

THE PREDICT-OBSERVE-EXPLAIN INSTRUCTION COUPLED WITH
REFLECTIVE JOURNAL WRITING FOR TEACHING
ELECTRICITY AND MAGNETISM:
A QUASI-EXPERIMENTAL STUDY WITH GRADE 10 STUDENTS

by

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ABSTRACT

THE PREDICT-OBSERVE-EXPLAIN INSTRUCTION COUPLED WITH REFLECTIVE JOURNAL WRITING FOR TEACHING ELECTRICITY AND MAGNETISM: A QUASI-EXPERIMENTAL STUDY WITH GRADE 10 STUDENTS

The main purpose of this quasi-experimental study was to explore the effectiveness of “Predict-Observe-Explain instruction coupled with Reflective Journal Writing” (POE-RJW) over POE instruction or Traditional Instruction (TI) in terms of improving Grade 10 students’ conceptual understandings of electricity and magnetism. The subsequent goal of the study was to investigate the effectiveness of the POE-RJW instruction over the POE instruction and the TI in terms of increasing students’ motivation to learning physics. A total of 135 male Grade 10 students from a high school located in Istanbul were involved in the study. The two of pre-existing classes of the school were randomly assigned as the POE-RJW group, including 39 students; three classes were randomly assigned as the POE group, including 59 students, and the two of them were assigned as the TI group, including 37 students. Three essential data sources were used in the current study: (1) Electricity and Magnetism Conceptual Test (EMCT), which comprised of 20 two-tier questions to assess students’ conceptual understandings of electricity and magnetism. (2) Physics Motivation Questionnaire (PMQ) which included 22 Likert-type items to assess students’ motivation to learning physics, and (3) Journal Writing Survey (JWS) to identify the opinions and perceptions of students regarding the act of journal writing. Both EMCT and PMQ were administered before and after a ten-week instruction in three different groups. Quantitative analysis was conducted for EMCT and PMQ. Before the instructions all three groups showed similar conceptual understanding about the concepts of electricity and magnetism, and motivation towards learning physics. After the instructions, the POE-RJW group outperformed the POE and the TI group in terms of understanding the concepts of electricity and magnetism, and motivation to learning physics. The findings of the study showed that “Predict-Observe-Explain instruction coupled with Reflective Journal Writing” (POE-RJW) can be used to promote students' conceptual understanding in science and also to increase their motivation towards learning physics.

ÖZET

10. SINIF ELEKTRİK VE MANYETİZMA KAVRAMLARININ ÖĞRETİMİNDE YANSITICI ÖĞRENME GÜNLÜĞÜ İLE BİRLEŞTİRİLMİŞ TAHMİN ET-GÖZLE-AÇIKLA (TGA-FÖG) YÖNTEMİ: YARI-DENEYSEL BİR ÇALIŞMA

Bu çalışmanın amacı, “Yansıtıcı Öğrenme Günlüğü ile birleştirilmiş Tahmin Et-Gözle-Açıkla yönteminin” (TGA-YÖG) kullanıldığı öğrenme ortamlarının sadece TGA yönteminin ve sadece Düz Anlatım (DA) yönteminin kullanıldığı öğrenme ortamlarına göre 10. sınıf öğrencilerinin elektrik ve manyetizma konularını kavramsal anlamalarına ve fizik dersine karşı motivasyonlarına olan etkisini incelemektir. Çalışmada kontrol gruplu öntest-sontest yarı-deneysel araştırma modeli kullanılmıştır. Çalışma, yatılı bir erkek lisesinin hâlihazırdaki 17 sınıfından rastgele seçilen 7 sınıfı dâhil edilerek gerçekleştirilmiş olup, 2 sınıfta sadece DA yöntemi (39 öğrenci), 3 sınıfta sadece TGA yöntemi (59 öğrenci) kullanılırken, diğer 2 sınıfta da TGA-FÖG yöntemi (37 öğrenci) kullanılmıştır. Veri toplama aracı olarak üç ayrı ölçek kullanılmıştır. Bunlardan birincisi, öğrencilerin kavramsal anlamalarını ölçmek amacıyla hazırlanan iki aşamalı 20 sorudan oluşan “Elektrik ve Manyetizma Kavram Testi” (EM-KT) iken; ikincisi öğrencilerin fizik dersine karşı motivasyonlarını tespit etmek amacıyla uygulanan “Fizik Motivasyon Anketi” (FMA) dir. Üçüncü veri toplama aracı olarak ise öğrencilerin öğrenme günlüğü yazma süreçlerine yönelik deneyimlerini tespit etmek amacıyla “Öğrenme Günlüğü Yazım Anketi” kullanılmıştır. Çalışmanın sonucunda TGA-FÖG yönteminin uygulandığı grubun hem elektrik ve manyetizma kavramlarını anlamaları hem de fizik dersine karşı motivasyonları bakımından diğer iki gruba göre daha üstün performans gösterdikleri tespit edilmiştir. Çalışmanın sonuçları, “fizik öğrenme günlüğü ile birleştirilmiş tahmin et-gözle-açıkla” (TGA-FÖG) yönteminin 10. Sınıf öğrencilerinin elektrik ve manyetizma konularını kavramsal anlamalarına ve fizik dersine karşı motivasyonlarının artmasına yardımcı olduğunu ortaya çıkarmıştır.

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LIST OF SYMBOLS

f	Frequency
M	Mean
N	Number
Q	Question
#	Number

LIST OF ACRONYMS / ABBREVIATIONS

ANOVA	Analysis of Variance
CUP	Conceptual Understanding Percentage
Df.	Degrees of Freedom
EMCT	Electricity and Magnetism Conceptual Test
JWS	Journal Writing Survey
PMQ	Physics Motivation Questionnaire
POE	Predict-Observe-Explain
POE-RJW	Predict-Observe-Explain coupled with Reflective Journal Writing
SD	Standard Deviation
Sig.	Significance Value
TI	Traditional Instruction

1. INTRODUCTION

“The most important single factor influencing learning is what the learner already knows; ascertain this and teach him accordingly” (Ausubel, 1968, p.iv).

The statement of Ausubel in the above quotation is now one of the widespread agreements within the science education community. Children’s already-existing ideas or alternative conceptions have a huge effect on science learning. Just as a doctor cannot prescribe an effective remedy without a suitable diagnosis, science teachers cannot decide how to begin modifying students’ alternative conceptions towards more scientifically acceptable ones. A vast body of research has been conducted on student learning in science, and these studies frequently focused on students’ pre-existing knowledge of science concepts and how these preconceptions have an impact on how and what they learn (Asghar and Libarkin, 2010; Driver, Guesne and Tiberghien, 1985; Osborne and Freyberg, 1985; Stavy and Tirosh, 2000). Studies of students’ conceptions suggest that their preconceptions may not be compatible with the scientific knowledge taught in the school and also these preconceptions can be very resistant to change (Driver, 1985). Therefore, learning entails re-organization of present knowledge structures, that is, *conceptual change*.

The two terms, learning and understanding, can be generally used as synonyms in everyday language. However, these terms are not the same as the viewpoint of the educational psychology and science education. While learning can be defined as acquiring knowledge, understanding refers to applying this knowledge to new situations (Norton-Meier *et al.*, 2008). If a connection is to be constituted between learning and understanding, simply learning can be categorized into two categories: learning for memorization and learning for understanding (Goodrum, 2004). In this respect, National Science Education Standards took the attention to this difference and specified the fundamental aim of science education as having “students learn scientific knowledge with understanding” (p.21). Therefore, meaningful science learning requires learning for understanding, that is, *conceptual understanding* instead of learning for memorization. Conceptual understanding refers to the ability of students to use knowledge, apply it to the

relevant problems and to make associations between related concepts (Stevens *et al.*, 2010).

The importance of conceptual change and conceptual understanding in science teaching and learning steered the ways of research in these terms as a final outcome of science teaching. To this end, during the last two decades, research on *writing to learn* in science gained much attention. Many research studies have been conducted to explore whether writing has an effect on learning in science, particularly enhancing conceptual understanding or promoting conceptual change (e.g., Fellows, 1994; Gunel *et al.*, 2009; Hand and Prain, 2002; Kalman, 2001; Keys, 1999; Mason and Boscolo, 2000, Rivard and Straw, 2000, Tynjälä, 1998). Although a vast majority of these studies suggest that writing activities in science classrooms can have a positive impact on students' science learning, now there is evidence that not all writing activities promotes conceptual learning in science (Bangert-Drowns *et al.*, 2004; Gunel *et al.*, 2009; Langer and Applebee, 1987). A key finding was that the efficacy of writing depends on the type of processing throughout writing (Galbraith, 2015). The most significant feature of writing activities that promote conceptual understanding is its potential to trigger cognitive and metacognitive processes or strategies in the learners' mind and to make learners use these learning strategies through the act of writing (Boscolo and Mason, 2001; Mason and Boscolo, 2001; McCrindle and Christensen, 1995; Wallace *et al.*, 2004). Therefore, such writing types that address these learning strategies are likely to increase conceptual understanding in science (Alagarmot and Chanquoy, 2001; Berthold *et al.*, 2007). Although there exist many writing tasks or types, learning journals proved to be better impacts over other writing types such as writing a summary (Cantrell *et al.*, 2000), writing a scientific report (McCrindle and Christensen, 1995) or short-answer topic tests. Contrary to other writing tasks, learning journals can be more prone to induce cognitive and metacognitive learning strategies through the act of writing (Hübner *et al.*, 2010).

If science learning is viewed as a process of replacing alternative conceptions with scientific understandings and conceptual understandings, activities in which students challenge with their alternative conceptions have to be designed. In this context, many constructivist learning/teaching strategies taking into account of students' conceptions were proposed to facilitate conceptual change and conceptual learning in science (e.g.,

Cosgrove and Osborne, 1985; Driver and Oldham, 1986; Glasson, 1993; Smith, 1991; Treagust and Duit, 2008; Vosniadou *et al.*, 2001). Learning through *inquiry* has been a significant feature of learning in science and inquiry-based learning in science education gained a considerable importance in recent years (Gallagher, 2007). Within the context of inquiry-based learning, specifically “Predict-Observe-Explain” (POE) model has been one of the important learning/teaching strategies in science education. Therefore, several studies has been conducted to provide conceptual change and conceptual understanding in various science topics, particularly physics topics (Kearney, 2004; Liew and Treagust, 1998; Tao and Gunstone, 1999; Zacharia *et al.*, 2008).

In addition to employing writing as a learning tool for fostering students' conceptual understanding, writing can also be used to assist inquiry learning in science. It can also be an effective instrument to “extend and support the overall inquiry process regarding the nature of science and science concepts rather than as a product of grading purposes” (Rowell, 1997, p.38). In this context, for example, Keys *et al.* (1999) investigated the *Science Writing Heuristics (SWH)* to guide students in writing about investigations in laboratory activities and many researchers used the SWH as a tool implementing that writing can be used as a learning instrument that aids the inquiry learning (Akkus *et al.*, 2007; Gunel *et al.*, 2010; Hand *et al.*, 2004; Hohenshell and Hand, 2006; Rudd *et al.*, 2001).

The topic of Electricity and Magnetism was chosen for the current study. The purpose of selecting this topic lies in its being a notoriously difficult topic for students at all age levels, secondary students as well. (Reiner *et al.*, 2000; Sengupta and Wilensky, 2009; Shipstone, 1985). There exist many basic concepts and associations between these concepts. Therefore, students may experience difficulties in differentiating between these basic concepts such as charge, current, electricity, voltage, and magnetic field. Moreover, several research studies showed that students may have numerous alternative conceptions about electricity and magnetism (e.g., Bilal and Erol, 2009; Borges and Gilbert, 1999; Çepni and Keleş, 2005; Maloney *et al.*, 2001; Tasker and Osborne, 1985), and they are very persistent to change through traditional instruction and often remain unchanged or can be affected in an unexpected ways by science teaching. In this study, “*reflective learning journals*” from between several writing to learn types and “*Predict Observe and Explain*”

(*POE*) learning/teaching inquiry model have been selected for the purpose of facilitating conceptual change and conceptual understanding of Electricity and Magnetism topic.

1.1. Purpose of the Study

The main purpose of this quasi-experimental study was to explore the effectiveness of “Predict-Observe-Explain instruction coupled with Reflective Journal Writing” (POE-RJW instruction) over POE instruction or traditional instruction (TI) in terms of improving Grade 10 students’ conceptual understandings of electricity and magnetism. The following goal of the study was to investigate the effectiveness of the POE-RJW instruction over on POE instruction and traditional instruction in terms of increasing students’ motivation to learning physics.

1.2. Research Questions

The following research questions guided this research:

- (i) How does the conceptual understanding of electricity and magnetism differ from pre to posttest for the three groups of Grade 10 students who engaged in POE-RJW Instruction, POE Instruction, or Traditional Instruction?
- (ii) Are there any differences among the three groups of Grade 10 students in terms of their understandings of electricity and magnetism before and after engaging in POE-RJW Instruction, POE Instruction, or Traditional Instruction?
 - Are there any differences among the three groups of Grade 10 students in terms of their understandings of electricity and magnetism before engaging in POE-RJW Instruction, POE Instruction, or Traditional Instruction?
 - Are there any differences among the three groups of Grade 10 students in terms of their understandings of electricity and magnetism after engaging in POE-RJW Instruction, POE Instruction, or Traditional Instruction?

(iii) How does the conceptual understanding of the associated concepts of electricity and magnetism change from pre to posttest for the three groups of Grade 10 students who engaged in POE-RJW Instruction, POE Instruction, or Traditional Instruction?

(iv) How does the motivation to learning physics differ from pre to posttest for the three groups of Grade 10 students who engaged in POE-RJW Instruction, POE Instruction, or Traditional Instruction?

(v) Are there any differences among the three groups of Grade 10 students in terms of their motivation to learning physics before and after engaging in POE-RJW Instruction, POE Instruction, or Traditional Instruction?

- Are there any differences among the three groups of Grade 10 students in terms of their motivation to learning physics before engaging in POE-RJW Instruction, POE Instruction, or Traditional Instruction?
- Are there any differences among the three groups of Grade 10 students in terms of their motivation to learning physics after engaging in POE-RJW Instruction, POE Instruction, or Traditional Instruction?

1.3. Significance of the Study

Research on writing to learn has suggested that writing does not automatically enhance learning (Bangert-Drowns *et al.*, 2004; Klein, 1999). In addition, the potential of writing for enhancing science learning have been a controversial issue among scholars within the last two decades. Thus, there is a need to elaborate what kind of writing might foster learning in science. In this context, many studies have been conducted to reveal whether and how the act of writing promotes science learning (e.g., Fellows, 1994; Mason and Boscolo, 2000; Rivard and Straw, 2000). Many of these studies focused on the impact of writing concerning its potential to increase students' conceptual understanding. Moreover, to identify the impact of writing on conceptual understanding, some studies investigated the impact of writing to different audiences such as teachers, younger students, older students, peers, and parents (Chen *et al.*, 2013; Hand *et al.*, 2007; Gunel *et*

al., 2009). In addition, various writing types such as letters, journals and reports were used in different studies to recognize their implications on enhancing science conceptual understanding. Several studies also associated writing with appropriate cognitive and metacognitive strategies in order to enhance students' conceptual understandings, and they pointed out that writing promotes learning if beneficial cognitive and metacognitive strategies are activated by the writing task (e.g., Hübler *et al.*, 2010; Glogger *et al.*, 2012; McCrindle and Christensen, 1995; Schmidt *et al.*, 2012; Wäschle *et al.*, 2015). It can be inferred from the literature that numerous and a wide range of studies have been conducted related to writing to learn in science learning or science conceptual understanding. However, very few studies have been focused on the types of constructivist classroom activities or specific teaching strategies which integrate inquiry based teaching/learning strategies into writing to learn tasks (Bullock, 2007). From this perspective, present study is remarkably significant that it combined a specific teaching/learning strategy (POE strategy) into a specific writing to learn task-reflective learning journals. Therefore a constructivist instruction method "Predict-Observe-Explain instruction coupled with Reflective Journal Writing" was developed.

One of the reasons that make the current study significant lies in the selected participants. Grade 10 students were selected as the participants of the present study. Although numerous studies related to writing to learn in science included various participants from different levels such as elementary school students (e.g., Atila *et al.*, 2010; Chen *et al.*, 2013; Mason, 2001; Mason and Boscolo, 2000; Rivard and Straw, 2000), undergraduate students (e.g., Dianovsky and Wink, 2012; Gunel *et al.*, 2009; McCrindle and Christensen, 1995; Tynjälä, 1998) as well as teachers (e.g., Hand and Prain, 2002), few of them selected secondary school students as participants (e.g., Gunel *et al.*, 2009). Besides, in the context of writing to learn studies in science, there exist few studies using especially learning journals as a learning tool in the level of secondary school students (e.g., Schmidt *et al.*, 2012). Therefore, this study will contribute to the related literature on writing to learn in science in terms of its selected participants, secondary school students.

In addition to the contribution of the current study in relation to the uniqueness of the participants within the framework of writing to learn studies in science, it is a unique study

for physics education. This study can be a useful model in which both learning journals and POE tasks have been combined with each other, providing an instructional strategy to increase the conceptual understanding of secondary school students on the topic of electricity and magnetism.

Furthermore, over the past two decades, researchers studying writing to learn including journal writing mainly focused on students' academic achievement, conceptual understanding or conceptual change in science or mathematics (e.g., Glogger *et al.*, 2012). In other words, scholars have been more concerned with students' science learning than how to increase their interest towards science and science lessons. However, few studies concentrated on the impact of journal writing to the motivation of participants towards learning science topics (e.g., Schmidt *et al.*, 2012; Wäschle *et al.*, 2015). The current study showed the potential of writing learning journals beyond facilitating science learning. Along with this study, the influence of writing learning journals on motivation to learning in science, particularly in physics, was explored.

2. LITERATURE REVIEW

This chapter is intended to provide an overview about the related literature, from which this study takes its roots. The first section includes a brief overview about constructivist views of learning, namely individual and social constructivism. Subsequent sections discuss the following issues respectively: conceptual understanding in science, conceptual change learning in science education, students' conceptions of electricity and magnetism, the predict-observe-explain (POE) strategy, and theoretical grounds of writing to learn and its practice in the classroom.

2.1. Constructivism

Many teachers frequently use the phrase 'Do you understand?' in their classrooms, and in response to this question, students would reply 'Yes, I do' or sometimes 'No, I don't'. Yet, what do teachers mean when they ask students if they "understand"? Or, when students say that they "understand", what do they really mean? If we want our students to "understand" the topics in a particular discipline, we have to reach an agreement on the definition of "understanding". In other words, we have to understand understanding. However, making the definition of "understanding" has been a controversial issue for philosophers, educators and scientists for centuries (Gallagher, 2007; Liew, 2010).

Constructivism is both a psychological theory (a theory of learning) and a philosophical theory (a theory of knowledge) (Matthews, 2015). It describes, on the one hand, "knowing", and on the other hand, how one "comes to know" (Fosnot, 2005). Constructivism postulates that understanding or the personal knowledge is the result of numerous connections that learners make during the integration of new information with their prior knowledge (Driver *et al.*, 1994). In the same manner, based on constructivist view of learning, Ross *et al.* (2010) stated that "by 'learning' we mean 'understanding' or taking the ownership of ideas, so they can be used and become part of our mental make-up" (p.57). Therefore, learning or understanding can be seen as a self-regulatory process of tackling with the contradiction between existing models in the mind and discrepant new insight (Fosnot, 2005).

Based on constructivist view of learning, the role of the learner is considered to be a constructor of knowledge. Therefore, learning is “not the result of teaching; rather it is the result of what students do with the new information they are presented with” (Sewell, 2002, p.24). In the same way, Jenkins (2000) indicated that “knowledge cannot be ‘given’ or handed over and received in the same way as a parent might give a child a book, a toy or a tool” (p. 601). Thus, knowledge cannot be transferred from one individual to another individual in any mode (Michael and Modell, 2003). In this respect, it can be inferred that knowledge is actively constructed by the learner, and the learner (rather than the teacher) is responsible for the learning that occurs. Indeed, understanding and interpretation of new experiences depend on the pre-existing knowledge the learner has.

There are two major views in constructivism. The first one is the individual constructivist view that students actively construct their ways of knowing by means of their personal experiences. The second is the social constructivist view that focuses on the social and cultural aspects of knowing and learning rather than individual features.

