ampul ile oluşturduğunuz seri bağlı devreyi yukarıdaki tabloya çiziniz.

Üç ampul ile oluşturduğunuz seri bağlı devreyi yukarıdaki tabloya çiziniz.

Sonuçlar

Deneylerde neler gözlemlediniz? Parlaklıklar nasıl değişti? Yorumlarınızı yazınız.

2. Deney

Paralel bağlı devrelerle ilgili oluşturduğunuz hipotezinizi test ediniz.

Araç-Gereçler:

- Pil
- Ampul
- Bağlantı kabloları
- Pil yuvası
- Duy

Deneyin Yapılışı

1- Önce 2 ampulün paralel olarak bağlandığı basit bir elektrik devresi oluşturalım. Ampullerin parlaklığına dikkat edelim.

2- Daha sonra devreye bir ampul daha ekleyerek 3 ampullü paralel bağlı devre oluşturalım. Ampullerin parlaklığına dikkat edelim

İki ampul ile oluşturduğunuz paralel bağlı devreyi yukarıdaki tabloya çiziniz.

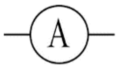
Üç ampul ile oluşturduğunuz paralel bağlı devreyi yukarıdaki tabloya çiziniz.

Sonuçlar

Deneylerde neler gözlemlediniz? Parlaklıklar nasıl değişti? Yorumlarınızı yazınız.

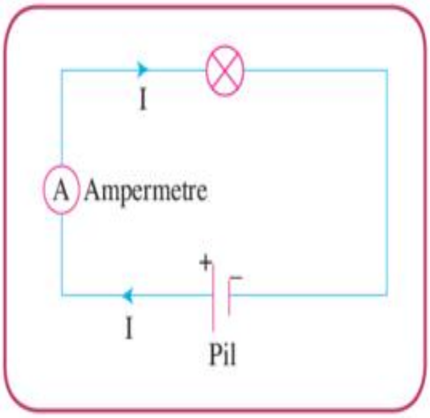
SERİ ve PARALEL BAĞLI DEVREYE AMPERMETRE ve VOLTMETRE BAĞLANMASI

Önemli Kavramlar

<u>Ampermetre:</u> Devreden geçen akımı ölçmeye yarayan alettir. Devreye seri olarak bağlanır. Devrede  ile gösterilir.

NOT: Ampermetrenin direnci ihmal edilecek kadar küçük olduğu için devreye seri olarak bağlanır.

Ampermetre

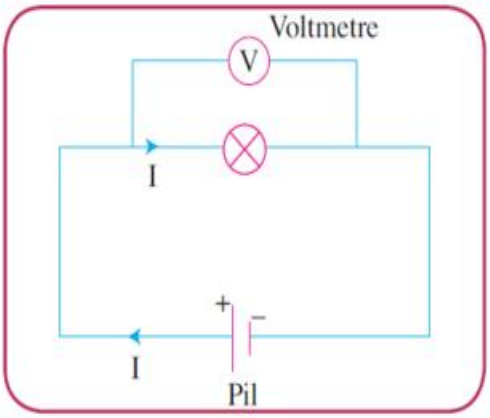


Ampermetrenin elektrik devresine bağlanışı

<u>Voltmetre:</u> Devrenin iki ucu arasındaki enerji farkını ölçmeye yarayan alettir. Devreye paralel olarak bağlanır. Devrede  ir.

NOT: Voltmetrenin direnci çok büyük olduğu için devreye paralel olarak bağlanır.

Voltmetre



Voltmetrenin elektrik devresine bağlanışı

1.Deney: Seri Bağlı Devreye Ampermetre ve Voltmetre Bağlanması

Amaç: Basit bir elektrik devresine ampermetre ve voltmetre bağlamak.

Araç-Gereçler:

- Pil
- Ampul
- Bağlantı kabloları
- Pil yuvası
- Duy
- Ampermetre
- Voltmetre

Deneyin Yapılışı:

Deneyin birinci aşamasında bir ampul, iki pil, ve bir ampermetreden oluşan basit bir elektrik devresi oluşturunuz. Ampermetrenin devreye seri olarak bağlandığını unutmayınız.