2.1.1. Individual Constructivism

Jean Piaget established the foundations of individual constructivist view nearly 70 years ago (Glaserfeld, 2005). Piaget (1937) stated that “Intelligence organizes the world by organizing itself” (p.311). He mainly focused on the cognitive structure of individuals while constructing knowledge. He developed a cognitive theory which explains how the learner interacts with new information. The cognitive theory posits that learners try to reach a balance between the environmental information and their prior knowledge (Piaget, 1970). Hence, equilibration was identified as a dynamic process of self-regulated behavior balancing two intrinsic behaviors, *assimilation* and *accommodation*. If new information fits into the existing knowledge without any conflict, then the new information is integrated into the prior knowledge, whereby *assimilation* occurs. However, if new information is not in congruent with the existing knowledge, then disequilibrium occurs. To overcome this disequilibrium, learners should modify or change their current knowledge with the new one in order to better understand the environment and the incoming information. This type of creation of new knowledge is named by Piaget as *accommodation*. In this framework,

teachers have to find ways of revealing students' prior ideas and design their instructions in a way to provide students conceptual contradictions (Tytler, 2002).

Fosnot and Perry (2005) stated that “we cannot understand an individual's cognitive structure without observing it interacting in a context, within a culture” (p.28). In this manner, the role of social and cultural effects in the learning process has gained much attention by numerous scholars. The next section will cover the social constructivist view of learning.

2.1.2. Social Constructivism

Humans are social beings, and so we do not act alone. Based on Vygotsky's work, social constructivist view of learning asserts that knowledge is produced through social interaction. While Piaget sought to study the role of contradiction and equilibration in learning, Vygotsky sought to study the dialogue. Hence, the main focus of Vygotsky's work has been associated with the role of social interaction, language, and culture on learning.

Vygotsky (1978) specified that scientific understanding is constructed by means of interaction between students in shared tasks. In harmony with the notions of Vygotsky, Driver *et al.* (1994) claimed that “knowledge and understandings, including scientific understandings, are constructed when individuals engage socially in talk and activity about shared problems or tasks” (p.7).

In addition, Vygotsky (1978) used the term “zone of proximal development” to clarify the distance that students can achieve beyond their current level. His definition of the term follows:

“the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers” (Vygotsky, 1978, p.86).

This zone of proximal development can change from student to student, and it portrays the capacity of the learner to understand the logic of the scientific concepts. However, school tasks, most of which solely focuses on the students' individual problem solving skills, are usually inadequate in meeting the capabilities of learners (Julyan and Duckworth, 2005). Instead, much more attention has to be given on the accomplishment levels of students with the assistance of knowledgeable others (Fosnot and Perry, 2005).

In conclusion, individual and social constructivist views of learning have common principles in terms of their assertions (Cobb, 2005). Firstly, learning is not seen as the transmission of truths; instead, learners actively built up their knowledge. Secondly, social interactions between and among individuals in a variety of communities are inevitable for constructing knowledge. However, social constructivist view emphasizes more attention on this issue than the individual constructivism. Moreover, both of them focused on the cognition and language which brings coherency to an individual's insights and a community's knowledge base (Staver, 1998).

The next section will describe the nature of conceptual understanding which is derived from the constructivist view of learning.

2.2. Conceptual Understanding in Science

A significant purpose of science education is to increase learners' conceptual understanding instead of equipping them with excessive factual knowledge. In other words, meaningful science learning requires conceptual understanding instead of rote memorization (Adadan *et al.*, 2010). Alao and Guthrie (1999) characterized conceptual understanding as the amalgamation of *breadth* and *depth*. While *breadth* is associated with "the extent that knowledge is distributed and represents the major sectors of a specific domain", *depth* is related to "the knowledge of scientific principles that describes the relationships among concepts" (p.244).

Alao and Guthrie (1999) asserted that both prior knowledge of students and their interest in the relevant concepts enhance the acquisition of conceptual understanding. Additionally, use of higher level learning strategies, such as monitoring of comprehension,

connection between the ideas, and elaboration of ideas, is found to be a powerful predictor of conceptual understanding (Entwistle and Ramsden, 1983).

According to Stevens *et al.* (2010), conceptual understanding refers to the potential of students to use knowledge, apply it to the relevant contexts, and make connections among the related ideas. They stated that students may have various pieces of knowledge, but it is difficult for them to use these separate knowledge pieces due to its compartmentalized structure. However, experts' knowledge structures are well linked and assembled with each other whereby conceptual understanding occurs. Students can develop their conceptual understanding by means of connecting isolated concepts within and through domains (see Figure 2.1.).

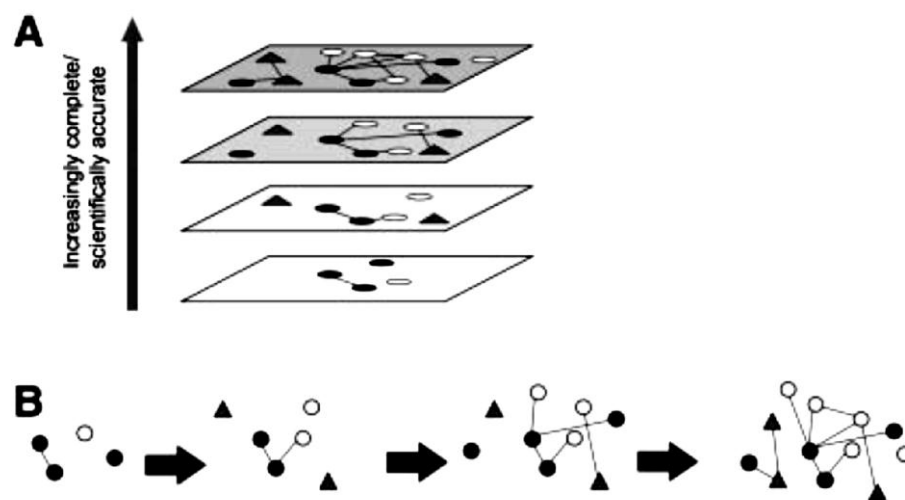


Figure 2.1. Illustration of the development of conceptual understanding. Each shape shows a different construct. (A) represents the multi-dimensional development of knowledge and (B) illustrates the process of integration and organization of knowledge structures.

(Stevens *et al.*, 2010, p. 689)

Conceptual understanding is a product of mental processes established by the learner and can be supported by the teachers (Gavalcante *et al.*, 1997). Teachers can only provide support and opportunities for students to constitute connections between their isolated ideas. McDermott (1984) states that “if the development of conceptual understanding is primary goal, then instruction must reflect this priority” (p. 32). In this context, conceptual tasks can be embedded in lessons, in homework assignments, and in laboratory reports and

particularly in examinations. In the same manner, Yadav *et al.* (2014) asserted that open-ended assessments that measure conceptual understanding are more likely to have an impact on students' conceptual learning rather than the fact-based assessments.

The next section will summarize the relevant literature regarding conceptual change learning.

2.3. Conceptual Change Learning in Science Education

Students' minds are not blank slates when they come to school. On the contrary, they come to school with previously acquired knowledge. Yet, their pre-existing knowledge is often inconsistent with the scientific knowledge covered in science classes. In this respect, classroom learning has a need of re-organization of preconceptions and existing knowledge into a new form (Driver, 1989). Such type of re-organization is often defined as "conceptual change" (Smith, 1991).

The pioneering notions regarding the conceptual change have been essentially put forward by Posner *et al.* (1982), and they proposed the best known conceptual change model in science education. Posner *et al.* (1982) claimed that learning is a rational activity which can be seen as a process of conceptual change. They concentrated on two similar terms, *assimilation* and *accommodation*, which are in harmony with Piaget's terms. Although Piaget did not mention the term "conceptual change", they used assimilation and accommodation to clarify conceptual change. Posner *et al.* stated that students use their existing ideas to cope with the incoming new information, which is called as assimilation, whereby the first phase of the conceptual change occurs. They defined accommodation as a radical phase of conceptual change, in which the old idea/concept is replaced or reorganized. In their model, they predominantly focused on accommodation for a complete conceptual change.

Posner *et al.* (1982) claimed that for a thorough conceptual change, two substantial elements have to be clarified explicitly: the conditions of *accommodation* and the *features of conceptual ecology*. Concerning the conditions of accommodation, they offered four conditions under which accommodation is likely to happen. First of all, there should be

dissatisfaction with existing conceptions. Students should realize that they cannot overcome a problem by the help of their existing concepts due to their insufficient capacity. Secondly, new conception must be *intelligible*. Students should manage to comprehend the new concept adequately and be able to describe it by using their own words. In addition, a new concept should be *plausible*, such that a new concept should be indispensably logical and have the potential to solve the problems generated by its predecessors. The final condition is that a new concept should provide a fruitful research program whereby new areas of inquiry can be developed (Posner *et al.*, 1982). After the fulfillment of these four conditions, the first component of conceptual change, *conditions of accommodation*, can be achieved. A second element which has an impact on conceptual change is *conceptual ecology*. Learners' conceptual ecology consists of their conceptions and ideas embedded in their epistemological belief. At this point, conceptual ecology steps in and governs the process of major conceptual changes. Important elements of conceptual ecology are as follows: *Anomalies, analogies and metaphors, epistemological commitments, metaphysical beliefs and concepts, and other knowledge*.

Most of the models offered to explain conceptual change have focused on the role of *cognitive conflict*, firstly introduced by Piaget, as a main condition for conceptual change. If new information is not in agreement with existing knowledge, this inconsistency results in a cognitive conflict (Piaget, 1970). Based on this claim, several theoretical and empirical studies drew attention to numerous aspects of this process, and many strategies have been proposed so as to promote conceptual change (Mason and Boscolo, 2000).

2.4. Students' Conceptions of Electricity and Magnetism

Over the last 30 years, physics education research has revealed that students already have alternative conceptions even before they start to learn the concepts in electricity and magnetism (Maloney *et al.*, 2001). Moreover, it is realized that even after being taught, students have not changed these alternative conceptions with the scientific ones. In other words, such conceptions often persist even they are not in congruent with the experimental results or the explanation of the teacher (Driver *et al.*, 1985).

Many of the common alternative conceptions in relation to electricity and magnetism were identified by several researchers in numerous studies (e.g., Driver *et al.*, 1985; Maloney *et al.*, 2001; Osborne and Freyberg, 1985). Some of the significant conceptions drawn from the literature were summarized in the following paragraphs. The following paragraphs will deal with only some of the most important alternative conceptions of electricity and magnetism held by students relevant with the aims of this thesis.

The earliest research studies about students' conceptions regarding simple electric circuits were conducted by Osborne and his colleagues (Osborne 1983, Tasker and Osborne, 1985), and three main alternative conceptions were detected. The first one is the *unipolar model* that a single wire is sufficient to light a bulb, and the return wire is unnecessary. The second conception specifies *clashing currents* model in which current flows to the bulb from both terminals of the battery. The third one, the *current consumed model*, suggests that current is 'used up' by the resistor or bulb, and so there will be less current in the wire returning to the battery. According to the research of Osborne and his colleagues, the third alternative conception was held by almost an half of both Grade 8 and Grade 9 students.

Students can have misconceptions about charge distribution on insulators and conductors. Maloney *et al.* (2001) investigated that many students believed that electric charges were distributed over both the inner and outer surface of a conducting metal sphere. They also found that students also had a confusion to differentiate the charge distribution on a conductor and an insulator. Students also seemed to believe that larger objects exert larger forces than the smaller ones (Maloney *et al.*, 2001). In their study, Bilal and Erol (2009) detected some alternative conceptions of students regarding charges and electric field, such as:

- The body having a larger charge exerts bigger force,
- Any charged particle independent of the charge polarity moves in the direction of the electric field,
- Particles moving in the opposite direction of the field always slow down (p.197).

Students believe that electricity, current, voltage, or energy is stored in the battery and flows to the load where it is consumed. In other words, students think that battery is a unipolar ‘giver’ of electricity (Driver, 2010). In addition, battery is seen as a supplier of constant current in a closed circuit rather than providing a constant voltage or potential difference (Cohen *et al.*, 1983).

Concerning the concept of electric current, students have different alternative conceptions. For example, students can use current as synonymous with electricity and electrical energy (Driver, 2010). In a serial circuit, students were intended to believe that the current on the larger resistor is lower than the current on the other resistors (Bilal and Erol, 2009).

In relation to the alternative conceptions regarding magnetism, Shipstone (1985) found that students linked magnetism with gravity and drew the magnetic force towards the earth. Moreover, students can consider that poles exist only at the end of magnets. They can also think that big magnets are magnetically stronger than the small ones (Driver, 2010). Bar and Zinn (1989) stated that many students consider that a conducting (air) medium is required for a magnet to attract, repel, or magnetize. According to the study of Barrow (1987), students were not aware of the magnetic effect of an electric current.

2.5. Predict-Observe-Explain (POE) Strategy

As stated previously, constructivist view of learning is based on the idea that learners construct their own knowledge with respect to what they already know (Nola, 1997). Therefore, eliciting students’ preconceptions is a central issue for a constructivist teaching approach (Kearney *et al.*, 2001). In addition, social interactions play a critical role in learners’ knowledge construction (Matthews, 1993). In this respect, White and Gunstone (1992) developed the predict-observe-explain (POE) strategy for revealing students’ predictions and their reasons behind those predictions about specific tasks whereby their pre-instructional ideas can be revealed. Additionally, POE strategy promotes groups discussions in which learners can refine their understandings. Moreover, POE is a powerful strategy in which cognitive conflict can be easily initiated. In accordance with the conceptual change model (Posner *et al.*, 1982), POE tasks reveal students’ existing non-

scientific ideas in its prediction step and assist them to replace them with the scientifically acceptable knowledge. In general, POE strategy can be used to find out learners' initial ideas, provide educators with information about learners' thinking, create discussion environment in the classroom, and motivate learners to explore the concepts and generate investigations (Tlala, 2011, p.15). So, in terms of science teaching method, POE strategy can be considered within the context of the second level inquiry in which students investigate a teacher-presented question through a prescribed procedure (Eick *et al.*, 2005). In harmony with the requirements of second level inquiry, in POE tasks students are asked to predict the outcome of a demonstration and teachers provide a particular structure for what they record and how they manipulate the data. Then, based on the collected data, students can formulate their explanations for the question previously asked.

Furtak (2009) stated that one of the most significant features of POE strategy is students' excitement factor (p. 90). Along with the representation of a demonstration that will be observed, students' interests and attention can be gained. After performing the demonstration, students can shout loudly "yes" if their predictions are correct. In contrast, if they fail in their predictions, they can be shocked and surprised. Therefore, POE tasks can assist students to recognize their existing explanations and force them to collect evidence to improve their inadequate understandings (Furtak, 2009).

POE strategy comprises of three basic steps: predict, observe, and explain.

- **Predict:** On the phase of prediction, learners are asked to state their predictions about an experiment or a demonstration. They have to write down their predictions on their worksheets or notebooks. According to Liew (2010), for an efficient POE implementation, teachers have to insist on written responses and do not let students express their notions verbally to anyone while making predictions. Hence, students can be required to make their predictions individually. However, in harmony with social constructivist view of learning, when students engage in this process in small groups, they can have a chance to articulate and clarify their individual thoughts and can reflect critically on their own and others' ideas (Kearney, 2004). As a result, based on the context of the classroom and the instructors' choice, learners have to write down their either final group predictions or individual predictions and also specify the reasons for their predictions. Thus, students

should be given sufficient time to write their predictions and reasoning. Then, students can share their predictions in front of the class or their ideas can be written on the board so that whole class can see (Furtak, 2009).

- **Observation:** In the observation phase, if it is a teacher-led POE task, teacher can carry out the experiment, and students just observe what happens. However, if groups have the opportunity to conduct the experiment, they can also perform the experiment and observe the results. While observing the demonstration, students are also asked to record their observations on paper. For the sake of clear observations, experiments can be conducted repeatedly.

- **Explain:** In the explain phase, students are required to write their explanations on paper related to the conducted experiment. Indeed, they are “asked to reconcile any discrepancy between their prediction and the observations in the experiment” (Zacharia *et al.*, 2008, p.1025). Enough time have to be provided to students to revise their explanations. Teachers have to engage in the whole class discussion to assist students in the processing of their new observations, which may empower their conceptual understanding of the explanation of the phenomenon (Keeley, 2008).

The next section will provide a theoretical information about ‘writing to learn’ by giving reference to its pioneering theorists.

2.6. Writing to Learn

Within the last 40 years, there has been increasing attention on the central role of writing as a learning tool and several scholars proposed different theories or models related to the role of writing in learning.

2.6.1. Britton’s Theory on Writing to Learn

One of the pioneering language scholars, Britton (1970), claimed that speech, thinking, and writing are strongly interrelated to each other. He closely associated the writings of young students with speech, which is the medium for learning. He used a

special term, *expressive*, which is a form of informal writing produced by the learners as a result of their incomplete ideas in the writers' minds. For example, both the writings of immature writers and early drafts of experienced writers can be thought within the context of *expressive* writing because the language in these texts are similar to the ones used in everyday speech. Since *expressive* writing is an influential instrument in which concepts can be associated with language, it has come to be known as writing to learn (Keys, 1999). Keys (1999) posited that "in recent years, expressive writing has been portrayed as an activity that helps students make connections, think deeply, and facilitate conceptual change" (p.117). In this vein, not only language but subject area teachers also paid attention to informal writing as a vehicle for students to explore and question subject matter content (Wallace *et al.*, 2004).

2.6.2. Emig's Model: Writing as a mode of Learning

Another popular language scholar throughout 1970s, Janet Emig (1977) accepted writing as a unique form of learning in contrast to reading or listening. In her famous article entitled "Writing as a mode of Learning," she expressed that "writing represents a unique mode of learning-not merely valuable, not merely special, but unique" (p.122). She stated that writing entails a coordination of eye, brain, and hand activity whereby both left and right sides of the brain can fully function simultaneously. She pointed out that writing is a process in which three categories of cognitive activity involves: (1) *the enactive learning*, which is, learning by doing; (2) *iconic learning*, which is, drawing images; (3) *symbolic learning*, which is representing ideas as verbal symbols or restatement in words. She indicated that "in enactive learning, the hand predominates; in iconic, the eye; and in symbolic, the brain" (p.124). She specified that writing must be detailed and compact, whereby it provides a reformulation of thoughts. In conclusion, Emig's article was one of the first efforts undertaking the writing as a learning tool and along with her study of writing as a mode of learning, the emphasis of cognitive approach on writing to learn gained much more emphasis (Boscolo *et al.*, 2007).

2.6.3. Writing as a Problem Solving Process

Flower and Hayes (1980) introduced the concept of writing as a problem-solving, cognitive process to clarify how writing might promote learning. They indicated that “because people only solve the problems they give themselves, the act of representing the problem has a dramatic impact on performance” and “even though a teacher gives 20 students the same assignment, the writers themselves create the problem they solve” (pp. 22-23). Accordingly, they associated writing with a rhetorical problem and defined it as “an elaborate construction which the writer creates in the act of composing” (p.22). In this framework, they offered a model of the rhetorical problem consisting of two major units: *the rhetorical situation* and *the writer’s own goals*. While *the rhetorical situation* includes audience and assignment, *the writer’s own goals* comprise of four basic set of goals the writer himself creates such as reader, person or self, meaning, and text (Flower and Hayes, 1980). They asserted that the main difference between good and poor writers lies in the number of aspects of these whole rhetorical problems they essentially consider.

In summary, Flower and Hayes proposed a model that emphasized a rhetorical problem with its two units and specifically the more a writer pays attention to both specified units of the total rhetorical problem and their sub-goals, the more he or she will be an expert in writing. One needs to manage all of these demands to be a good writer.

2.6.4. Cognitive Process Theory for Writing

In 1981, Flower and Hayes proposed a cognitive process theory that was based on four key points:

- (i) The process of writing is best understood as a set of distinctive thinking processes, which writers orchestrate or organize during the act of composing.
- (ii) These processes have a hierarchical, highly embedded organization in which any given process can be embedded within any other.

(iii) The act of composing itself is a goal-directed thinking process, guided by the writer's own growing network of goals.

(iv) Writers create their own goals in two key ways: by generating both high-level goals and supporting sub-goals which embody the writer's developing sense of purpose, and then, at times, by changing major goals or even establishing entirely new ones based on what has been learned in the act of writing (p.366).

The writing model proposed by Flower and Hayes (1981) essentially included three main components: (1) *the task environment*, (2) *the writer's long term memory*, and (3) *the writing process*. First, the task environment was regarded as something outside of the individual and included rhetorical problem or assignment and the growing text itself. Second, the writer's long term memory was viewed as a place in which writer stores both knowledge of the topic and various personal plans including audience and writing. Third, the writing processes, which can be predominantly associated with the cognitive activity, handle three crucial processes used in the course of writing (see Figure 2.2). These are *planning*, *translating*, and *reviewing*, all of which are under the control of the writer. These three processes are at the hearth of the act of writing and also involve specific sub-processes. *Planning* has to do with *generating ideas*, including retrieving related information from long term memory. In addition to generating ideas, planning involves *organizing* which has an impact on making connection between thoughts, structuring ideas, and forming new concepts whereby the writer can make meaning. Planning also includes *goal setting* which involves the writer generating procedural and substantive goals in order to succeed in writing task. *Translating* is "the process of putting ideas into visible language" (p.373). Translation goes beyond only consideration of rhetorical elements, and it also involves global aims of transforming content into linear expression. *Reviewing* includes *evaluating* and *revising* (see Figure 2.2.). Throughout writing, writers monitor the movements between these different phases of the process.

Flower and Hayes (1981) offered a remarkable writing model associated with cognitive process that focused on goal-directed and hierarchical process in which both writing process and content goals are taken into consideration. In the course of writing, the writer was to equilibrate the goals of the task with the content knowledge to be presented,

and the text that was being created. The noteworthy implication of their notions can be regarded as writing is a valuable learning tool in which cognitive processes activate.

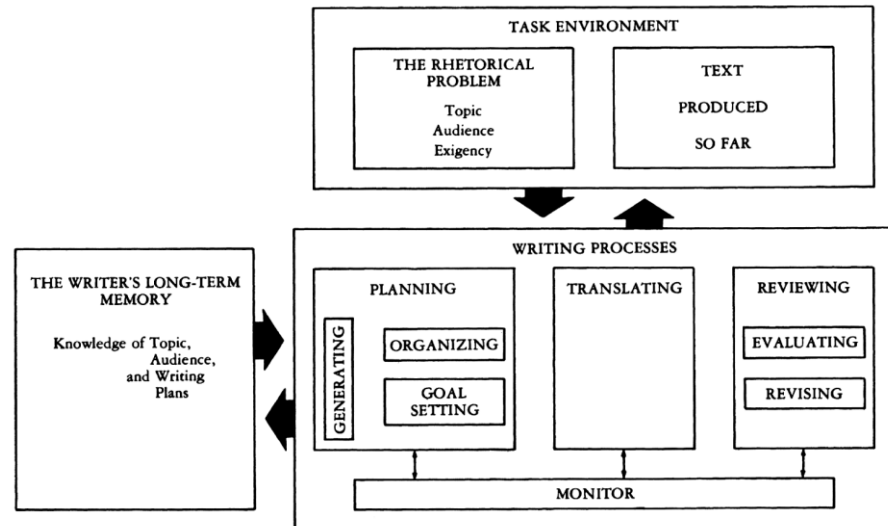


Figure 2.2. Structure of the writing model. (Flower and Hayes, 1981)

2.6.5. Knowledge-Telling and Knowledge-Transforming Model

Students tend to learn better and effectively, when they are provided an opportunity (e.g., writing tasks) to analyze, represent or manipulate their understanding in a new form (Prain and Hand, 1996). In this context, Bereiter and Scardamalia (1987) identified two distinct models of the writing process: (1) *Knowledge-telling* model, and (2) *Knowledge-transforming* model. Knowledge telling model requires writers to use their readily existing knowledge and can be viewed as a recall process. It involves simply writing down ideas or factual knowledge stored in the writer's mind. As an example of this type of text generation, Bereiter and Scardamalia specified a quote of a 12-year-old boy student as follows:

“I have a whole bunch of ideas and write down until my supply of ideas is exhausted. Then I might try to think of more ideas up to the point when you can't get any more ideas that are worth putting down on paper and then I would end it” (p.9).

Bereiter and Scardamalia (1987) stated that “Learning is thought to add not only new elements to memory but also new connections, and it is the richness and structure of

these connections that would seem” (p.187) and therefore “the knowledge-telling strategy is educationally faulty because it specifically avoids the forming of connections between previously separated knowledge sites” (p.187). In other words, since knowledge-telling model is based on pre-existing connections between content elements and readily available discourse knowledge, it does not promote the generation of new knowledge. However, Bereiter and Scardamalia listed many school practices within the context of knowledge-telling model which is applicable for routine writing tasks such as testing a subject covered in the course, giving long pages of homework including excessive amount of knowledge on a single topic and reviewing by identifying superordinate categories of particular items necessary on the examination (p.188). It can be deduced that this type of writing does not promote learning since it does not make any changes in the existing knowledge.

While knowledge-telling model mainly focuses on writing down the past knowledge and thoughts stored in the writer’s mind, *knowledge-transforming* model involves reprocessing of knowledge by which writer’s thoughts can change and develop through composing process itself. Similar to the notions of Flower and Hayes (1981), this model can be seen as a problem solving activity, but unlike Flower and Hayes, Bereiter and Scardamalia (1987) put more emphasis on content knowledge and rhetorical knowledge. Although knowledge-telling is still a part of this model, writers are not simply transferring their existing thoughts and knowledge into paper. Instead, the thoughts of the writers develop and come into existence through the writing process itself. The small pieces of information or “driblets” gradually become fully developed thoughts by means of many rethinking and restating processes. As an example, in the book *Writers at Work*, the composing process of Aldous Huxley is described as follows:

“Generally, I write everything many times over. All my thoughts are second thoughts. And I correct each page a great deal, or rewrite it several times as I go along...Things come to me in driblets, and when the driblets come I have to work hard to make them into something coherent” (as cited in Bereiter and Scardamalia, 1987).

According to Bereiter and Scardamalia (1987), each writer has to concentrate on the dimensions of the writing task by setting goals and sub-goals so as to complete writing. In other words, writers have to cope with both content knowledge related to the topic and discourse knowledge required to achieve the writing task. Each of these knowledge

components forms a whole “problem space”. These knowledge types have associated with a content problem space and rhetorical problem space, respectively (see Figure 2.3). While content space deals with problems of belief and knowledge (“what do I mean?”), rhetorical space handles problems of achieving goals of the composition, that is, how to best represent writer’s belief and knowledge in relation to the appropriate language for the intended audience (“How do I say what I mean?”). The interaction within and between these problem spaces result in transformation of knowledge. Knowledge transforming process involves a cycling between two distinct problems spaces. Until the text or the writer’s latest understanding is finally composed, this cycling process occurs many times through the act of writing. Contrary to knowledge-telling model, knowledge transforming model is more usual for expert writers than for novices.

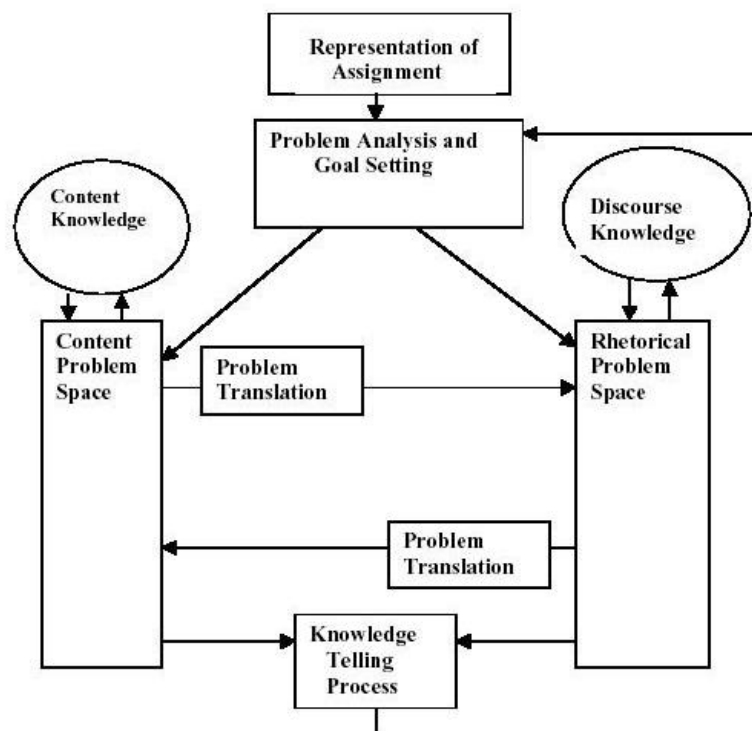


Figure 2.3. Structure of the knowledge-transforming model.

(Bereiter and Scardamalia, 1987)

The knowledge transforming model promotes both writing expertise and subject-matter understanding at the same time (Bereiter and Scardamalia, 1987). Contrary to the writers who employed the knowledge-telling model, writers engaging in the knowledge-

transforming model of writing, they increased their knowledge acquisition due to the interaction between content process and discourse process.

Although many differences exist between the cognitive models discussed above, there are also definite similarities between them. Particularly, the two models proposed by Flower and Hayes (1980, 1981) and Bereiter and Scardamalia (1987) have concentrated primarily on explaining cognitive processes in the development of writing competence and handled writing as a problem solving task. Effective writing is regarded as “a matter of finding the right solution to rhetorical problem, and identified writing expertise with the possession of a set of sophisticated problem solving strategies” (Galbraith, 1999, p.2). Moreover, all models of writing to learn, more or less, mention two distinct but interacting elements of content knowledge and rhetorical knowledge, which entails the accommodation of these two knowledge bases.

The considerations in this section about writing indicate that writing can be a tool for learning. Then, in terms of science education, an important question can be probed. What can be the role of writing in science education? In this vein, some important questions can be asked: Does writing foster science understanding? How can writing assist learning in science? What is the relationship between writing and learning in science? What types of writing activities support science learning? If these leading questions cannot be answered satisfactorily, then writing to learn interventions in the science education field might be worthless.

2.6.6. Writing to Learn in Science Education

The idea that learners could generate new science knowledge by means of writing was suggested in the early 1970s (Wallace *et al.*, 2004). Since then, many researchers focused on writing in the context of science learning. According to Wallace *et al.* writing enhances science learning even though there is an inevitable impact of many contextual factors in science learning settings. In their book, they asserted that “writing is one mode of “doing science”, just as hands-on laboratory work, internet research, reading, or oral discourse constitute other ways of doing science” (p.2).

Based on Bereiter and Scardamalia's (1987) knowledge-transforming model, Keys (1999) explained science learning in association with writing tasks and clarified how writing enhances the production of new scientific knowledge. Keys (1999) stated that "the dynamic relationship between the content space and the rhetorical space in the knowledge-transforming model illuminates why writing is such a critical part of science learning" (p.120). According to Keys (1999), within the framework of scientific inquiry, the content space includes "prior knowledge" and "new data". In order to make the data, which can be considered in the content problem space, meaningful, a writer should engage in the rhetorical problem space. As a result of the dynamic interaction between these two knowledge bases, new scientific knowledge is produced (see Figure 2.4). Thus, what makes the production of new scientific knowledge lies on the interaction of content problem space and rhetorical problem space. Content problem space involves "identifying relevant data", "determining meaning of data", constructing inferences," and "developing conceptual knowledge structures" to make the data meaningful in relation to the investigation problem. On the other hand, rhetorical problem space deals with "making language choices", "communicating meaning of data", "constructing canons of arguments", and "developing knowledge of scientific genre and nature of science (p.121). When writers write for an audience, they try to make arrangements for appropriate language and formulate syntax choice for written text. Therefore, these language choices and regulations provide "direct connections between data as evidence and knowledge claims in the form of meaningful inferences" (Keys, 1999, p.120).

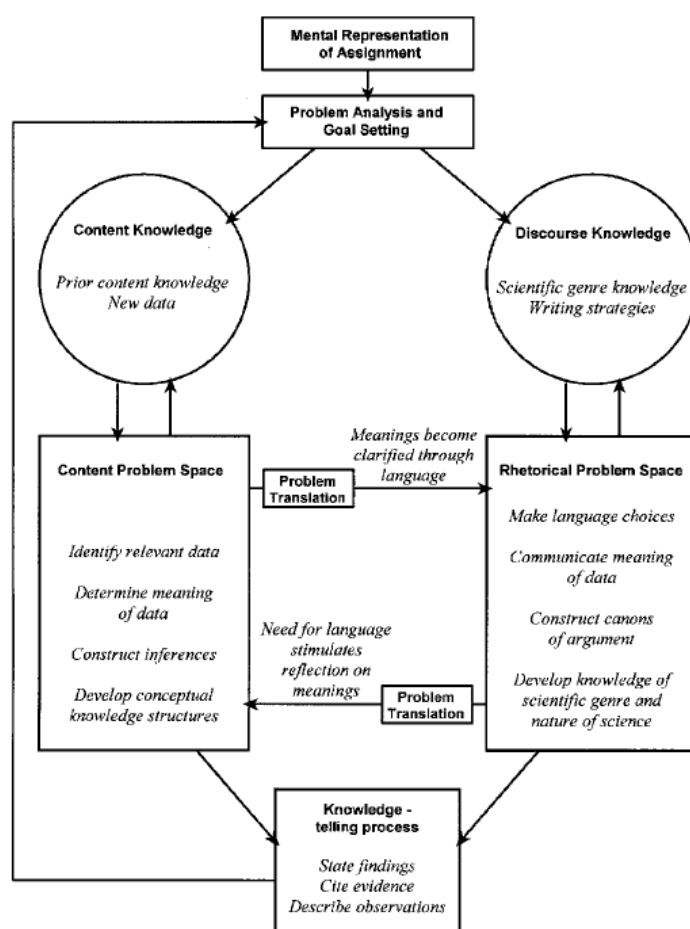


Figure 2.4. Modified structure of Bereiter and Scardamalia's (1987) knowledge-transforming model. (Keys, 1999, p.121)

Prain and Hand (1996) discussed the types of writing tasks enabling students to learn about science and to exhibit scientific understanding. They handled writing activity from the view of both modernist and postmodernist constructivist perspectives. As a result, based on research findings grounded in constructivism, they proposed a model for writing for learning in science (see Figure 2.5). The model consists of five crucial basic elements, namely *topic*, *types of writing*, *writing purposes*, *audience*, and *method of text production*. *Topic* refers to the instructional concept which writing task handles. *Types of writing* indicate the kinds of writing tasks such as journals, letters, reports, concept maps, and narratives. *Writing purposes* contain diverse range of purposes including hypothesizing, exploring, clarifying, revising, etc. According to Prain and Hand, these different purposes can be used by teachers so as to increase the conceptual understanding of students and to make the students compare their pre-existing ideas with new concepts. The success of a teacher, who wants to use writing activities, depends on his/her skills to make these

purposes explicit for the learners. In short, the more these purposes are engaged in writing tasks, the more conceptual understanding can be extended. The fourth element in the model is *audience*, which refers to the reader or recipient of the written text produced by the learners. The audience can be peers, younger students, parents, teachers, etc. Finally, *method of text production* deals with the processes of physical production of the text.

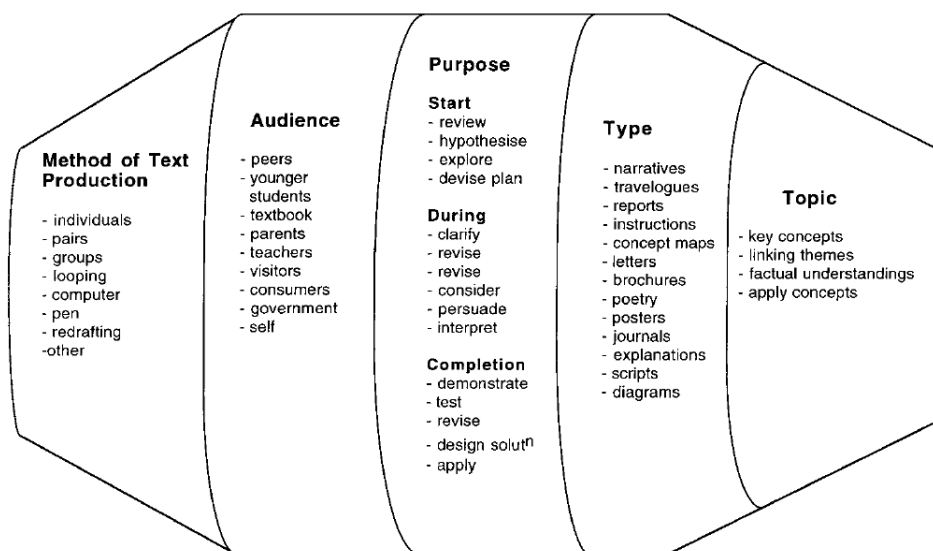


Figure 2.5. Model for writing to learn in science. (Prain and Hand, 1996)

Writing in science classrooms has simply focused on the outcome of the writing with the audience being the teacher for evaluative purposes (Gunel *et al.*, 2009). In addition, science teachers predominantly used traditional writing activities such as note taking and short answers to questions (Hand and Prain, 2004). For instance, in a recent study, Öztürk and Gunel (2015) found out that most of the science teachers used writing activities in their classrooms as a note taking tool, and they had a misconception that the “dictation” method in which students copy what the teacher said was a beneficial activity to enhance science learning.

In contrast to the use of writing in association with evaluative and traditional purposes, after 1990s the role of writing in science education has been pointed out in numerous studies in order to clarify the positive impact of writing on science learning. For example, Fellows (1994) examined the sixth grade students’ explanations whether and to what extent they have become more scientific throughout a unit on matter, and he found that the more explanations the students wrote, the more conceptual gains were identified.

Similarly, Rivard and Straw (2000) examined the effect of talk and writing on learning science concepts in an exploratory study, which represented a qualified evidence for writing to foster conceptual change. Forty-three eight grade students were randomly assigned to four groups containing three treatment groups, and one control group. The treatment groups were 'talk only-group' which involved in peer discussion, 'writing-only group' which engaged in individual writing tasks, and 'talk and writing group' which were asked to discuss the problems before writing individually. The results showed that 'talk and writing group' performed significantly better than all the other groups on delayed posttests of both simple and integrated science knowledge. The 'talk-only' group outperformed the control group on simple knowledge. Although 'writing-only group' did not outperform the control group on simple and integrated knowledge, the authors concluded that writing was essential for the retention of science knowledge and also useful for consolidating and integrating knowledge.

Although it is not universally accepted, recent studies have shown that there is an influential relationship between writing and science conceptual understanding. For example, Mason and Boscolo (2000) examined the conceptual understandings of elementary students in a unit on photosynthesis. Thirty-six Grade 4 students were divided into two groups. The experimental group engaged in writing for learning activities such as commenting on, reasoning, reflecting upon ideas, and synthesizing what one has learned, whereas the control group involved in the same teaching activities except writing tasks. The results showed that experimental group students reached a more scientific conceptual understanding on the related concepts.

In a mixed method design study, Hand *et al.* (2007) investigated the influence of writing letter to a younger audience on students' conceptual understanding in chemistry on stoichiometry. They found that the writing group performed significantly better on conceptual questions than the control group who completed the traditional activities, including chapter summary and end-of-chapter problems. In addition, the students in the treatment group specified that the writing activity provided strong support for them to understand the concepts addressed in the class.

Gunel *et al.* (2009) investigated the impact of writing-to-learn on conceptual understandings of Grade 9/10 students' understanding of biology topics. They explored the value of writing to different audiences. There were four different types of audiences in the study including teacher, younger students, peers, and parents. Firstly, the study provided strong evidence that writing promotes conceptual understanding. Secondly, the researchers found that the groups writing for peers or younger students performed significantly better than the other two groups on conceptual understanding of two biology topics.

In a recent experimental study, Chen *et al.* (2013) investigated the conceptual understandings of Grade 4 students on the topic of force and motion. While students in treatment group were required to write three letters to older peers (Grade 11 students) through an 8-week teaching unit about force and motion, the control group was exposed to the same pedagogical practices with treatment group, except letter writing. In the two year project, the researchers found that the experimental group performed significantly better than the control group in terms of understanding the concepts of force and motion.

In summary, these studies indicate that writing can be used as an effective tool for science learning or conceptual change in contrast to its traditional and evaluative purposes.

In the light of the literature regarding the writing-to-learn issues in science education, some inferences can be presented to clarify what kind of writing assignments can assist learning and provide development of expertise in science learning. In this sense, Tynjälä (1998) indicated five essential properties indispensable for a writing task in promoting learning. First, writing tasks should be designed in a form of knowledge-transforming process (Bereiter and Scardamalia, 1987) instead of knowledge-telling activities so that they can produce active knowledge construction. Second, the tasks should make students confront with their pre-existing knowledge related to the topic they are studying; therefore, they can reflect on their thoughts with regard to the new knowledge. Third, the tasks should provide students an opportunity for reflecting on their own experiences. Fourth, the writing tasks should engage students in the application of theories into practical situations. Fifth, they should present students opportunities in which they can specify their conceptual understanding and construct their own meanings. Although various writing types can satisfy these five basic principles for writing to learn in science, in this study, learning

journals were utilized for this purpose. Dianovsky and Wink (2012) noted “the process of writing journals helps with the process of understanding between ideas, knowledge transformation, and construction of new meaning” (p.546). In this regard, *reflective learning journals* can be a useful learning tool as long as the properties stated above embedded in them properly.