Oluşturduğunuz devreyi yukarıdaki tabloya çiziniz.

Deneyin ikinci aşamasında bir ampul, iki pil ve bir ampermetreden oluşturduğunuz basit elektrik devresine voltmetre bağlayınız. Voltmetrenin devreye paralel olarak bağlandığını unutmayınız.

Oluşturduğunuz devreyi yukarıdaki tabloya çiziniz.

2.Deney: Paralel Bağlı Devreye Ampermetre ve Voltmetre Bağlanması

Amaç: Paralel bağlı bir elektrik devresine ampermetre ve voltmetre bağlamak.

Araç-Gereçler:

- Pil
- Ampul
- Bağlantı kabloları
- Pil yuvası
- Duy
- Ampermetre
- Voltmetre
- Duy

Deneyin Yapılışı:

Deneyin birinci aşamasında iki ampul, iki pil ve bir ampermetreden oluşan paralel bağlı bir elektrik devresi oluşturunuz. Ampermetrenin devreye seri olarak bağlandığını unutmayınız.

Oluşturduğunuz devreyi yukarıdaki tabloya çiziniz.

Deneyin ikinci aşamasında iki ampul, iki pil ve bir ampermetreden oluşturduğunuz basit elektrik devresine voltmetre bağlayınız. Voltmetrenin devreye paralel olarak bağlandığını unutmayınız.

Oluşturduğunuz devreyi yukarıdaki tabloya çiziniz.

PİLLERİN SERİ ve PARALEL OLARAK BAĞLANMASI

Ampulleri seri ve paralel olarak bağlayarak devre oluşturmayı öğrenmiştik. Şimdi de pilleri seri ve paralel olarak bağlamayı öğreneceğiz.

NOT: Pillerin seri veya paralel bağlı olması devrenin seri veya paralel bağlı olarak adlanmasına sebep olmaz. Bir devrenin seri ya da paralel olması **sadece** *dirençlerin* (Örneğin ampulleri) *seri ya da paralel olmasına göre* belirlenir.

3.Deney: Seri ve Paralel Bağlı Elektrik Devrelerinde Pillerin Seri Olarak Bağlanması

Amaç: Seri bağlı bir elektrik devresinde pilleri seri ve paralel olarak bağlayarak ampulün parlaklığındaki, devredeki akım ve devrenin uçları arasındaki potansiyel farktaki (gerilimi) farklılığı gözlemlemek.

Araç-Gereçler:

- Pil
- Ampul
- Bağlantı kabloları
- Pil yuvası
- Duy
- Ampermetre
- Voltmetre

Deneyin Yapılışı:

Deneyin birinci aşamasında seri bağlı bir elektrik devresine ikinci bir pili seri olarak bağlayınız. Ampulün parlaklığındaki, akımdaki ve gerilimdeki değişimi not edelim.

Oluşturduğunuz devreyi yukarıdaki tabloya çiziniz.

Deneyin ikinci aşamasında ise paralel bağlı bir elektrik devresine ikinci bir pili yine seri olarak bağlayınız. Ampulün parlaklığındaki, akımdaki ve gerilimdeki değişimi not edelim.

Oluşturduğunuz devreyi yukarıdaki tabloya çiziniz.

Sonuçlar

Yaptığınız bu iki deneyde neler gözlemlediniz? Devredeki ampullerin parlaklıkları, akım ve potansiyel fark (gerilim) nasıl değişti? Gözlemlerinizi ve sonuçlarınızı aşağıya yazınız.

4. Deney: Seri ve Paralel Bağlı Elektrik Devrelerinde Pillerin Paralel Olarak Bağlanması

Amaç: Seri bağlı bir elektrik devresinde pilleri seri ve paralel olarak bağlayarak ampulün parlaklığındaki, devredeki akım ve devrenin uçları arasındaki potansiyel farktaki (gerilimi) farklılığı gözlemlemek.

Araç-Gereçler:

- Pil
- Ampul
- Bağlantı kabloları
- Pil yuvası
- Duy
- Ampermetre
- Voltmetre

Deneyin Yapılışı:

Deneyin birinci aşamasında seri bağlı bir elektrik devresine ikinci bir pili paralel olarak bağlayınız. Ampulün parlaklığındaki, akımdaki ve gerilimdeki değişimi not edelim.