The following section will present a discussion about the reflective learning journals and provide relevant literature review including empirical research evidences regarding understanding of science concepts.

2.6.7. Reflective Learning Journals

There is no universally accepted definition of the term, reflective learning journal. For example, Thorpe (2004) defined reflective learning journals as “written documents that students create as they think about various concepts, events, or interactions over a period of time for the purposes of gaining insights into self-awareness and learning ” (p.328).

Langer (2002) specified three types of learning journals those can be produced in different formats. The first one is *unstructured* journals which provide students to create their individual format. Students are left freely to write whatever they like about the content, and to design the structure independently. In other words, the format of the unstructured journals is similar to the diaries. Contrary to the unstructured learning journals, the second type of learning journals are *structured* journals. They include some particular constraints through which students can be engaged in particular thought activities, and they have to follow a template guiding them what to write. Moreover, structured journals are also beneficial for teachers by which they can capture ideas, understandings and reflections of the students on a particular topic. The third type of learning journals is *dialogue* journals. They are a kind of face-to-face written communication tool between two or more writers (Langer, 2002). Hence, through writing with any other, writers can not only share and exchange their ideas, but they can also develop and improve their thoughts (Ersözülü, 2008).

Learning journals provide a rich opportunity for reflection. In relation to reflection, “having students write brief journal entries into a science journal or learning log can be a convenient way for students to reflect on their own learning and for a teacher to monitor all students’ thinking” (NSTA, 2002, p.110). Carin and Bass (2001) indicated that learning journals or logs can include observations of a demonstration, individual explanations of an discrepant phenomenon or personal notes from any events, providing students an opportunity to reflect their ideas in their own words and explore the subject personally. In learning journals, students can be asked to write down their experiences, thoughts, and their understandings on previously covered contents. Many studies showed that students are generally not aware of what they know or don’t know (Hartman and Glasgow, 2002). However, well-structured learning logs can assist students to reflect on what they have learnt or not learned. Throughout writing process, learners constantly plan, monitor, and reflect on their learning process. Schmidt *et al.* (2012) stated that learning journals attempt to express what students found personally interesting and important, and how the new information interact with previously known ideas relevant to the subject.

Prain and Hand (1996) pointed out that writing for learning in science should go beyond the traditional records of observations and formal reports. Instead of simply reporting observations, students should also write down their initial ideas, predictions, and revision of their thoughts. Along with writing down the learning journals, students not only compose factual knowledge related to the topic, but “they can also be required to use cognitive skills such as analyzing, synthesizing, and evaluating to apply the knowledge” (Liu, 2010, p.126). In this way, journaling can be a powerful tool for students to make them understand the science content. In this context, predictions, observations, and explanations can be embedded into reflective science journals so as to promote scientific understanding and conceptual change.

Some scholars asserted that writing-to-learn depends on complex strategies (e.g., Bereiter and Scardamalia, 1987; Flower and Hayes, 1980, 1981), but most students’ writings does not include appropriate strategies by which learning occurs. For example, in a quantitative study, Klein (2000) examined the explanations of 36 Grade 4, 6, and 8 students after their participation to science experiments related to buoyancy and balance. After students made explanations about the experiments, they were required to write

journal-style notes just after think-aloud training task. The results showed that only a small portion of students improved their explanations and learning by means of writing. The reason of why other students did not improve their understanding was associated with their unawareness of the learning strategies, particularly, cognitive strategies (Wallace, 2004). Therefore, a reflective learning journal, which is a type of writing to learn tool, needs to be amended to engage students in proper learning strategies. Then, what can be these learning strategies?

2.6.7.1. Cognitive and Metacognitive Learning Strategies. Several learning strategies are available in the literature. Specifically, they can be broadly categorized as cognitive and metacognitive learning strategies (Weinstein and Mayer, 1986; Glogger *et al.*, 2012). McCrindle and Christensen (1995) asserted that both cognitive and metacognitive strategies strongly have an impact on the learning process. Cognitive strategies comprise three basic strategies. The first one, *rehearsal strategies* refers to the repetition of the knowledge directly without making any changes in its form. “Oral repetition, underlining, copying and making selective verbatim” (p.170), can be considered as various examples of rehearsal strategies. The second one is *organization strategies* which includes the reorganization of the information to be learned to make it more meaningful. “Grouping, sorting, categorizing, development of hierarchies and constructing networks” (p.170) are the examples of organization. The last one is *elaboration strategies* which provide connections between ones’ pre-existing knowledge and the new information. The examples of elaboration strategies can be stated as “using mental images, paraphrasing text, creating analogies, generative note taking and self-questioning” (p.171). According to McCrindle and Christensen (1995), the most effective cognitive strategy to enhance meaningful learning is elaboration strategies because of the fact that they engage the learner into much more mental activity and effort requiring the integration of pre-existing and new knowledge. In other words, elaboration strategies help the learner create connections between existing knowledge and new information (Mayer, 1984). As a result, all of the cognitive learning strategies have a direct contribution to knowledge acquisition and learning (Glogger *et al.*, 2012).

Metacognitive strategies also have a strong impact on promoting learning. They assist in the selection, execution, monitoring, and control of cognitive strategies

(McCrinkle and Christensen, 1995). Indeed, they “control and regulate cognitive strategies” (Berthold *et al.*, 2007, p.566) and also initiate the cognitive strategies. Hence, when students are encouraged to use cognitive and metacognitive learning strategies in learning journals, journal writing substantially enhances content learning.

Since journal writing is relatively open-ended, journals offer students opportunities to use various writing and learning strategies through the act of writing (Klein, 2000). For instance, in an experimental study, McCrinkle and Christensen (1995) investigated the learning of forty first-year students in a biology course. The students in the experimental group received a blank book titled “Learning Journal” and they were required to record their reflections on the content addressed in the lab sessions within five weeks. However, the students in the control group were asked to write scientific reports through the same time period with the experimental group. Both groups were instructed how to write their related tasks. The researchers found that learning journal group demonstrated more integrated science knowledge and also used more metacognitive and sophisticated cognitive strategies. Moreover, learning journal group significantly outperformed the scientific report group on the final exam.

2.6.7.2. Prompts in Learning Journals. Wallace (2004) specified that learners need to be taught how to use cognitive and metacognitive strategies during writing in order to maximize the impact of writing on learning. Thus, “prompts” can be used as *strategy activators* to overcome production deficiencies and to facilitate journal writing (King, 1992). Prompts can be defined as the hints or questions which can engage the writers or learners into organization, elaboration, reflection, and comprehension during writing process (Berthold *et al.*, 2007). If journal prompts are provided to students, they are not allowed to write freely whatever they want in relation to the particular topic. By using such prompts, students are directed to consider how to organize the content, how to make connections with their prior knowledge, how to reflect on their understanding and develop useful strategies to cope with understanding (Galbraith, 2015). In this way, journal writing in science education can be an effective task to increase students’ learning.

Cognitive and metacognitive prompts can be viewed as important predictors of the learning effects of writing journals (Bangert-Drowns *et al.*, 2004). Therefore, in several

studies, learners were required to write journals in which various appropriate prompts included (e.g., Berthold *et al.*, 2007; Glogger *et al.*, 2012; Hübner *et al.*, 2010; Schmidt *et al.*, 2012). For instance, in a recent quasi-experimental study, Wäschle *et al.* (2015) examined the effects of journal writing after biology lessons in terms of comprehension, interest, and critical reflection. In their first study, they have structured the journals with two categorized prompts: cognitive prompts and metacognitive prompts. Cognitive prompts, which are associated with organization and elaboration respectively, included two questions: (1) “How can you structure and summarize the content in a meaningful way?” and (2) “Which examples can you think of that illustrate, confirm or conflict with the learning contents?” (p.47). In addition to the cognitive prompts, two metacognitive prompts related with monitoring and planning of remedial strategies were asked as: (1) “Which main points do you now understand, and which haven’t you understood” and (2) “What possibilities do you have to overcome your comprehension problems?” (p.47). The results showed that journal writing group showed better scores in comprehension, interest, and critical reflection than the control group who completed traditional homework assignments such as summarizing, concept mapping, and answering predefined questions.

In summary, reflective learning journals are such a kind of promising writing tools that enable learning in science. In particular, the journals presenting the writers appropriate prompts such as cognitive and metacognitive prompts are crucial for enhancing learning. In comparison to other writing tasks such as writing summary writing, prompted journal writing can be a useful tool for enhancing science learning and comprehension.

3. METHODOLOGY

The main purpose of this quasi-experimental study was to explore the effectiveness of Predict-Observe-Explain instruction coupled with “Reflective Journal Writing” (POE-RJW instruction) over POE instruction or Traditional Instruction (TI) in terms of improving Grade 10 students’ conceptual understandings of electricity and magnetism. The subsequent goal of the study was to investigate the effectiveness of the POE-RJW instruction on students’ motivation to learning physics compared to the POE instruction and Traditional instruction. The following research questions guided this research:

- (i) How does the conceptual understanding of electricity and magnetism differ from pre to posttest for the three groups of Grade 10 students who engaged in POE-RJW Instruction, POE Instruction, or Traditional Instruction?
- (ii) Are there any differences among the three groups of Grade 10 students in terms of their understandings of electricity and magnetism before and after engaging in POE-RJW Instruction, POE Instruction, or Traditional Instruction?
 - Are there any difference among the three groups of Grade 10 students in terms of their understandings of electricity and magnetism before engaging in POE-RJW Instruction, POE Instruction, or Traditional Instruction?
 - Are there any difference among the three groups of Grade 10 students in terms of their understandings of electricity and magnetism after engaging in POE-RJW Instruction, POE Instruction, or Traditional Instruction?
- (iii) How does the conceptual understanding of the associated concepts of electricity and magnetism change from pre to posttest for the three groups of Grade 10 students who engaged in POE-RJW Instruction, POE Instruction, or Traditional Instruction?

(iv) How does the motivation to learning physics differ from pre to posttest for the three groups of Grade 10 students who engaged in POE-RJW Instruction, POE Instruction, or Traditional Instruction?

(v) Are there any differences among the three groups of Grade 10 students in terms of their motivation to learning physics before and after engaging in POE-RJW Instruction, POE Instruction, or Traditional Instruction?

- Are there any differences among the three groups of Grade 10 students in terms of their motivation to learning physics before engaging in POE-RJW Instruction, POE Instruction, or Traditional Instruction?
- Are there any differences among the three groups of Grade 10 students in terms of their motivation to learning physics after engaging in POE-RJW Instruction, POE Instruction, or Traditional Instruction?

3.1. Research Design

This study was a quasi-experimental control group design with pre and posttest (Cook and Campbell, 1979). Although quasi-experimental studies include control and experimental group(s), the use of random assignment is not employed due to the inappropriate setting conditions (Creswell, 2012). In the current study, two of the pre-existing Grade 10 classes of the school were designated as experimental group 1 (POE-RJW group), the other three classes of the school were randomly designated as experimental group 2 (POE group), and the other two classes were designated as control group (Traditional Instruction group). The design of the study is shown in Table 3.1.

Table 3.1. Design of the study.

Group	# of Classes	Pretest	Intervention	Posttest
POE-RJW	2	O	X ₁	O
POE	3	O	X ₂	O
TI	2	O	X ₃	O

Note: X₁: POE-RJW instruction; X₂: POE instruction; X₃: Traditional Instruction

3.2. Participants of the Study

The sample included a total of 145 male Grade 10 students, with an age range of 15-16, from one of all-boys boarding high schools located in Istanbul. In this school there were 17 pre-existing Grade 10 classes, and seven of them were randomly selected for the study. The two of them were randomly assigned as the POE-RJW group including 39 male students; three classes were randomly assigned as the POE group including 59 male students, and the two of them were assigned as the TI group including 39 male students as well. Two students from the POE-RJW group, which was comprised of 42 students initially, were dropped out of the study due to missing data. Table 3.2 demonstrates the demographics of the groups.

Table 3.2. Demographics of the groups.

Group	N	Grade	Age
POE-RJW	40 males	10	15-16
POE	66 males	10	15-16
TI	39 males	10	15-16

While both the POE-RJW and the POE group instructions were implemented by the teacher/researcher, traditional instruction was implemented by another physics teacher with 10-year experience, who also held the doctor of philosophy degree in physics education. The backgrounds of both teachers were summarized in Table 3.3. In order to provide consistency between two teachers in terms of the topics covered in their classes, they had a meeting at the beginning of each week about 15 minutes.

Table 3.3. Background of the teachers.

	Teacher/Researcher		Teacher
Instruction Type	POE-RJW	POE	Traditional
Major Degree	Physics Education		Physics Education
Academic Degree	M.S.		Ph.D.
Year of Experience	4		10

3.3. The Framework of the Instructions

This section includes the description of three types of instructions employed in the study on the subject of electricity and magnetism, respectively: Predict-Observe-Explain instruction coupled with reflective learning journal writing (POE-RJW) instruction, Predict-Observe-Explain (POE) instruction, and Traditional Instruction (TI) as well. All of the instructions were performed throughout the same 10 weeks. Additionally, the 8 instructional objectives were selected from Turkish National Curriculum (MEB-TTKB, 2013) for Grade 10 Physics, and these same 8 objectives were addressed in all three instruction groups. The only difference between these three groups was the type of instructions.

3.3.1. Predict-Observe-Explain Instruction Coupled with Reflective Journal Writing (POE-RJW Instruction)

3.3.1.1. Predict-Observe-Explain (POE) Strategy. The Predict-Observe-Explain (POE) strategy was firstly proposed by White and Gunstone (1992). It has been widely used to reveal various aspects of students' understanding of science. POE tasks are used effectively as a mixture of writing and discussion (Furtak, 2009). In POE tasks, students are firstly introduced to an experiment, a scientific event or a demonstration which will be performed. Then, based on their existing conceptions, they are asked to predict what will happen together with reasons for their predictions. Secondly, students observe, when the teacher or students themselves carry out the experiment, and record their observations. Thirdly, students are given opportunity to specify whether their prediction is accurate or inaccurate, and they are asked to explain the discrepancies between their predictions and observations if there is any discrepancy.

In a ten-week period, the POE-RJW participants involved in the fourteen different POE tasks (see Table 3.4. for a detailed description of the tasks) related to the concepts of electricity and magnetism. All the POE activities were designed by the researcher. While designing these POE tasks, especially events that have unexpected outcomes were planned to create a cognitive dissonance. Two of the 14 POE tasks (Task 8 and Task 14) were performed by utilizing the laboratory equipment. According to Tao and Gunstone (1999),

computer-supported POE tasks can also be used in order to make demonstration experiments more concrete and observable. In doing so, the other 12 POE tasks were completed by utilizing the computer-based simulation experiments for the sake of clear observation of the phenomenon. Such simulation experiments were projected on the smart board to be observed by all students at the same time. The simulation experiments were chosen from the “PhET Interactive Online Simulations” which are supported and designed by Colorado University. A sample snapshot can be seen in Figure 3.1.

Each week (including two 40-minute lessons), students completed one or two POE tasks. Among the 14 POE tasks, eight of them directly started with POE demonstrations. At the beginning of each lesson, students were told that an experiment (or a demonstration or a simulation experiment) would be conducted, and they were asked what would happen during the experiment. Next, they stated their reasons for their predictions. After the experiment(s) were conducted, students individually wrote down their observations and explanations based on their understandings. The other six POE tasks were performed in an appropriate time of the lesson just after introduction of some basic concepts and lecturing on relevant factual knowledge. There exist many studies in which students were provided activity sheets by the teacher (e.g., Kearney *et al.* 2001, Liew and Treagust, 1998). However, in the current study, students were not provided any teacher-prepared activity sheets, instead, they wrote down their predictions, observations and explanations on their notebooks by using “Predict”, “Observe”, and “Explain” headings.

The POE tasks were started with the teacher/researcher’s introduction and demonstration of a computer-based simulation experiment on the smart board, or an experiment involving laboratory equipment. According to Liew (2010), for an efficient POE implementation, teachers have to insist on written responses and do not let the students express their ideas verbally to their classmates while making predictions. The reason behind this notion is the possibility that some students can change their predictions because of hearing what other students say. Although students worked in groups of 4, they were asked to write down their predictions on their notebooks individually under the title of “Prediction” in their notebooks together with the reasons in their minds. The questions guided their predictions were as follows:

- Predict what will happen...?
- Write down your prediction(s) into your notebook.
- State and explain the reason(s) for your prediction(s).

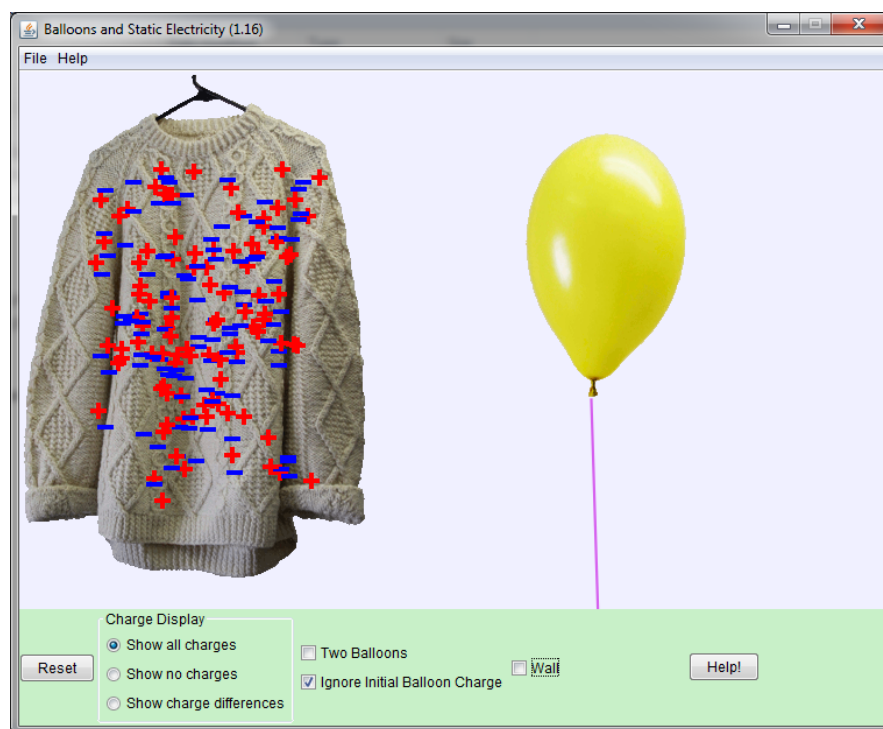


Figure 3.1. Balloons and static electricity, simulation experiment
(Colorado University, 2014)

Just after the students recorded their predictions, they were allowed to share their predictions with their friends within the groups. Then, the teacher/researcher randomly selected two or three groups to share their predictions and explain their reasoning in front of the whole class.

Two or three of the students among the volunteers were randomly selected by the teacher in order to perform the experiment with the equipment (or computer-based simulation demonstration). The task was carried out two or three times in total so as to ensure that all of the students observed what happened in a detailed manner. If the task was performed by using a computer-based simulation, students, who were on the board, manipulated the variables in the simulation experiment based on the other students' instructions and the guidance of the instructor. As in the prediction part, students again

were asked to independently write down their observations based on the experiment performed. This is because even if they observe the same experiment or phenomenon, each student may observe different things depending on their different beliefs or conceptions (Liu, 2010). That is to say, when students make observations, ‘believing is seeing’ can be more appropriate than the more usual ‘seeing is believing’ (Driver, 1985). Hence, students were asked to record and wrote down their individual observations and possible reasons of the outcome of the phenomenon. The questions guided their observations and explanations were as follows:

- What happened...?
- Write down your observations.
- State and explain the reason(s) for your observations.

Then, each group in the class shared their explanations to the class, and a whole-class discussion was held considering the explanations provided by each group. In line with social constructivist theory, whole class discussions and rich conversations occurred among the students accompanied by the guidance of the instructor. In the course of the discussions, in general, many new questions were produced by the students regarding the experiment, and they were written on the board to be explored through the discussions. These unexplored questions were answered and eliminated one by one, by manipulating the variables in the animation along with collection of evidence.

Finally, students were requested to make comparison between their predictions and observations. They were asked for their reasoning and how their ideas have changed after their observations and the discussions. They were provided sufficient time for revisiting and revising their explanations. The questions guided the comparison between their predictions and observations were as follows:

- Compare your observation with your prediction.
- Are they in harmony with each other or not?
- Explain with your reason(s).

In line with the suggestions of Liew (2010), throughout the POE tasks, the following issues were taken into account by the instructor for an effective POE task administration:

- It was ensured that students clearly understood the POE tasks.
- Students individually wrote down their responses and were not allowed to share their ideas in the prediction and observation steps until they wrote down their responses.
- Students' notebooks were checked out during the instruction to make sure that they wrote their responses.
- Students were encouraged to share their ideas even if such ideas were in agreement with others or not.
- It was ensured that all students' ideas were in value and respected.

At the end of POE tasks, the students reached the most plausible and reasonable explanations of the phenomenon. However, they were curious about whether their explanations were in congruent with the scientific explanation of the phenomenon. Therefore, the teacher shared the scientific explanations of the events that were performed in the class with the students whether their final explanations were in harmony with the scientific ones or not. In most of the POE task, with the help of group discussions, the evidence collected, and the teacher's guidance, students developed and reached acceptable explanations by themselves in agreement with the scientific explanations of the phenomenon.

Table 3.4. describes the 14 POE tasks and related concepts as well as the instructional strategies conducted throughout the lessons. All of the prepared slides used throughout POE lessons can be seen in Appendix A.

3.3.1.2. Reflective Journal Writing. Reflective learning journals (sometimes used as reflective learning logs) refer to the written documents that students create as they consider on several concepts, events, or interactions over a period of time for the purposes of gaining insights into self-awareness and learning (Thorpe, 2004). Bangert-Drowns *et al.* (2004) claimed that writing enhances learning by providing useful cognitive and metacognitive strategies of self-regulated learning. In comparison to other writing tasks

Table 3.4. Description of the 14 Predict–Observe–Explain (POE) tasks and related concepts.

Lesson	Task #	Task Name	Concept(s)	Description	Prediction Question(s)	Instructional Strategy
1	1	Sweater and Balloon	Electric Charges & Electric Force	There is an electrically neutral balloon and a sweater in the simulation experiment and one can rub the balloon to the fixed sweater.	What do you think will happen to the balloon if we slowly bring the sweater and a balloon close to one another just after they are rubbed with each other?	Predicting the result of the simulation experiment and observing the phenomenon Explaining it with respect to the observations Allowing students to ask several further questions to be explored in the context of the simulation experiment Discussing the explanation of such further questions Inviting students to compare their explanations of the phenomenon and the further questions with the scientifically accepted explanations provided by the teacher/or textbook Explaining how an electrostatic painting machine works
2	2	Balloon and Wall	Electric Force	There is an electrically neutral balloon, a sweater and a wall in the simulation experiment. One can rub the balloon to the fixed sweater and bring the balloon closer to the wall.	What do you think will happen to the balloon if we slowly bring it to the wall just after it is rubbed with the sweater?	Predicting the result of the simulation experiment and observing the phenomenon Explaining it with respect to the observations Inviting students to compare their explanations of the phenomenon and the further questions with the scientifically accepted explanations provided by the teacher/or textbook Explaining how a stretch film works
3	3	John Travolta	Conductors & Insulators	A man (John Travolta) in the simulation experiment is about to rub his feet to the carpet and also he is about to touch his hand to a metal doorknob	1. What do you think about the charge distribution on the body of the man when he rubs his feet on the carpet? 2. What happens if the man touches to the doorknob?	Predicting the result of the simulation experiment and observing the phenomenon Explaining it with respect to the observations Asking several questions to be explored in the context of the simulation experiment Discussing the student questions Inviting students to compare their explanations of the phenomenon and the further questions with the scientifically accepted explanations provided by the teacher/or textbook Explaining how thunder and lightning occurs

Table 3.4. Description of the 14 Predict–Observe–Explain (POE) tasks and related concepts. (cont.)

Lesson	Task #	Task Name	Concept(s)	Description	Prediction Question(s)	Instructional Strategy
4	4	Electric Force	Electric Force	There are two opposite point charges on the simulation experiment. The amount of charges and the distances between them can be manipulated by the user. The quantity and the direction of the electric force can be automatically calculated by the computer.	<ol style="list-style-type: none"> 1. What do you think about the relationship between the amount of charge(s) and electric force? 2. What do you think about the relationship between the distance of two charges and the electric force? 3. What happens if we change the medium with a change (e.g., air to water)? 	<p>Teacher providing factual knowledge about the charge on a single electron and a proton by using the “Coulomb” unit</p> <p>Predicting the result of the simulation experiment and observing the phenomenon</p> <p>Explaining the phenomenon with respect to observations</p> <p>Inviting students to compare their explanations of the phenomenon and the further questions with the scientifically accepted explanations provided by the teacher/or textbook</p>
	5	Electric Field	Electric Field	A uniformly charged hollow metal sphere is represented in simulation. One can work on it to show the electric field lines.	Predict and draw the electric field lines at the inner and outer part of the uniformly charged hollow conductor sphere.	<p>Predicting the result of the simulation experiment and observing the phenomenon</p> <p>Explaining the phenomenon with respect to the observations</p> <p>Inviting students to compare their explanations of the phenomenon and the further questions with the scientifically accepted explanations provided by the teacher/or textbook</p> <p>Explaining how a Faraday Cage works</p> <p>Watching video about Faraday cage</p>
5	6	Resistance of a Wire	Electric Resistance	There is a wire in the simulation. One can change the variables such as its resistivity, length and cross-sectional area to see how they affect the wire’s resistance	<ol style="list-style-type: none"> 1. What do you think about the relationship between the length of the wire and its resistance? 2. What do you think about the relationship between the wire’s cross-sectional area and its resistance? 	<p>Teacher providing factual knowledge about electric current, resistance and potential difference</p> <p>Discussing the water-circuit analogy</p> <p>Predicting the result of the simulation experiment and observing the phenomenon</p> <p>Explaining the phenomenon with respect to the observations</p> <p>Explaining what types of wires should be used to carry out the electricity to distant places and to explain the reasons</p> <p>Explain what types of wires should be used to in the light bulbs, hair dryers and heater including wires</p>

Table 3.4. Description of the 14 Predict–Observe–Explain (POE) tasks and related concepts. (cont.)

Lesson	Task #	Task Name	Concept(s)	Description	Prediction Question(s)	Instructional Strategy
5	7	Ohm' Law	Ohm' Law	A light bulb (resistance) is connected to a battery in a closed circuit in the simulation experiment. One can change the voltage of the battery, and the value of the current can be measured by an ammeter. Besides, along with the change in the voltage, the brightness of the bulb can be recognized easily.	<ol style="list-style-type: none"> 1. What do you think about the relationship between potential difference and current in the circuit? 2. What do you think about the relationship between the potential difference and the resistance of the bulb in the circuit? 3. What do you think about the relationship between the resistance of the bulb and the current in the circuit? 4. What do you think about the relationship between the current flowing in the circuit and the brightness of the light bulb? 	<p>Predicting the result of the simulation experiment and observing the phenomenon</p> <p>Collecting data by changing the variables in the simulation experiment</p> <p>Explaining the phenomenon with respect to the gathered data and observations</p> <p>Inviting students to compare their explanations of the phenomenon and the further questions with the scientifically accepted explanations provided by the teacher/or textbook</p> <p>Solving problems related to Ohm's Law</p>
6	8	Rheostat	Rheostat	A circuit was designed with the laboratory equipment. One power supply, one rheostat, one light bulb, and one voltmeter connected across the terminals of the light bulb were connected to each other to create a closed circuit. One can move the cursor of rheostat to see the changes in the circuit	<p>If the cursor of the rheostat moves on the direction of the arrow (specified in the experiment);</p> <ol style="list-style-type: none"> 1. How does the magnitude of the current flowing in the circuit change? 2. What happens to the brightness of a light bulb? 	<p>Introduction of the rheostat and its components such as terminals, sliding contact and coil of wire</p> <p>Predicting the result of the experiment and observing the phenomenon</p> <p>Collecting experimental data by moving the cursor on the rheostat</p> <p>Explaining the phenomenon with respect to the gathered data and observations</p> <p>Inviting students to compare their explanations of the phenomenon and the further questions with the scientifically accepted explanations provided by the teacher/or textbook</p> <p>Explaining how a dimmer switch works</p>

Table 3.4. Description of the 14 Predict–Observe–Explain (POE) tasks and related concepts. (cont.)

Lesson	Task #	Task Name	Concept(s)	Description	Prediction Question(s)	Instructional Strategy
7	9	Series Connected Resistors (Bulbs)	Resistors in Series	There exists an open circuit in the simulation experiment. One battery, one open-switch, one ammeter and two different light bulbs are connected in series. One can close the switch to make the circuit closed and take readings by using ammeter and voltmeter	<p>If the switch is closed,</p> <ol style="list-style-type: none"> 1. Compare the magnitudes of the currents on the first resistor, on the second resistor and in the battery 2. Compare the magnitude of the voltage between the ends of the first resistor, the second resistor and the battery. 3. What is the relationship between the resistance of the first bulb, the second bulb and the equivalent resistance? 4. How does the brightness of the first and the second light bulb change, if one more bulb is connected to the circuit in series? 	<p>Predicting the result of the simulation experiment and observing the phenomenon</p> <p>Collecting data by changing the variables in the simulation experiment</p> <p>Explaining the phenomenon with respect to the gathered data and observations</p> <p>Inviting students to compare their explanations of the phenomenon and the further questions with the scientifically accepted explanations provided by the teacher/or textbook</p> <p>Explaining what type of connection is used in household electric circuits</p> <p>Discussing the sprinkles on water hose and series connected resistors analogy</p> <p>Solving problems related to the series connected resistors</p>
8	10	Parallel Connected Resistors	Resistors in Parallel	There exists an open circuit in the simulation experiment. The circuit included one battery, one open switch, one ammeter and two different light bulbs connected in parallel. One can close the switch to make the circuit closed and take readings by using ammeter and voltmeter.	<p>If the switch is closed,</p> <ol style="list-style-type: none"> 1. Compare the magnitudes of the currents at the first resistor, at second resistor and in the battery 2. Compare the magnitude of the voltage with the ends of first resistor, second resistor and the battery 3. What is the relationship between the resistance of the first bulb, second bulb and equivalent resistance? 4. How does the brightness of the first and second light bulb change if one more bulb is connected to the circuit in parallel? 	<p>Predicting and discussing on the short circuit shown in the simulation experiment</p> <p>Predicting the result of the simulation experiment and observing the phenomenon</p> <p>Collecting data by changing the variables in the simulation experiment</p> <p>Explaining the phenomenon with respect to the gathered data and observations</p> <p>Comparing the explanation of the phenomenon with the scientific explanations (resistors in parallel)</p> <p>Transferring their knowledge to explain what type of connection is used in household electric circuits</p> <p>Discussing on the school sports hall and parallel connected resistors analogy</p> <p>Solving problems related to parallel connected resistors</p>

Table 3.4. Description of the 14 Predict–Observe–Explain (POE) tasks and related concepts. (cont.)

Lesson	Task #	Task Name	Concept(s)	Description	Prediction Question(s)	Instructional Strategy
9	11	Series Connected Batteries	Batteries in Series	There exists a closed circuit, including one battery and a light bulb in the simulation experiment. One can connect another battery in series to take measurements with an ammeter and a voltmeter	If one more battery is connected to the circuit in series, 1. What is the relationship between the voltage of the first battery, the second one and the total voltage in the circuit? 2. Compare the magnitudes of the currents passing through the two batteries? 3. How does the brightness of the light bulb change? 4. How does the duration of battery exhaustion change?	Predicting the result of the simulation experiment and observing the phenomenon Collecting data by changing the variables in the simulation experiment Explaining the phenomenon with respect to the gathered data and observations Inviting students to compare their explanations of the phenomenon and the further questions with the scientifically accepted explanations provided by the teacher/or textbook Solving problems related to series connected batteries
	12	Parallel Connected Batteries	Batteries in Parallel	There exist a closed circuit, including one battery and a light bulb in the simulation experiment. One can connect another battery in parallel to take measurements with an ammeter and a voltmeter	If one more battery is connected to the circuit in parallel, 1. What is the relationship between the voltage of the first battery, the second one and the total voltage in the circuit? 2. Compare the magnitudes of the currents passing through the two batteries? 3. How does the brightness of the light bulb change? 4. How does the duration of battery exhaustion change?	Predicting the result of the simulation experiment and observing the phenomenon Collecting data by changing the variables in the simulation experiment Explaining the phenomenon with respect to the gathered data and observations Inviting students to compare their explanations of the phenomenon and the further questions with the scientifically accepted explanations provided by the teacher/or textbook Watching video related to the invention of the batteries Solving problems related to parallel connected batteries

Table 3.4. Description of the 14 Predict–Observe–Explain (POE) tasks and related concepts. (cont.)

Lesson	Task #	Task Name	Concept(s)	Description	Prediction Question(s)	Instructional Strategy
10	13	The Brightness of Bulbs	Electric Power	An open-circuit is created with three identical bulbs in the simulation experiment. Two of them is connected in series and one is connected in parallel to them. Then, a potential difference is applied to the set of resistors. One can make close the switch to make the circuit closed and to observe the brightness of the bulbs.	Compare the brightness of each identical lamps	Predicting the result of the simulation experiment and observing the phenomenon Collecting data by changing the variables in the simulation experiment Explaining the phenomenon with respect to the gathered data and observations Inviting students to compare their explanations of the phenomenon and the further questions with the scientifically accepted explanations provided by the teacher/or textbook
	14	Relationship between Current and Magnetic Field	Magnetic Field of a Current Carrying Wire	A circuit is designed by with the laboratory equipment. The circuit consists of one power supply, one copper coil, one rheostat and one ammeter in series connection. One can change the voltage or the resistance in the circuit.	1. What is the relationship between the current flowing through the wire and the amount of movement of the compass needle? 2. How does the distance between compass and wire affect the amount of movement of the compass needle? 3. What happens to the amount of movement of the compass needle, if another material different than the air is inserted between compass and wire?	Predicting the result of the designed laboratory experiment and observing the phenomenon Collecting data by changing the variables in the simulation experiment Explaining the phenomenon with respect to the gathered data and observations Inviting students to compare their explanations of the phenomenon and the further questions with the scientifically accepted explanations provided by the teacher/or textbook

such as writing a summary and a scientific report, learning journals can clearly provide creative cognitive and metacognitive strategies. Thus, in the current study, a structured reflective learning journal template with five *prompts* was designed to promote students' cognitive and metacognitive processes.

According to Hübner, Nückles, and Renkl (2010), high school students need additional support throughout writing learning journals with prompts. Since the participant students had a lack of experience in journal writing, they were instructed in 30 minutes of time by the teacher, and they were told that writing learning journals would help them document and empower their understandings related to the electricity and magnetism concepts. At the same time, they were given two pages of “Physics Reflective Journal Writing Guidelines” (see Appendix B) regarding how to write a reflective learning journal. This guidelines document included a brief description about the definition of reflective learning journal and its contributions, what and how to write the journals as well.

According to Liu (2010), a scoring rubric can be identified by the teacher in order to evaluate student journals. In this manner, journals can clarify both common and individual concerns and deficiencies among students so that appropriate interventions in the next lesson can be conducted by the teacher. Yet, reading the journals of each student can be very time consuming for teachers but “they have tremendous value for teachers and students” (McIntosh and Draper, 2001, p. 554). Therefore, a grading rubric was included in the guideline (see Appendix B).

In writing assignments, learning is likely to occur when they were pre-structured by prompts directing important cognitive and metacognitive learning strategies (Berthold, Nückles, and Renkl, 2007). In this context, to facilitate journal writing, the reflective learning journal template included one prior knowledge prompt, one cognitive prompt stimulating elaboration as well as three metacognitive prompts stimulating monitoring strategies. The reflective journal prompts provided in the current study are included in Table 3.5. Examples from students' journals can be seen in Appendix C.

Each prompt in the journal template served different purposes for both students and the teacher. Along with the first prompt, students were expected to write down their initial

ideas which they had learnt in previous courses or developed through their prior experiences related to the subject of the week. That is to say, before instruction, they were engaged in a confrontation with their prior learning related to the content and concept of the week. From the teacher's point of view, drawing out students' pre-knowledge related to the concepts provided him to realize what and to what extent they were familiar with the topic.

The second prompt which is a monitoring prompt within the framework of metacognition, is the most significant prompt in the journal. Metacognition includes what one has learned. Therefore, students were required to write what they have learned throughout the lesson and to reflect on their understanding. Especially, they were asked to write scientific explanations and cause-effect relationships related to the concepts based on their understandings. Moreover, this prompt provided valuable feedback to the teacher to realize how students deepened their ideas over the course of instruction, how well students were aware of their learning, what concepts were misunderstood by the students, and which concepts have to be revisited in the next class hour. In short, the teacher gained an insight into what students learnt in the lesson.

The third prompt was a cognitive prompt intended to foster elaboration strategy. Students were asked to compose what was interesting for them in the lesson of the week and to provide their reasons. Based on the compositions of students in reply to this prompt, the teacher had a chance to realize why and what type of activities stimulated students' interest in the content of the lesson.

The fourth prompt was a metacognitive prompt including monitoring. Students were required to write what they used to think about a concept or a phenomenon, but what they learned just after the instruction. Along with this prompt, students had an opportunity to self-assess and reflect on their existing knowledge and how it has changed or evolved from their pre-existing thoughts. In this context, POE tasks were very effective for them to easily write down to the fourth prompt. They were asked to write down their predictions and their previously held ideas related to the POE task presented in the class. Besides, they were required to write down the scientific explanation of the phenomenon by providing

reasons and evidences from the observations and explanations held in the POE activity during the class.

Table 3.5. Prompts used in the reflective learning journals.

Condition	Prompt #	Prompts
Prior knowledge prompt	1	What would you know about the topic before you attend to today's lesson?
Metacognitive prompt	2	What have you learnt today? Explain in details (with scientific explanations and the answers of why and how questions)
Cognitive prompt	3	What was interesting for you in today's lesson? Explain your reasoning.
Metacognitive prompt	4	What was confusing for you? Explain your reasoning. (Your ideas at the beginning of the instruction and your changed ideas close to the scientific one after instruction)
Metacognitive prompt	5	Which issues/concepts haven't you understood in class today?

The fifth and the last prompt was also a metacognitive prompt serving a purpose of monitoring. The students were asked to write which points they did not understand, whether they had still questions in their minds or not and what type of questions were still confusing for them. Thus, the ideas offered for this prompt provided the teacher to notice which parts of the lesson was not well-understood and need extra guidance and support in the next lesson.

Students need guidance in journal writing (Hartman and Glasgow, 2002). In order to make students in the journal writing group confident and prepared in journal writing, they were asked to write a couple of trial journals before they were taught the electricity and magnetism unit. Therefore, they were asked to write their trial journals in association with Buoyancy which is the previous topic from electricity and magnetism unit in the curriculum.

Although learning journal is one of the writing assignment types, generally to be applied as a follow-up course-work activity (Hübner, Nückles, and Renkl, 2010), there is no one correct method to use learning logs (Hartman and Glasgow, 2002). Hence, in this study, the students were required to write their journals after the end of the class, at any

time in the day of the lesson. They had to submit their final journals one day after the lesson. That is to say, journals were given as a homework which was to be submitted for the next day as a deadline. The students were asked to submit two trial journals throughout the two weeks trial journal writing period, one per week, so that they experienced what and how to write their learning journals.

Feedbacks from a teacher on a single writing assignment can assist students to learn about the nature of the journals (Hartman and Glasgow, 2002). Therefore, feedbacks given by the teacher including various written comments on the journals throughout the weeks of trial journal writings helped the students improve their writing skills and realize the expectations of journal writing.

Journals were assessed and graded by the teacher based on the rubric provided in the guidelines. McAdams (2013) asserted that writing is a skill, and to improve this skill, feedback plays a significant role. Providing feedback is a powerful strategy so as to enhance student learning. Butler and Nisan (1986) found that students who received comments on their written work scored significantly higher from the performance task than the other group who did not take feedback. While providing feedbacks to the students, it is highly significant to give students information about how they did and how they can do better next time (Furtak, 2009). However, simply putting smiley faces, writing “nice work” or grading at the top of page is not effective strategy in terms of feedback. Instead, informative feedback has to be provided in which feedback concentrates on “what specifically the student did well, point out where the student may have made errors or demonstrated incomplete thinking, or discuss how the student could improve” (Froschauer and Bigelow, 2012, p.114). In this respect, the teacher not only graded the journals but also provided appropriate written feedbacks to each student in the journal writing group.