Oluşturduğunuz devreyi yukarıdaki tabloya çiziniz.

Deneyin ikinci aşamasında ise paralel bağlı bir elektrik devresine ikinci bir pili yine paralel olarak bağlayınız. Ampulün parlaklığındaki, akımdaki ve gerilimdeki değişimi not edelim.

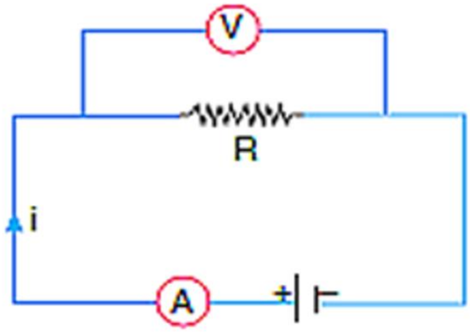
Oluşturduğunuz devreyi yukarıdaki tabloya çiziniz.

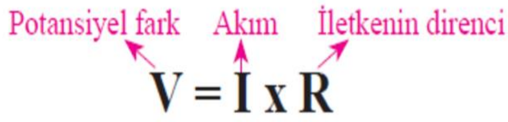
Sonuçlar

Yaptığınız bu iki deneyde neler gözlemlediniz? Devredeki ampullerin parlaklıkları, akım ve potansiyel fark (gerilim) nasıl değişti? Gözlemlerinizi ve sonuçlarınızı aşağıya yazınız.

OHM YASASI

OHM Yasası: İletken bir telden geçen voltajın (V) akıma (I) oranı sabittir ve buna direnç denir.





Seri Bağlı Devrelerde Ohm Yasasının Uygulanması ile İlgili Hipotezimizi (İddiamızı) Oluşturalım

Seri bağlı devrelerde pil sayısını değiştirmeden ampul sayısını artırırsak devredeki ampullerin parlaklığı, akım ve gerilim nasıl değişir? Bu durumla ilgili düşüncenizi belirten bir hipotez(ler) yazınız. Aşağıdaki kavramlar size yardımcı olabilmesi için verilmiştir.

- Seri bağlı devrede - ampul sayısı - eğer - azalırsa - parlaklık
- patlar - artar - azalır - artarsa - aynı kalır
- devredeki akım - devredeki potansiyel fark

Hipotez(ler)inizi aşağıdaki kutucuğa yazabilirsiniz.

1. Deney: Seri Bağlı Devrelerde Ohm Yasasının Uygulanması

Amaç: Farklı ampul bulunduran seri bağlı elektrik devrelerinde Ohm yasasından yararlanarak ampulün direncini hesaplamak.

Araç-Gereçler:

- Pil
- Ampul
- Bağlantı kabloları
- Pil yuvası
- Duy
- Ampermetre
- Voltmetre

Deneyin Yapılışı:

1) Bir pil (üreteç), bir ampul, bir voltmetre ve bir ampermetre kullanarak seri bağlı bir devre oluşturunuz. Voltmetre ve ampermetrenin gösterdiği değerleri not alınız.
2) Bir pil (üreteç), iki ampul, bir voltmetre ve bir ampermetre kullanarak seri bağlı bir devre oluşturunuz. Voltmetre ve ampermetrenin gösterdiği değerleri not alınız.
3) Bir pil (üreteç), üç ampul, bir voltmetre ve bir ampermetre kullanarak seri bağlı bir devre oluşturunuz. Voltmetre ve ampermetrenin gösterdiği değerleri not alınız.

Bir pil (üreteç), bir ampul, bir voltmetre ve bir ampermetre kullanarak oluşturduğunuz devreyi yukarıdaki tabloya çiziniz.

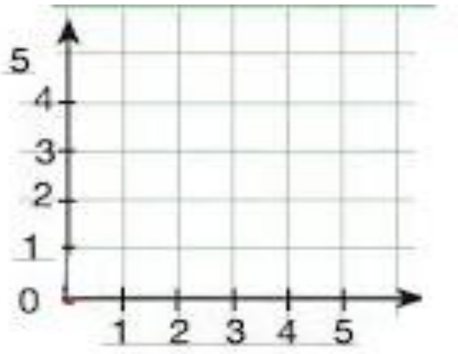
Bir pil (üreteç), iki ampul, bir voltmetre ve bir ampermetre kullanarak oluşturduğunuz devreyi yukarıdaki tabloya çiziniz.