The feedback of the teacher on students’ journals contained different types of comments such as reminding the students to fit their answers to the expected content of the prompt, corrections on the wrong usage of some scientific terms, demanding for much more reflection about their thoughts in association with the concepts covered in the class and particularly asking for the reasons of their thoughts. In agreement with Piaget (1978), understanding science concepts entails to understand cause–effect relationships (Hong,

et al., 2014). Gunel *et al.*, (2009) pointed out that when students are asked to write to a teacher, they generally wrote explicitly by sharing big ideas and expect the teacher to be able to understand them. To overcome this problem, feedback of teacher played a critical role. Therefore, when students wrote didactic information related to concepts or they repeated facts presented during the lesson in their journals, the teacher wrote down such comments like “why do you think so?” or “you have to specify the cause-effect relationship”. Examples of some feedbacks can be seen in Appendix D.

Some other feedback statements provided by the teacher were as follows:

- It is nice! You have supported your ideas with evidence from the simulation experiment.
- Your explanation was very clear and included several supporting reasons.
- Instead of just writing the formula, you have to clarify what the formula tells us.
- I don't understand what you mean in this sentence/paragraph. Could you clarify it?
- So good! Your ideas are very creative and your writing is unique.
- You have to reflect more ideas from the content of the lesson.
- You have to associate your ideas with the concepts addressed in the class.

The teacher never corrected the nonscientific explanations of students with the correct ones; instead, underlined the nonscientific explanations of students and commented on those types of sentences by jotting down such comments:

- You have to revise your statements.
- You can read the relevant part in your book about this idea.
- You have to share and discuss this opinion with your friends and revise your statements.

Along with such comments above; the teacher avoided the didactic transmission of scientific explanations and knowledge to the students. Moreover, spelling, punctuation and grammar which are several conventions of writing were not taken into account for grading and were not corrected by the teacher. That is to say, these types of mistakes were

disregarded because corrections of such types of mistakes could spend hours trying to edit student work. More importantly, plenty of corrections related to grammar and spelling could discourage students from writing (Froschauer and Bigelow, 2012).

Each week, one or two concepts of electricity and magnetism were addressed in the class. Thus, the students in the journal writing group were required to write one journal per week. Thus, a total of 10 journals were written during the ten-week instruction. The list of journal topics can be seen in Table 3.6. The length of the journals was not limited with any numbers of words or pages.

Table 3.6. List of journal topics through 10 weeks instruction.

Week#	Physics Concept	Week#	Physics Concept
1	Electric charges	6	Rheostat
2	Conductors	7	Resistors in series
3	Insulators	8	Resistors in parallel
4	Electric force	9	Batteries in series
	Electric field		Batteries in parallel
5	Electric resistance	10	Electric power
	Ohm's law		Magnetic field of a Current

According to Baker (2003), a learning log or a journal can be examined every week or every other week. Hence, just after the students submitted their written journals, they were evaluated by the teacher in a week, and the evaluated and graded journals were returned to the students before the next class hour which is approximately one week later. Although it was occasionally very time consuming for the teacher to assess and provide written feedback to each journal, based on the research evidence (e.g., Butler and Nisan, 1986), it was an effective way to motivate students and help them learn. Each journal was graded over 20 points according to the rubric in the guideline (see Appendix B).

3.3.2. Predict-Observe-Explain (POE) Instruction

The second experimental group involved in only Predict-Observe-Explain (POE) instruction. All the POE activities were designed by the researcher, and they were entirely the same activities conducted for the POE-RJW group. So, such activities were administered in the same way to POE group as applied in POE-RJW group. Different from

the POE-RJW, the POE instruction did not include journal writing. Therefore, all the instructional pedagogies were completely the same with the POE-RJW instruction, except journal writing.

3.3.3. Traditional Instruction (TI)


While the students in the treatment groups carried out the POE-RJW instruction and the POE instruction respectively, the control group received the Traditional Instruction (TI) comprising lecturing, questioning, and solving drill-and-practice problems.

3.3.3.1. Lecturing. The driving force of the lessons was teacher explanations, and students were in listening position. They listened to the teacher and were not given permission to write anything while the teacher was speaking and writing on the board. Just after the teacher had finished writing and talking, they copied the notes written on the whiteboard into their notebooks. The students followed the MEB resource book, and they got this book ready throughout the lessons (Aydoğdu and Dedeoğlu, 2014).

3.3.3.2. Demonstrating Experiments. In the TI group, students were involved in the teacher designed demonstration experiments in order to understand scientific principles covered in the lesson. One of the demonstration experiments can be seen in Figure 3.2. The experiments were mostly carried out by the teacher instead of students' active participation. Therefore, they observed the teacher-conducted experiments passively. They had a chance to ask questions related to the experiments, and the teacher replied their questions.

3.3.3.3. Questioning. At the beginning of the lessons, students were asked several warm-up questions, and they verbally replied to the topic-related questions. Such questions were usually taken from the Grade 10 MEB physics book (see Figure 3.3). The purpose of these questions was to understand students' pre-knowledge associated with the related topic. Thus, there was a class environment in which students communicate with the TI teacher. Moreover, at the end of each lesson, the TI teacher usually summarized the concepts addressed in the class by asking questions to the students. Thus, the students were required to participate in summarizing the related concepts with their own words.


3.3.3.4. Solving Drill-and-Practice Problems. After teaching the relevant concepts, the numeric problems were solved on the board. The problems were selected both from the Grade 10 MEB textbook and from different sources including problems related to the topic. After a problem was written on the board, the students were given time to solve the problem on their notebooks. Generally the TI teacher solved the first or second problem on the board to show the students how to solve the problem. The other problems were solved by different students on the board.

 3. ETKİNLİK
ETKİYLE ELEKTRİKLENME

Sürtünme yoluyla yüklenmiş cam veya plastik çubuğu birbirine değmekte olan alüminyum kürelerden birine yaklaştırıp yakınında tutulurken küreleri birbirinden ayırarak yüklenmelerini sağlamaya çalışacağız.

Aşağıdakileri Yapalım


1. Dörder kişilik çalışma grupları oluşturalım. Aşağıdaki etkinlik basamaklarını okuyarak aramızda görev paylaşımı yapalım.
2. Alüminyum folyoları kullanarak yaklaşık 2 cm çapında iki adet küre yapalım.
3. Resim 2.11’de gösterilen araç ve gereçleri kullanarak askı düzeneğini kurup eşit uzunluktaki iplere bağlanmış folyo küreleri birbirine değecek biçimde Resim 2.12’deki gibi asalım.
4. Cam çubuğu ipek kumaşa sürterek kürelerden birinin yanına yaklaştıralım. Cam çubuk küre yakınında tutulurken kürelere dokunmadan, ipinden tutarak kürelerin birbirinden ayrılmasını sağlayalım.
5. İpek kumaşa sürtülmüş cam çubuğu kürelerden birine yaklaştırarak küreyi gözlemleyelim. Diğer küreye de yaklaştırıp gözlemleyelim. Gözlemlerimizi defterimize yazalım.



Resim 2.11: Etkinlikte kullanılacak araç ve gereç

ARAÇ VE GEREÇ

- 1 adet üçayak
- 2 adet destek çubuğu
- 1 adet bağlantı parçası
- Alüminyum folyo
- İplik
- Yünlü kumaş parçası
- İpek kumaş parçası
- Cam çubuk
- Plastik çubuk
- Strafor köpük parçası



Resim 2.12: Alüminyum folyo kürelere yükü çubuğun yaklaştırılması

Figure 3.2. Grade 10 MEB textbook, charging by induction experiment.

(Eğitim Bilişim Ağı, 2014)

3.4. Data Collection and Recording Procedures

Several data sources were used in the current study. All of these data sources were in written form. These written data sources included Electricity and Magnetism Conceptual Test (EMCT), Physics Motivation Questionnaire (PMQ), Journal Writing Survey (JWS) and field notes.

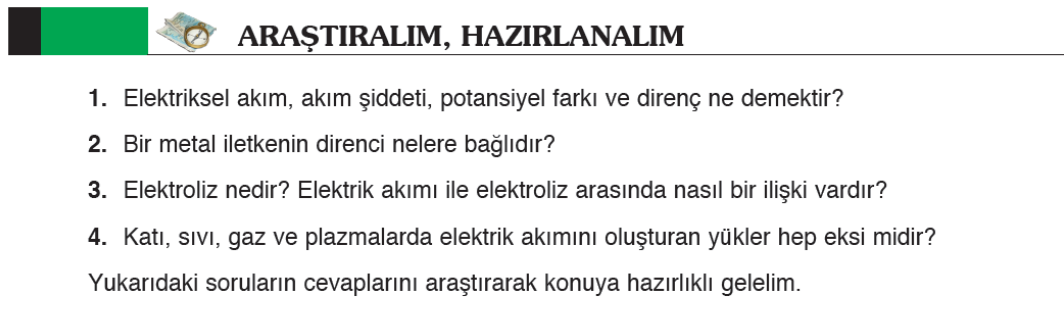


Figure 3.3. Grade 10 MEB textbook, the preparation questions for the concepts related to electricity. (Eğitim Bilişim Ağı, 2014)

Both Electricity and Magnetism Conceptual Test (EMCT) and Physics Motivation Questionnaire (PMQ) were administered in the fall of 2014-2015 academic year before and after a ten-week instruction for three different groups. While they were administered as a pretest one week before the instruction, they were administered as a posttest one week after the instruction. The EMCT test took 80 minutes to complete, whereas the PMQ took 15 minutes.

In addition to posttests, the journal writing group (POE-RJW) was asked to fill the JWS.

3.4.1. Electricity and Magnetism Conceptual Test (EMCT)

The questions of EMCT were adapted from the several instruments published in different articles that included conceptual understanding questions related to electricity and magnetism. Such instruments included: Conceptual Survey in Electricity and Magnetism (CSEM developed by Maloney *et al.*, 2001), Electrostatic Conceptual Test (Çirkinoğlu-

Şekercioğlu, 2011), Electric Conceptual Test (Karakuyu and Tüysüz, 2011), Elektrik ve Manyetizma Kavram Testi (Demirci and Çirkinoğlu, 2004) and Basit Elektrik Devreleri Başarı Testi (Şen and Eryılmaz, 2011). However, some of the questions in these sources were modified based on the purpose of this study.

EMCT was prepared by the researcher as a two-tier test to measure students' conceptual understandings of electricity and magnetism. Two-tiered tests are written assessments that both ask students for an answer to a problem, and also require students to explain the reasoning behind their answer. In two-tier tests, while the first tier can include an ordinary multiple choice question, the second tier contains a set of reasons for the given answer in the first tier (Peşman, 2005). Two-tier instruments have been used by many science educators to identify students' alternative conceptions (Treagust, 1988; Tan *et al.*, 2002). Additionally, by this way, the correct answers given by chance to the multiple choice questions were addressed.

In the Grade 10 physics curriculum of Turkey, there existed 13 different objectives in relation to electricity and magnetism unit. The content of EMCT items consisted of 8 objectives, but each objective was assessed more than once throughout the test to check if students were offering consistent responses regardless of the context of the test questions. The objectives included in the test and the corresponding items are shown in Appendix E.

EMCT questions were categorized into nine associated concepts that they cover in the context of electricity and magnetism. These six associated concept categories were (1) Conductors, (2) Insulators, (3) Coulomb Force, (4) Electric Field, (5) Electric Circuit, (6) Electric Current, (7) Electrical Resistance, (8) Electric Potential Difference and (9) Magnetic Field. The EMCT questions which were assigned into these categories were shown in Table 3.7 (see Appendix F for the details of the associated concepts).

3.4.1.1. Validity and Reliability Analysis of EMCT. To test the content and face validity of the EMCT, two physics teachers, two science education professors, one of whom specialized in physics education, and a graduate student in science education took part in the panel of experts. Moreover, two Turkish language teachers examined the questions in terms of linguistic aspects such as word selection, readability, punctuation and grammar.

Based on the opinions of the experts in the panel, some items were revised and reworded whereas some dropped out from the test. Thus, the pilot test consisted of 23 two-tier questions about electricity and magnetism. Along with a pilot test implementation to 82 Grade 11 students, three of the questions were dropped out from the test due to insufficient fulfillment of criteria in terms of item analysis. While two of these three questions had difficulty index (p-value) 0.06, one of them had a discrimination index below zero. Hence, the final version of EMCT comprised of 20 two-tier questions related to the relevant concepts in the unit. Whereas the average p-value for the total of questions included in EMCT was 0.49, the average discrimination index for the whole EMCT was 0.34. The final draft of EMCT test is available in Appendix G.

Table 3.7. Associated concepts and relevant EMCT questions.

#	Associated Concept	Related Question
1	Conductors	Q1
2	Insulators	Q2
3	Coulomb Force	Q3 and Q4
4	Electric Field	Q5
5	Electric Circuit	Q6 and Q10
6	Electric Current	Q7, Q11, Q12, Q13, Q19 and Q20
7	Electrical Resistance	Q8
8	Electric Potential Difference	Q9, Q14 and Q15
9	Magnetic Field	Q16, Q17 and Q18

Reliability indicates the consistency and the stability of the scores obtained from the instruments used in a research (Fraenkel and Wallen, 2006). An aim of a good research is to have measures that are reliable (Creswell, 2012). Therefore, researchers have to pay attention to the reliability issues in their research. The reliability analysis of the EMCT was performed with the data obtained from the actual study. Cronbach's alpha was calculated so as to check the internal consistency of the EMCT that indicates the average correlation among all of the items which forms the scale (Pallant, 2010). Reliability analysis was performed for only the first tier of EMCT which was a multiple choice question. Cronbach's alpha value was found to be 0.611 for the posttest scores. Therefore, the alpha value was found to be acceptable, because the alpha value suggested to be equal or higher than 0.6 (Akbulut, 2010).

Electricity and Magnetism Conceptual Test (EMCT) was scored by the teacher/researcher for data collection primarily. However, for the sake of inter-rater reliability, another physics teacher from the same school who did not teach any of the three groups was requested to score the data. To this end, 10 participants' papers were selected from each of the three groups and so, totally 30 papers were given to him to score. Since there were 30 papers, each including 20 items, the scores of 600 items were compared for both instructors. After the scored data, the scores of both instructors were compared with each other by calculating Cohen's Kappa (κ) which is an index of inter-rater reliability measuring the level of agreement between two scores (Wood, 2007). Cohen's κ was run to determine if there was an agreement between teacher/researcher and the other physics teacher in scoring the post EMCT. According to Wood (2007), there is a general agreement that Kappa should be at least .60 or .70. So it can be inferred that there was a substantial agreement between the two teachers' scores, $\kappa = .732$, $p < .0005$.

3.4.2. Physics Motivation Questionnaire (PMQ)

Physics Motivation Questionnaire was utilized to assess students' motivation to learning physics. The questionnaire was originally developed by Glynn *et al.* (2007) and Glynn *et al.* (2009). It was translated and adapted to Turkish as Chemistry Motivation Questionnaire (KMA) by İlhan *et al.* (2012). In this study, this Turkish version was modified to Physics Motivation Questionnaire (PMQ) by replacing the word "chemistry" to "physics". Thus, all the items remained the same except the word "chemistry" that changed to physics.

PMQ included 22 Likert-type items (see Appendix H). PMQ was conducted before and after the instruction. In terms of reliability, the reliability analysis was conducted for both pre and posttests. The items 4, 5, 10 and 13 which are negatively worded, were reversed before checking the reliability. The Cronbach alpha value was calculated to be 0.84 for the pretest, and it was found to be 0.89 in the posttest.

3.4.3. Journal Writing Survey (JWS)

One week after the POE-RJW instruction, students in the POE-RJW group were provided two pages of Journal Writing Survey (JWS) including three open ended questions to be answered. The aim of this survey was to understand the opinions and perceptions of students regarding the act of journal writing. So, students were given one week of time to submit the survey so that they can deeply think and reflect their thoughts thoroughly. The JWS is available in Appendix I.

3.4.4. Field Notes

Field notes are the notes researchers take in the field (Fraenkel and Wallen, 2006). In the current study, field notes were taken just after the lessons so as to remember and describe the incidents happened throughout the instruction, when needed. The researcher wrote the activities carried out in the class, method of instructions, types of assignments, learning materials, the POE tasks, some remarkable discussions and responses of students, creative ideas and questions probed by the students. Moreover, the challenging topics and unexpected events during the POE instruction (if occurred) were included in the field notes.

3.5. Data Analysis

The two major means of data collection in the current study included the EMCT and the PMQ instruments. Quantitative analysis was conducted on both of the tests. The additional data source was Journal Writing Survey (JWS), and it is used for supporting the findings of the study.

3.5.1. Coding of Electricity and Magnetism Conceptual Test

To analyze the data, Statistical Program for the Social Sciences (SPSS), version 18.0 was used. The students' responses to the first tier of the items in Electricity and Magnetism Conceptual Test (EMCT) constituted the raw data. The first tier of the items in EMCT included multiple choice questions. These questions included three to five choices. In

coding of raw data, a numeric point of 1 was given to the Choice A, a numeric point of 2 was given to the Choice B, a numeric point of 3 was given to the Choice C, a numeric point of 4 was given to the Choice D, and lastly a numeric point of 5 was given to the Choice E. For the second tier of the items, which asked for the reasoning given in the first tier, an answer key was developed. The raw data was recorded by assigning a numeric point 2 to the answers which were thoroughly correct; a numeric point 1 was assigned to the answers which were partially correct, and a numeric point 0 to the answers which were wrong or non-scientific.

Based on the given points for the first and second tier of items, five conditions occurred to calculate the total points for the items. Firstly, when both the first and second tier of the item was correct, a total point of 3 was assigned. Secondly, when the first tier was correct and the second one was partially correct, then a total point of 2 was assigned. Thirdly, in the case that the first tier was correct but the second one was wrong, then a total point of 1 was assigned. Fourthly, the case where the first tier was incorrect and the second one was correct, a numeric point 2 was assigned. Finally, the case in which both the first and the second tier was incorrect, a numeric point of 0 was assigned (see Table 3.8). Since EMCT comprised of 20 items, maximum total score was 60.

Table 3.8. Coding criteria for the items in EMCT.

Assessment Criteria (first-tier)	Point	Assessment Criteria (second-tier)	Point	Total Point
Correct answer	1	Correct answer	2	3
Correct answer	1	Partially correct	1	2
Correct answer	1	Wrong answer	0	1
Wrong answer	0	Correct answer	2	2
Wrong answer	0	Wrong Answer	0	0

3.5.2. Coding of Physics Motivation Questionnaire

Data was coded and analyzed by using SPSS Statistics version 18.0. There were 22 items in the PMQ. All the items were required to be responded on a five-point Likert-type scale of temporal frequency ranging from 1 (never) to 5 (always) where 5=always,

4=usually, 3=sometimes 2=rarely and 1=never. The items 4, 5, 10 and 13 which are related to the anxiety were reverse scored while coding the data. Therefore, the PMQ maximum total score was 110 and the minimum was 22. While higher scores on the PMQ indicated the high motivation, lower scores referred to the low motivation.

3.5.3. Statistical Analyses of Data

The first research question intended to investigate whether an improvement occurred or not in the students' conceptual understanding of electricity and magnetism in each group from pre to posttest. In pretest/posttest quasi-experimental designs, or when the samples are the matched pairs, a paired sample t-test is used (Pallant, 2010). Therefore, the first research question was analyzed by using a paired sample t-test. The following null hypothesis was tested by using the paired-sample t-test procedures:

- (i) There is no statistically significant mean difference in each group of students' conceptual understandings of electricity and magnetism before and after the instructions of POE-RJW, POE, and TI.

The research question 2(a), tested whether there is any difference or not between the three groups of students in terms of understanding the electricity and magnetism concepts before the instruction. Similarly, the research question 2(b), intended to identify whether there is a difference or not between the three groups in terms of understanding the electricity and magnetism concepts after the instruction. The one-way analysis of variance (ANOVA) is used to identify whether there are any significant differences between the means of three or more independent groups (Hinkle *et al.*, 2003). Therefore, the following two null hypotheses were tested by using the ANOVA procedures for the research questions 2(a) and 2(b) respectively:

- (ii) There is no statistically significant mean difference between the three groups of Grade 10 students' pretest scores in terms of understanding the electricity and magnetism concepts before engaging in POE-RJW Instruction, POE Instruction, or TI.

(iii) There is no statistically significant mean difference between the three groups of Grade 10 students' posttest scores in terms of understandings the electricity and magnetism concepts after engaging in POE-RJW Instruction, POE Instruction, or TI.

The third research question aimed to investigate whether an improvement occurred or not in the students' conceptual understanding of the associated concepts of electricity and magnetism from pre to posttest for the three groups of Grade 10 students who engaged in POE-RJW Instruction, POE Instruction, or TI. The percentages and frequencies of the answers of questions e associated with particular concepts in the pre and post-EMCT were calculated in order to detect the progression on the understandings of the students.

The fourth research question investigated whether a progression occurred or not in each group of students' motivation to learning physics from pretest to posttest. Thus, the fourth null hypothesis was tested by using the paired samples t-test:

(iv) There is no statistically significant mean difference in each group of Grade 10 students' motivation to learning physics before and after the instructions of POE-RJW, POE, and TI.

The research questions 5(a) and 5(b) aimed to test whether there was any difference or not between the three groups of students' motivation to learn physics before and after engaging in the instructions of POE-RJW, POE, and TI. The following two null hypotheses were tested using the ANOVA procedures:

(v) There is no statistically significant mean difference between the three groups of Grade 10 students' pretest scores in terms of motivation to learning physics before engaging in POE-RJW Instruction, POE Instruction, or TI.

(vi) There is no statistically significant mean difference between the three groups of Grade 10 students' posttest scores in terms motivation to learning physics after engaging in POE-RJW Instruction, POE Instruction, or TI.

3.6. Validity Issues

A significant consideration in planning and conducting a quasi-experimental research is the likelihood of threats to validity (Fraenkel and Wallen, 2006). Creswell (2012) reported the two types of threats that may generate uncertainty to make inferences from the results of the study which are internal and external validity threats. Internal threats are the most severe threats because they can compromise an otherwise good experiment (Creswell, 2012). Therefore, probable internal threats have to be taken into account and controlled by the researchers.

- **History:** Time passes between the beginning of the intervention and the end. In addition, there might be extraneous events between the pre and posttest that affect the dependent variable (Gay, Mills, and Airasian, 2006). In the current study, any unexpected events that influence the students' understanding of the electricity and magnetism concepts and their motivation to learning physics did not occur. In addition, the tests were administered to all three groups in the same week.

- **Maturation:** The results of a study can be affected due to the change or growth of participants such as becoming more experienced, older, and knowledgeable throughout the time period from pre to posttest (Creswell, 2012). In the current study, all the students in the three instructional groups were at the same grade level, and the time period of each instruction was the same for each group. Thus, maturation was not considered as a threat.

- **Selection:** Selection is a validity threat which refers to the selection of participants for the different groups in the study (Creswell, 2012). For example, participants of one group may be brighter than the ones in the other groups. To overcome this issue, subjects can be selected by random sampling. However, the participants of the current study were selected with regard to convenient sampling. Thus, a one-way analysis of variance (ANOVA) test was conducted on students' pretest scores, and it was investigated that there was no statistically significant difference between the three groups in terms of understanding the electricity and magnetism.

- **Mortality:** There may be likelihood to “lose” some of the participants throughout a study even they are selected carefully (Fraenkel and Wallen, 2006). For example, some of them may be ill or participate in other activities during the study whereby mortality threat occurs. There were a total of 145 students took the pretest at the beginning of the study. In the posttest, there were again a total of 145 students. However, 135 students’ test scores were used in the analysis. The reason is that 10 of the students did not take either the pre or the post-EMCT or the post-PMQ.

- **Testing:** Participants who were pretested at the beginning of an intervention may become aware of what may be about to take place or remember the answers for later testing (Fraenkel and Wallen, 2006). In the current study, students did not know whether they were going to take the same test as a posttest or not. Therefore, they did not attempt to memorize the questions. Students were not allowed to take the exam sheets with them. Moreover, the pretest questions and answers were not discussed in the class after the administration of the pretest. Since the time period between pre and posttest was 10 weeks, which is a long period of time to remember the questions, testing threat was eliminated. In addition, during this time period, students were not only concentrated on the physics lessons but they also focused on the other lessons.

- **Instrumentation:** If the instruments used in the pretest and posttest to measure the dependent variables were different, instrumentation threat to the internal validity of a study occurs (Fraenkel and Wallen, 2006). In the present study, the pretest and posttest items were completely the same as each other, whereby instrumentation threat was eliminated.

4. RESULTS

In this section, the findings were organized around the research questions. All of the research questions, except research question 3, involved the statistical analysis of the data within and across the groups, exploring students' conceptual understanding of the electricity and magnetism concepts in science. Thus, to answer the research question 3, the change in students' understanding of nine associated concepts of the electricity and magnetism from pre to post instruction is outlined by using the frequency and percentages together with the relevant tables and exemplary excerpts.

4.1. Findings Related to the Research Question 1

- Research Question 1: How does the conceptual understanding of electricity and magnetism differ from pre to posttest for the three groups of Grade 10 students who engaged in POE-RJW Instruction, POE Instruction, or TI?
- Null Hypothesis 1: There is no statistically significant mean difference in each group of students' conceptual understandings of electricity and magnetism before and after the instructions of POE-RJW, POE, and TI.

Students' conceptual understanding of electricity and magnetism was measured through the instrument named as "Electricity and Magnetism Conceptual Test" (EMCT). The maximum score that can be taken from EMCT was "60" and the lowest score was "0". The data from EMCT were coded and analyzed, and the scores of the three groups of students, namely POE-RJW group, POE group, and TI group, were identified. Then, a paired sample t-test was conducted to test whether there was any significant difference or not between the pre and post-EMCT scores of each group in terms of understanding the electricity and magnetism concepts after the interventions.

4.1.1. Comparison of the Pre and Post-EMCT Scores for the POE-RJW Group

The mean scores of the students, who engaged in POE-RJW instruction, on the pre and posttest are demonstrated in Table 4.1. The mean score of the POE-RJW group on pre-

EMCT was found to be $M=12.92$ ($SD=4.20$), while the mean of the post-EMCT scores was found to be $M=29.25$ ($SD=9.80$). As it can be easily realized, the post-EMCT scores of the POE-RJW group were higher than their scores in pre-EMCT. The highest score of the pre-EMCT was 25, and the lowest one was 6. On the other hand, the highest score of the post-EMCT was 51, and the lowest one was 12.

Table 4.1. The mean of the pre and post-EMCT scores of the POE-RJW group.

	Mean	N	Std. Deviation	Highest Score	Lowest Score
Pre-EMCT	12.92	39	4.20	25	6
Post-EMCT	29.25	39	9.80	51	12

Results from the paired sample t-test (see Table 4.2) showed that there was a statistically significant difference in EMCT mean scores of the POE-RJW group students from the pre-EMCT ($M = 12.92$, $SD = 4.20$) to the post-EMCT ($M = 29.925$, $SD = 9.80$), $t(38) = -9.76$, $p < 0.05$. The mean difference in pre and post-EMCT scores was 16.33 with a 95% confidence interval ranging from -19.71 to -12.94. Since the calculated p value ($t(38) = -9.76$, $p < 0.05$) was lower than the critical p value of 0.05; the null hypothesis was rejected.

Table 4.2. Results from the paired sample t-test on the pre-post EMCT mean scores of the POE-RJW group.

	Mean	Std. Deviation	t	df	Sig.(2-tailed)
Pre-EMCT Post-EMCT	-16.33	10.45	-9,76	38	.000

4.1.2. Comparison of the Pre and Post-EMCT Scores for the POE Group

In the context of the first research question, secondly, the POE group students' conceptual understandings of electricity and magnetism was examined. The mean scores of the POE group on the pre and posttest are demonstrated in Table 4.3. The mean score of the POE students on pre-EMCT was found to be $M=12.15$ ($SD=4.29$), whereas the mean of their post-EMCT scores was found to be $M=21.00$ ($SD=7.41$). That is, the post-EMCT scores of the POE group were higher than their scores in the pre-EMCT. While the highest score of the POE group on pre-EMCT was 26, the lowest one was 5. For the same group, the highest score was 46 on the post-EMCT, the lowest one was 8.

Table 4.3. The mean of the pre and post-EMCT scores of the POE group.

	Mean	N	Std. Deviation	Highest Score	Lowest Score
Pre-EMCT	12.15	59	4.29	26	5
Post-EMCT	21.00	59	7.41	46	8

In order to detect whether there was a statistically significant difference in the mean scores of the pre and post-EMCT or not, paired sample t-test was used. On the basis of the output of the paired sample t-test in SPSS (see Table 4.4), it can be inferred that there was a statistically significant difference in EMCT scores of the POE group from the pre-EMCT ($M = 12.15$, $SD = 4.29$) to the post-EMCT ($M = 21.00$, $SD = 7.41$), $t(58) = -9.78$, $p < 0.05$. The mean difference in EMCT scores was 8.85 with a 95% confidence interval ranging from -10.65 to -7.03. Since the calculated p value ($t(58) = -9.78$, $p < 0.05$) was lower than the critical p value of 0.05; the null hypothesis was rejected.

Table 4.4. Results of the paired sample t-test on the pre-post EMCT mean scores of the POE group.

	Mean	Std. Deviation	t	df	Sig.(2-tailed)
Pre-EMCT Post-EMCT	-8.85	6.94	-9,78	58	.000

4.1.3. Comparison of the Pre and Post-EMCT Scores for the TI Group

The mean scores of the TI group students on the pre and posttest are demonstrated in Table 4.5. The mean of the TI students' scores on pre-EMCT was found to be $M=11.29$ ($SD=3.58$), whereas the mean of their post-EMCT scores was found to be $M=19.48$ ($SD=6.46$). It can be recognized that the post-EMCT scores of the students in TI group were higher than their scores in the pre-EMCT. While the highest score of the TI students on the pre-EMCT was 19, the lowest one was 2. For the same group, on the post-EMCT, the highest score was 35, the lowest one was 5.

Table 4.5. The mean of the pre and post-EMCT scores of the TI group.

	Mean	N	Std. Deviation	Highest Score	Lowest Score
Pre-EMCT	11.29	37	3.58	19	2
Post-EMCT	19.48	37	6.46	35	5

In order to determine whether there was a statistically significant difference in the mean scores of pre and post-EMCT or not, paired sample t-test was used. On the basis of the output of the paired sample t-test in SPSS (see Table 4.6), it can be concluded that there was a statistically significant difference in EMCT scores of the TI students from pre-EMCT ($M = 11.46$, $SD = 3.57$) to post-EMCT ($M = 19.38$, $SD = 6.43$), $t_{(38)} = -6.54$, $p < 0.05$. The mean difference in EMCT scores was 7.92 with a 95% confidence interval ranging from -10.15 to -6.22. Since the calculated p value ($t_{36} = -8.45$, $p < 0.05$) was lower than the critical p value of 0.05; the null hypothesis was rejected.

Table 4.6. Results of the paired sample t-test on the pre-post EMCT mean scores of the TI group students.

	Mean	Std. Deviation	t	df	Sig.(2-tailed)
Pre-EMCT	-8.18	5.89	-8,45	36	.000
Post-EMCT					

Based on the analysis of the data for the first research question, the results indicated that all three groups of students, who engaged in three different types of instruction, improved their conceptual understanding of electricity and magnetism from pre to posttest. However, these results do not provide information about the magnitude of the interventional effect. Therefore, an effect size was calculated for each instructional group. One of the most commonly used effect size statistics for paired samples t-test is to calculate and interpret eta squared (Pallant, 2010). As shown in Table 4.7, the POE-RJW instruction effect size is 0.69; POE instruction effect size is 0.53, and Traditional instruction effect size is 0.52 as well. Cohen (1988) divided effect size values into three categories which are (1) values $< .06$ as small effect, (2) values in the range between 0.06 and 0.13 as moderate effect and (3) values $> .14$ as large effect. Based on the Cohen's guidelines to interpret the values, it can be concluded that there was a large effect for each type of instruction, with a substantial difference between the pre and post-EMCT scores.

Table 4.7. Effect sizes of the interventions on EMCT for the paired sample t-test.

	POE-RJW	POE	TI
Eta squared	.69	.53	.52

4.2. Findings Related to the Research Questions 2(a) and 2(b)

4.2.1. Comparison of the Pre-EMCT Scores between Three Instructional Groups

- Research Question 2(a): Are there any difference among the three groups of Grade 10 students in terms of their understandings of electricity and magnetism before engaging in POE-RJW Instruction, POE Instruction, or TI?
- Null Hypothesis 2(a): There is no statistically significant mean difference between the three groups of Grade 10 students' pretest scores in terms of understanding the electricity and magnetism concepts before engaging in POE-RJW Instruction, POE Instruction, or TI.

A one-way ANOVA was conducted to determine if the understanding of the electricity and magnetism concepts (pre-EMCT scores) was different across the three groups who engaged in POE-RJW Instruction, POE Instruction, or Traditional Instruction. Participants were divided into three groups with respect to their instruction types: POE-RJW (n=39), POE (n=59) and TI (n=37). The assumption of homogeneity of variances was met for the pre-EMCT data as assessed by Levene's test of homogeneity of variances ($p = .709$) (see Table 4.8). That is, all groups have the similar variance.

Table 4.8. Test of homogeneity of variances for the pre-EMCT scores.

Levene's Statistic	df1	df2	Sig.
.344	2	132	.709

The pre-EMCT score increased from the TI group (M=11.29, SD=3.58) to the POE group (M=12.15, SD=4.29), to the POE-RJW group (M=12.92, SD=4.20); but the differences between these instructional groups were not statistically significant, $F(2, 132) = 1.505$, $p=0.226$ (see Table 4.9).

Table 4.9. One-Way ANOVA results for the pre-EMCT scores.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	50.200	2	25.100	1.505	.226
Within Groups	2202.126	132	16.683		
Total	2252.326	134			

The group means were not statistically different ($p > .05$); therefore, we could not reject the null hypothesis.

4.2.2. Comparison of the Post-EMCT Scores between Three Instructional Groups

- Research Question 2(b): Are there any difference among the three groups of Grade 10 students in terms of their understandings of electricity and magnetism after engaging in POE-RJW Instruction, POE Instruction, or TI?
- Null Hypothesis 2(b): There is no statistically significant mean difference between the three groups of Grade 10 students' posttest scores in terms of understandings the electricity and magnetism concepts after engaging in POE-RJW Instruction, POE Instruction, or TI.

Similar to the data analysis of the pre-EMCT scores, for post-EMCT scores, a one-way ANOVA was conducted if the understanding of the electricity and magnetism concepts (post-EMCT scores) was different across the three groups who engaged in POE-RJW Instruction, POE Instruction, or TI. Again, participants were divided into three groups according to their instruction types: POE-RJW ($n=39$), POE ($n=59$), and Traditional instruction ($n=37$). The assumption of homogeneity of variance was met for the post EMCT data as assessed by Levene's test of homogeneity of variances ($p = 0.102$) (see Table 4.10).

Table 4.10. Test of homogeneity of variances for the post-EMCT scores.

Levene's Statistic	df1	df2	Sig.
2.328	2	132	.102

Based on the analysis of the post-EMCT data, it was found that there was a statistically significant difference across the post-EMCT mean scores of the three instructional groups, $F(2,132) = 17.552$, $p=0.000$ (see Table 4.11). The effect size, calculated using eta squared, was 0.210 that shows a large effect. Post Hoc comparisons using the Tukey HSD test indicated that the mean score for POE-RJW instruction group ($M=29.25$, $SD=9.80$) was significantly different from both POE group ($M=21.00$,

SD=7.41) and Traditional instruction group (M=19.48, SD= 6.46). The POE group (M=21.00, SD=7.41) did not differ significantly from TI group (M=19.48, SD= 6.46).

Table 4.11. One-Way ANOVA results for the post-EMCT scores.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2219.202	2	1109.601	17.552	.000
Within Groups	8344.679	132	63.217		
Total	10563.881	134			

Since the means across the groups were statistically significant different ($p < .05$), therefore, we rejected the null hypothesis and accepted the alternative hypothesis.

4.3. Findings Related to the Research Question 3

- Research Question 3: How does the conceptual understanding of the associated concepts of electricity and magnetism change from pre to posttest for the three groups of Grade 10 students who engaged in POE-RJW Instruction, POE Instruction, or TI?

The third research question aimed to explore whether an improvement occurred or not in the students' conceptual understanding of the associated concepts of electricity and magnetism from pre to posttest for the three groups of Grade 10 students who engaged in POE-RJW Instruction, POE Instruction, or TI. To this end, the EMCT questions were divided into nine associated concepts in relation to electricity and magnetism. These nine associated concepts were (1) conductors, (2) insulators, (3) coulomb force, (4) electric field, (5) electric circuit, (6) electric current, (7) electrical resistance, (8) electric potential difference, and (9) magnetic field. The EMCT questions which were assigned into these categories were shown in Table 3.7 in the previous chapter.

The frequency and percentage values were calculated for each question both for the pre-EMCT and the post-EMCT for the three groups of Grade 10 students who engaged in POE-RJW Instruction, POE Instruction, or Traditional Instruction. In the following subsections, percentages and frequencies of the answers of questions associated with

particular concepts in the pre and post-EMCT were given in order to take a closer look at the change in students' conceptual understanding of electricity and the magnetism.

Students' responses to each question in the EMCT on the pre and posttest were coded as zero "0" point, one "1" point, two "2" points and three "3" points based on the criteria in Table 3.8. Zero "0" point showed *no understanding* regarding the concept. One "1" point indicated that only the first tier of the question was correct, showing that the correct choice was marked for the multiple choice part but the second tier was not explained scientifically. Two "2" points represented that the second tier was explained scientifically with partially correct reasoning along with the correct answer to the first tier. Therefore, "2" points demonstrated a *partial conceptual understanding* of the concept assessed by the relevant question. The students who gave a wrong answer to the first tier along with a correct scientific explanation could also get two "2" points as well. However, there was only one student fitting into this case in the post-EMCT. Therefore, it was disregarded. Furthermore, three "3" points indicated a *complete conceptual understanding* displaying that the first tier was correctly marked beside the complete scientific explanation provided to the second tier.

4.3.1. Concept 1: Conductors

In Table 4.12, the frequencies and percentages of the three groups of students' scores for question 1 (Q1) can be seen. This question aimed to assess the understanding of "conductors" concept (see Appendix G). Before instruction, the number of the POE-RJW students who got "0" point from this question was 27 from among 39 students (69%). After the POE-RJW instruction, the number of these students decreased to 10 (26 %) showing that 17 of them (43 %) shifted toward more scientific understandings, obtaining at least "1" point. On the other hand, the frequency of the students who increased their scores from "0" to "1", "0" to "2" or "0" to "3" points in the POE and the TI groups was 14 (24 %) and 4 (10 %) respectively. In addition, it is remarkable that the percentage of the POE-RJW students who got at least "1" point on post-EMCT was 75%, but it was 51% and 41% for POE and TI groups, respectively. Moreover, neither the POE students nor the TI students could get "3" points in this question. In other words, there existed no student who demonstrated a *complete conceptual understanding* about "conductors" concept from the

POE or the TI group. On the other hand, in the post-EMCT, there existed one POE-RJW student who obtained “3” point in this question showing that he correctly answered both the multiple choice tier and also explained his reasoning scientifically in the second tier regarding “conductors” concept. The following excerpt represents the understanding of the student selected randomly from POE-RJW group on the post-EMCT:

“b- John Travolta deneyinde olduğu gibi iletken bir cisme yük geçerse yükler iletken cismin en uç noktalarına dağılıyordu. Burda cisim küre olduğu ve her noktanın merkeze uzaklığı aynı olduğu için kürenin dış yüzeyine eşit olarak dağılır. - As in John Travolta experiment, if a conductor is charged, the charges moves to the surface of the object. Here, the object is sphere on which every point is at equal distance to the center of the sphere. So the charges are distributed evenly over the outer surface of the sphere.”

Table 4.12. Frequencies and percentages of the questions related to concept 1 for the three instruction groups in the pre and post-EMCT.

Concept 1	Q#	Pre-EMCT						Post-EMCT						
		POE-RJW (n=39)		POE (n=59)		TI (n=37)		POE-RJW (n=39)		POE (n=59)		TI (n=37)		
		f	%	f	%	f	%	f	%	f	%	f	%	
Conductors	Q1	0	27	69	43	73	26	70	10	26	29	49	22	60
		1	8	21	16	27	11	30	19	49	22	37	14	38
		2	4	10	0	0	0	0	9	23	8	14	1	3
		3	0	0	0	0	0	0	1	3	0	0	0	0

Before the instructions, a large number of students in the pre-EMCT selected the choice C in the POE (27 %) and the TI (46%) groups. Similarly, a substantial number of students in the post-EMCT from these two groups kept selecting the same choice (POE: 26% and TI: 39%) which can be seen as an alternative conception that the charges were distributed over both the inner and outer surface of the sphere. Explanations to the second tier of Q1 that revealed alternative conceptions of students after the instructions were as follows:

“c- Dokundurma esnasında küre negatif yüklendiği için ve herhangi bir kutuplaşma olmadığı için yükler kürenin her yerine eşit bir şekilde dağılır.- Since the sphere is charged negatively at the moment of touching, and since there was no polarization, the charges are evenly distributed over every point of the sphere.” (POE_student)

“ c- ...yükler kürenin iç ve dış yüzeyine eşit oranda dağılır- ... charges were evenly distributed over both the inner and outer surface of the sphere.” (POE_student)

“c- Kürenin içi boş olduğundan yükler kürenin iç ve dış yüzeyine eşit oranda dağılır.- Since the sphere is hollow, charges were evenly distributed over both the inner and outer surface of the sphere.”(TI_student)

4.3.2. Concept 2: Insulators

In EMCT, the question 2 (Q2) intended to identify the understandings of students concerning the concept of “insulators” (see Appendix G). From the pre to post-EMCT, the number of students who got “0” point in the pre-EMCT decreased for POE-RJW (80 % to 41 %) and POE (86 % to 41 %) group as well. On the other hand, the number of students in the TI group who got “0” point increased from pre-instruction (73 %) to post-instruction (81%) unexpectedly (see Table 4.13). Besides, 10% of the POE-RJW students and 2 % of the POE students scored “3” points, respectively in the post-EMCT, showing that they demonstrated a *complete conceptual understanding* about the “insulators” concept. However, there was no student getting “3” points for this question among the TI students.