Bir pil (üreteç), üç ampul, bir voltmetre ve bir ampermetre kullanarak oluşturduğunuz devreyi yukarıdaki tabloya çiziniz.

Sonuçlar

Gerilim

1)



Yukarıdaki deneylerde (1., 2. ve 3.deneyde) bulduğunuz voltmetre ve ampermetre değerlerini yandaki grafiğe yazınız.

Akım (A)

2) Ohm yasasını (V=IxR) kullanarak ampulün direncini hesaplayınız.

Paralel Bağlı Devrelerde Ohm Yasasının Uygulanması ile İlgili Hipotezimizi (İddiamızı) Oluşturalım

Paralel bağlı devrelerde pil sayısını değiştirmeden ampul sayısını artırırsak devredeki ampullerin parlaklığı, akım ve gerilim nasıl değişir? Bu durumla ilgili düşüncenizi belirten bir hipotez(ler) yazınız. Aşağıdaki kavramlar size yardımcı olabilmesi için verilmiştir.

- Paralel bağlı devrede	- ampul sayısı	- eğer	- azalırsa	- parlaklık
- patlar	- artar	- azalır	- artarsa	- aynı kalır
- devredeki akım	- devredeki potansiyel fark			

Hipotez(ler)inizi aşağıdaki kutucuğa yazabilirsiniz.

2. Deney: Paralel Bağlı Devrelerde Ohm Yasasının Uygulanması

Amaç: Farklı ampul bulunduran paralel bağlı elektrik devrelerinde Ohm yasasından yararlanarak ampulün direncini hesaplamak.

Araç-Gereçler:

- Pil
- Ampul
- Bağlantı kabloları
- Pil yuvası
- Duy
- Ampermetre
- Voltmetre

Deneyin Yapılışı:

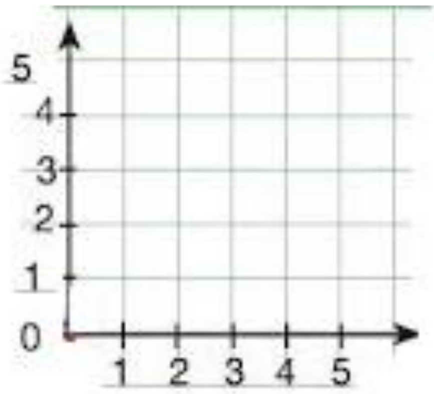
1) Bir pil (üreteç), iki ampul, bir voltmetre ve bir ampermetre kullanarak seri bağlı bir devre oluşturunuz. Voltmetre ve ampermetrenin gösterdiği değerleri not alınız.
2) Bir pil (üreteç), üç ampul, bir voltmetre ve bir ampermetre kullanarak seri bağlı bir devre oluşturunuz. Voltmetre ve ampermetrenin gösterdiği değerleri not alınız.

Bir pil (üreteç), iki ampul, bir voltmetre ve bir ampermetre kullanarak oluşturduğunuz devreyi yukarıdaki tabloya çiziniz.

Bir pil (üreteç), üç ampul, bir voltmetre ve bir ampermetre kullanarak oluşturduğunuz devreyi yukarıdaki tabloya çiziniz.

Sonuçlar

1) Gerilim



Akım (A)

Yukarıdaki deneylerde (1., 2. ve 3.deneyde) bulduğunuz voltmetre ve ampermetre değerlerini yandaki grafiğe yazınız.

2) Ohm yasasını (V=IxR) kullanarak ampulün direncini hesaplayınız.

F
PERMISSION FORM

T.C.
İSTANBUL VALİLİĞİ
İl Millî Eğitim Müdürlüğü

Sayı : 59090411-44-E.1267830 31.01.2017
Konu: Anket Araştırma İzni

YILDIZ TEKNİK ÜNİVERSİTESİ REKTÖRLÜĞÜNE
(Fen Bilimler Enstitüsü)

İlgi: a) 05.01.2017 ve 1701050225 sayılı yazınız.
b) Valilik Makamının 27.01.2017 tarih ve 1161579 sayılı oluru.

Üniversiteniz Fen Bilimleri Enstitüsü doktora programı öğrencisi Hasan Özgür KAPICI'nın **"Farklı Laboratuvar Metotlarının Ortaokullarda Fen Öğretimine Etkisi"** konulu tezi hakkındaki ilgi (a) yazınız ilgi (b) valilik onayı ile uygun görülmüştür.

Bilgilerinizi ve araştırmacının söz konusu talebi; bilimsel amaç dışında kullanmaması, **uygulama sırasında bir örneği müdürlüğümüzde muhafaza edilen mühürlü ve imzalı veri toplama araçlarının uygulanması,** katılımcıların gönüllülük esasına göre seçilmesi, araştırma sonuç raporunun müdürlüğümüzden izin alınmadan kamuoyuyla paylaşılmaması koşuluyla, gerekli duyurunun araştırmacı tarafından yapılması, okul idarecilerinin denetim, gözetim ve sorumluluğunda, eğitim-öğretimi aksatmayacak şekilde ilgi (b) Valilik Onayı doğrultusunda uygulanması ve işlem bittikten sonra 2 (iki) hafta içinde sonuçtan Müdürlüğümüz Strateji Geliştirme Bölümüne rapor halinde bilgi verilmesini arz ederim.

İbrahim POLAT
Müdür a.
Müdür Yardımcısı V.

EK:1- Valilik Onayı
2- Ölçekler

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No:1 Eski Adliye Binası Sultanahmet Fatih/İstanbul
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G
PERMISSION E-MAILS

Re: about the figure about cognitive theory of multimedia learning

Rich Mayer — 13 Aralık 2017 Çarşamba

Kime: hokapici@yildiz.edu.tr — Ayrıntıları G

Dear Hasan Ozgur Kapici: You have have my permission to include the figure in your PhD dissertation. Best wishes, Rich Mayer

On Dec 13, 2017, at 12:40 AM, hokapici@yildiz.edu.tr wrote:

Dear Prof. Richard Mayer,

My name is Hasan Ozgur Kapici, Phd student at Yildiz Technical University, Istanbul, Turkey. I have been writing my Phd dissertation and would like to use the figure created by you about cognitive theory of multimedia learning. Of course, I will cite the paper and give information in the reference section. Can I use it?

Kind regards,

Res. Asst. Hasan Ozgur KAPICI

Yildiz Technical University
Faculty of Education
Department of Science Education

Permission email for Figure 2.1

Re: about the figure created by you in the paper titled as "From things to processes: A theory of conceptual change for learning science concepts"

Micki Chi — 13 Aralık 2017 Çarşamba

Kime: hokapici@yildiz.edu.tr — Ayrıntıları (

Bilgi: Michelene Chi

Yes. Thank you for your interest in my work.
Best,
Micki

On Wed, Dec 13, 2017 at 1:16 AM, <hokapici@yildiz.edu.tr> wrote:

Dear Prof. Michelene Chi,

My name is Hasan Ozgur Kapici, PhD student @ Yildiz Technical University, Istanbul, Turkey. I have been writing my PhD dissertation and would like to use the figure about ontological categories of all entities in the world. Of course, I will cite the paper and will give reference. Can I use the figure?

Kind regards,

Res. Asst. Hasan Ozgur KAPICI

Yildiz Technical University
Faculty of Education
Department of Science Education

Permission email for Figure 2.2

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Papers

1. Kapici, H. O., Akcay, H., & de Jong, T. (2019). Using hands-on and virtual laboratories alone or together–which works better for acquiring knowledge and skills? *Journal of Science Education and Technology, 28*(3), 231-250.

2. Kapici, H. O., Akcay, H., & de Jong, T. (2020). How do different laboratory environments influence students' attitudes towards science and science courses? *Journal of Research on Technology in Education, 52*(4), 534-549.

Conference Papers

1. Kapici, H. O., Akcay, H., & de Jong, T. (2018, July). *Learning science in hands-on and online laboratories.* Paper presented at Junior Researcher of EARLI, Antwerp, Belgium.