Here are two randomly selected students’ scientific explanations taken from the second tier of their answers for both the POE-RJW group and the POE group as well.

“a- I. doğrudur çünkü balonu kazağa sürme deneyinde yalıtkan cismin sadece sürtünen kısmında kalır yükler. II. yanlıştır çünkü yine aynı deneyde balon yalıtkindir fakat yüklenebilir. III. yanlıştır çünkü yüzey yükleri sıfır demek nötr cisim demektir ve bu daima sıfır değildir, değişebilir. – I. is correct because the charges on an insulated material stay on the rubbed surface as in the experiment of rubbing balloon to the sweater. II. is incorrect because again in the same experiment the balloon is insulator but it can be charged. III. is incorrect because zero surface charges means the material is insulator, and this is not always zero, it depends.” (POE-RJW_student)

“a- Yalıtkan bir maddenin yapısından dolayı yüklerin geçişi sağlanamaz bu yüzden yüklenemez, serbestçe hareket edemez. Madde yalıtkan olabilir ama yüzeyi yüklenebilir. Camın kazağa sürtüldüğünde yüklendiği gibi.- Because of the structure of an insulator the charges does not move from place to place, they can not be charged, the charges do not move freely. A substance can be an insulator but the surface of it can be charged. As in the example of rubbing a glass with a sweater.” (POE_student)

Table 4.13. Frequencies and percentages of the questions related to concept 2 for the three instruction groups in the pre and post-EMCT.

Concept 2	Q#	Pre-EMCT						Post-EMCT						
		POE-RJW (n=39)		POE (n=59)		TI (n=37)		POE-RJW (n=39)		POE (n=59)		TI (n=37)		
		f	%	f	%	f	%	f	%	f	%	f	%	
Insulators	Q2	0	31	80	51	86	27	73	16	41	24	41	30	81
		1	6	15	7	12	5	14	9	23	19	32	3	8
		2	2	5	1	2	5	14	10	26	15	25	4	11
		3	0	0	0	0	0	0	4	10	1	2	0	0

On the pre-EMCT, a considerable amount of students selected choice E (POE-RJW: 23%, POE: 34%, TI: 30%) for this question. Likewise, on the post-EMCT, a substantial number of students also selected the choice E from all the three groups (POE-RJW: 26 %, POE: 29%, TI: 49 %). Choice E states that an insulator cannot be charged and also the total surface charge is always zero. However, insulators can also be charged and the excess charge will remain at the initial location of charging. In addition, the particles of the insulator do not permit the free flow of electrons whereby the total surface charge may be different than zero. It appears that students had confusion about understanding the charge distribution on insulators and the properties of insulators as well. Explanations written by the students in the second tier of Q2 can be considered as alternative conceptions about insulators. Followings are the examples:

“e- Yalıtkan bir madde yüklenirse iletken olur. Yani iletir. Bu yüzden yüklenemez. Yalıtkan bir maddenin üzerindeki yükler sıfır olmasaydı madde yine iletken olurdu. Bu yüzden daima sıfırdır.-If an insulator is charged, it becomes conductor. That is, it conducts. So it is not charged. If the charges on a substance were not zero, again the substance would have been a conductor. So, it is always zero.”(TI_student)

“e- Hepsi doğrudur çünkü; yalıtkan bir madde üzerinde yükler hareket edemez. Yük alışverişi olmaz. Hiçbir şekilde değişiklik olmaz.-All of them are correct, because the charges cannot move on an insulator. No charge transfer exists. There exist no changes in any way.”(POE_student)

4.3.3. Concept 3: Coulomb Force

Students’ understandings of the “coulomb force” concept were assessed by the question 3 (Q3) and question 4 (Q4) together (see Appendix G). From the pre to post-EMCT, the percentage of students scoring “0” point for Q3 decreased both for POE-RJW

(44% to 13%) and for the TI group (35% to 5 %) (see Table 4.14). However, interestingly there was no decrease in the ratio of students in POE group scoring “0” points (20 % remained the same from the pre to post-EMCT). It is also noteworthy that the percentage of students who scored “3” points was high and almost the same for the three groups of students (POE-RJW: 62%, POE: 66% and TI: 60%, respectively). In relation to Q4, the number of students who scored “0” point in the pre-EMCT was 49 (83%). Interestingly, similar to the findings of Q3, the number of students scoring “0” remained nearly the same in the post-EMCT (80%) only for POE group. On the other hand, the number of students scoring “0” in the post-EMCT decreased for both POE-RJW group (87% to 67%) and TI group (83% to 73%). When the three groups of students were taken into consideration for Q4 in the post-EMCT, all of them demonstrated a low level of conceptual understanding in a way that the number of students scoring “0” was noticeably very high for all of them (POE-RJW: 67%, POE: 80% and TI: 73%, respectively).

Table 4.14. Frequencies and percentages of the questions related to concept 3 for the three instruction groups in the pre and post-EMCT.

Concept 3	Q#	Pre-EMCT						Post-EMCT						
		POE-RJW (n=39)		POE (n=59)		TI (n=37)		POE-RJW (n=39)		POE (n=59)		TI (n=37)		
		f	%	f	%	f	%	f	%	f	%	f	%	
Coulomb Force	Q3	0	17	44	12	20	13	35	5	13	12	20	2	5
		1	4	10	28	48	18	49	7	18	6	10	7	19
		2	5	13	9	15	1	3	3	8	2	3	6	16
		3	13	33	10	17	5	14	24	62	39	66	22	60
	Q4	0	34	87	49	83	35	95	26	67	47	80	27	73
		1	4	10	6	10	2	5	1	3	4	7	4	11
		2	0	0	1	2	0	0	0	0	0	0	2	5
		3	1	3	3	5	0	0	12	31	8	14	4	11
Total (Average)	0		65		52		65		40		50		39	
	1		10		29		27		10		9		15	
	2		6		9		1		4		2		11	
	3		18		11		7		46		40		35	

In addition to the frequency and percentage values of Q3 and Q4 one by one, the average percentage values of Q3 and Q4 was calculated so as to identify students' understandings about the “coulomb force” concept (see Table 4.14). On the post-EMCT, the number of students scoring either “0” or “3” was very high for all the three groups (40% and 46% for POE-RJW, 50% and 40% for POE, and 39% and 35% for TI, respectively), whereas the number of students scoring “1” or “2” was very low across the

instructional groups (14%, 11%, 26%, respectively). The three groups of demonstrated either *no understanding* or *complete conceptual understanding* about the “coulomb force” concept.

When the responses to this question were considered, some of students’ alternative conceptions were revealed. On the pre-EMCT, a large number of students selected choice D (POE-RJW: 57%, POE: 37%, and TI: 31%). After the instructions, they overly kept selecting the choice D (POE-RJW: 49%, POE: 46%, and TI: 32%). They thought that the magnitude of the force on +4Q charge was four times bigger than the magnitude of the force on +Q charge.

The following excerpt shows the alternative conception about the Coulomb force assessed by Q4 after instruction:

“+Q yükünün değeri +4Q dan dörtte bir oranında küçük olduğu için +Q nun +4Q ya uygulayacağı kuvvet de dörtte birine iner.-Since the value of +Q charge was 1/4 of +4Q charge, the force of the +Q exerting on the +4Q will be four times smaller than the force of +4Q exerting on the +4Q.”(TI_student)

The following excerpt is an example of scientific explanation given by a POE-RJW student for Q4:

“İki cisim de yükleri ne olursa olsun birbirlerine aynı kuvveti uygularlar. Yükün değeri 4 katına çıktığı için 4F olur.- Whatever the magnitude of their charges was, they exert the same force to each other. Since the magnitude of charge increased up to four times, the force will be equal to 4F.” (POE-RJW_student)

4.3.4. Concept 4: Electric Field

The “electric field” concept was assessed by the question 5 (Q5) in EMCT (see Appendix G). As can be seen in Table 4.15, the percentage of students who got “0” point showing *no understanding* about this concept in the pre-EMCT was very high for all three groups (POE-RJW: 77%, POE: 85% and TI: 89% respectively). Following the instructions, the percentage of students who scored “2” points (showing *partial conceptual understanding*) was higher for the POE-RJW group (33%) compared to the percentage of students in the POE (2%) and the TI (3%) group.

Table 4.15. Frequencies and percentages of the questions related to concept 4 for the three instruction groups in the pre and post-EMCT.

Concept 4	Q#	Pre-EMCT						Post-EMCT						
		POE-RJW (n=39)		POE (n=59)		TI (n=37)		POE-RJW (n=39)		POE (n=59)		TI (n=37)		
		f	%	f	%	f	%	f	%	f	%	f	%	
Electric Field	Q5	0	30	77	50	85	33	89	18	46	43	73	32	87
		1	8	21	9	15	3	8	7	18	15	25	4	11
		2	1	3	0	0	1	3	13	33	1	2	1	3
		3	0	0	0	0	0	0	0	0	0	0	0	0

Additionally, there was no student in any of the three groups who got “3” points for this question assessing the “electric field” concept. Furthermore, when cross tabulation was performed for this question on the pre-EMCT, the percentages of choice A marked by the students were very high for all the three groups (POE-RJW: 65%, POE: 68% and TI: 72%). Similarly the choice A was also selected primarily by the students on the post-EMCT (POE-RJW: 40%, POE: 57% and TI: 75%). Therefore, the explanations written to this choice were considered as an alternative conception of students regarding the concept of “electric field”. The following excerpts represent how some students thought unscientifically about the electric field at the center of the sphere. The students specified that:

“a- Yük sağdan getirildiği için merkezdeki yükü zıt yönde itecektir- Since the charge is brought up from the right side; it will repulse the charges at the center to the left side” (POE_student)

“a- Artı yüklü küreye artı yük yaklaştırırsak iter birbirini. Bu yüzdende sağ taraftan yaklaştırdığımız için sol tarafa doğru itecektir.- If positive charge is brought up near the sphere they repel each other. Since, we brought up from the right side, they will repel to the left side.” (POE_student)

4.3.5. Concept 5: Electric Circuit

The “electric circuit” concept was assessed by the combination of question 6 (Q6) and question 10 (Q10) in EMCT (see Appendix G). For Q6, the number of students who scored “0” point showing *no understanding* in the pre-EMCT was 7 (18%), 16 (27%), and 5 (14%) for the POE-RJW, POE, and TI groups, respectively (see Table 4.16). Following the instructions, the number of students who still held *no understanding* was very few for

all the groups (3%, 3% and 5%, respectively). In other words, the students in all the groups improved their understanding about making an analogy between electric circuit and the water pipe system in the buildings. Yet, the number of the POE-RJW students who scored “3” points in Q6 (28%) was greater than the number of the POE (5%), and the TI students (3%).

Table 4.16. Frequencies and percentages of the questions related to concept 5 for the three instruction groups in the pre and post-EMCT.

Concept 5	Q#	Pre-EMCT						Post-EMCT						
		POE-RJW (n=39)		POE (n=59)		TI (n=37)		POE-RJW (n=39)		POE (n=59)		TI (n=37)		
		f	%	f	%	f	%	f	%	f	%	f	%	
Electric Circuit	Q6	0	7	18	16	27	5	14	1	3	2	3	2	5
		1	19	49	28	48	23	62	9	23	21	36	19	51
		2	13	33	13	22	8	22	18	46	33	56	15	41
		3	0	0	2	3	1	3	11	28	3	5	1	3
	Q10	0	23	59	40	68	21	57	10	26	20	34	4	11
		1	11	28	16	27	14	38	9	23	25	42	24	65
		2	1	3	0	0	0	0	5	13	3	5	0	0
		3	4	10	3	5	2	5	15	39	11	19	9	24
Total (Average)	0		38		47		35		14		19		8	
	1		38		37		50		23		39		58	
	2		18		11		11		30		31		20	
	3		5		4		4		33		12		14	

Q10 was asked to detect students’ understandings about the parallel connected circuits involving one battery and two light bulbs (see Appendix G). As shown in Table 4.16, the number of students scoring “0” point decreased in all of the three groups (POE-RJW: 59% to 26%, POE: 68% to 34%, and TI: 57% to 11%). The percentage of students exhibiting complete conceptual understanding was higher for the POE-RJW group (39%) compared to the POE (19%) and TI (24%) groups. When students’ answers to Q10 were taken into account, the percentage of students selecting the choice C on the pre-EMCT was very high for all the three groups (POE-RJW: 58%, POE: 44% and TI: 43%). In choice C, the circuit in figure A was not considered as a parallel connected circuit including two parallel bulbs and one battery. Therefore, students’ explanations to the second tier of Q6 can be thought as alternative conceptions of students concerning electric circuits. Some alternative conceptions excerpted from students’ answers were as follows:

“c- C’dir çünkü bir adet anahtara ve iki adet lambaya sahiptir. C şeklini sağa döndürdüğümüzde lambaların paralel olduğunu görürüz-The answer is C because it

has two bulbs and one switch. If the shape C is rotated to the right side, we will see that the lambs are parallel.” (POE-RJW_student)

“c-...Paralel olması aynı hizada değil de üst üste olması gibidir.- ...Parallel means not being in the same line instead being one on the top of the other.” (POE-RJW_student)

“c-Tek paralel devre C devresidir.- C is the only parallel connected circuit.” (POE_student)

To identify students’ understanding of the “electric circuit” concept, the average of percentage values for Q6 and Q10 were calculated. As can be seen in Table 4.16, the number of students who scored “0” decreased for all the groups after instructions. (POE-RJW: 38% to 14%, POE: 47% to 19%, and TI: 35% to 8%). That is to say, all of the groups showed a fair improvement in terms of understanding the “electric circuit” from the pre to post-EMCT. However, the percentage of students who showed at least *partial conceptual understanding* on the post-EMCT was higher for POE-RJW (63%) group than the POE (43%) and TI (34%) groups.

4.3.6. Concept 6: Electric Current

In EMCT, “electric current” concept was assessed by the combination of six questions: question 7 (Q7), question 11 (Q11), question 12 (Q12), questions 13 (Q13), question 19 (Q19), and question 20 (Q20) as well. As shown in Table 4.17, the number of students scoring “0” point from Q7 on the pre-EMCT conceivably decreased for all three groups after the interventions (POE-RJW: 59% to 21%, POE: 51% to 27%, and TI: 62% to 57%). A noticeable percentage of the TI students (57%) seemed to be confused about how a rheostat changes the current and the brightness of bulbs in an electric circuit.

Q11 was asked to identify students’ understandings about the magnitude of electric current flowing through a series connected circuit (see Appendix G). As can be seen in Table 14.7, although the number of students scoring “0” point from the POE-RJW and the POE groups decreased from the pre to post-EMCT (POE-RJW: 77% to 44%, POE" 70% to 61%, respectively), this number increased for the TI group (57% to 81%).

Table 4.17. Frequencies and percentages of the questions related to concept 6 for the three instruction groups in the pre and post-EMCT.

Concept 6	Q#	Pre-EMCT						Post-EMCT						
		POE-RJW (n=39)		POE (n=59)		TI (n=37)		POE-RJW (n=39)		POE (n=59)		TI (n=37)		
		f	%	f	%	f	%	f	%	f	%	f	%	
Electric Current	Q7	0	23	59	30	51	23	62	8	21	16	27	21	57
		1	13	33	19	32	11	30	24	62	25	42	13	35
		2	3	8	10	17	3	8	6	15	16	27	3	8
		3	0	0	0	0	0	0	0	1	3	2	3	0
	Q11	0	30	77	41	70	21	57	17	44	36	61	30	81
		1	7	18	13	22	13	35	1	3	8	14	2	5
		2	0	0	2	3	3	8	0	0	3	5	0	0
		3	2	5	3	5	0	0	21	54	12	20	5	14
	Q12	0	24	62	44	75	28	76	7	18	22	37	8	22
		1	12	31	11	19	6	16	5	13	21	36	14	38
		2	3	8	4	7	3	8	16	41	8	14	10	27
		3	0	0	0	0	0	0	11	28	8	14	5	14
	Q13	0	31	80	42	71	22	60	18	46	32	54	8	22
		1	3	8	13	22	10	27	4	10	13	22	12	32
		2	3	8	3	5	5	14	3	8	4	7	7	19
		3	2	5	1	2	0	0	14	36	10	17	10	27
	Q19	0	16	41	17	29	23	62	7	18	8	14	12	32
		1	19	49	39	66	10	27	10	26	34	58	20	54
		2	2	5	3	5	4	11	11	28	12	20	4	11
		3	2	5	0	0	0	0	11	28	5	9	1	3
	Q20	0	29	74	50	85	33	89	23	59	43	73	21	57
		1	4	10	7	12	3	8	4	10	11	19	3	8
		2	2	5	0	0	0	0	1	3	0	0	0	0
		3	4	10	2	3	1	3	11	28	5	9	13	35
	Total (Average)	0		65		63		68		34		44		45
		1		25		29		24		21		32		29
		2		6		6		8		16		12		11
		3		4		2		0		29		12		15

The number of students selecting choice C for Q11 was very high for all the groups before and after the instructions (POE-RJW: 77% and 39%, POE: 62% and 58%, TI: 51% and 76%). Choice C states that the magnitude of the current flowing through a circuit including one series connected bulb to a battery is equal to the one when one more bulb is connected in series. However, doubling of the total resistance serves to halve the current in the circuit. Therefore, the explanations given to the second tier of Q11 can be thought as alternative conceptions in relation to “electric current” concept in a series connected circuit. The following excerpts represent students’ various alternative conceptions in relation to this concept on the post-EMCT:

“c-Seri bağlı devrelerde $I=I_1=I_2$ olduğu için her ikisinde de eşittir.-Since in series connected circuits the equation $I=I_1=I_2$ is true, both of the currents were equal.”(TI_student)

“c-Aynıdır, çünkü o noktaya gelene kadar hiçbir dirençle karşılaşmaz.-They are the same, because up to that point, current encounters no resistance.” (TI_student)

“c-Her ikisinde de eşittir. Çünkü 1 noktasında akım bir dirençle karşılaşmamıştır.-Both are equal, because current does not encounter any resistance at point 1.” (TI_student)

“c- ‘1’ noktasından önce her iki devrede de bir direnç olmadığı için akımlar aynıdır.- Since there exist no resistance before point ‘1’ for both of the circuits, the currents are equal.” (TI_student)

“c-Her iki şekilde eşittir. Çünkü henüz bir dirence denk gelmemiştir.- In both shapes they are equal because the current meets no resistance yet.” (POE-RJW_student)

Q12 was asked to discover students’ understandings about both the magnitude of current flowing through a series circuit and also the brightness of the series connected bulbs (see Appendix G). As can be seen in Table 4.17, a large number of students from all three groups improved their scores from the pre to post-EMCT. The percentage of the POE-RJW students exhibiting *complete conceptual understanding* (28%) on the post-EMCT was two times higher than the percentage of both POE (14%) and TI groups (14%). It was also remarkable that the majority of the students (38% of whole students) selected the choice C on the pre-EMCT, indicating that the current at point 1 is greater than the one at 2, and the current at point 2 is greater than the one at point 3 ($i_1 > i_2 > i_3$) and also bulb B is brighter. But, the current is everywhere the same within the electric circuit given in Q12. Therefore, students’ explanations provided for the choice C can be considered as alternative conceptions of students. Many of them thought that charge becomes used up as it flows through a circuit or the amount of charge that exits a light bulb is less than the amount that enters the light bulb. Below are some student excerpts from each group:

“c- Akım dirençten sonra azalır. Bu yüzden B ampulu A’dan az parlak yanar.- The current decreases after resistance. Therefore, the lamp B will be less brighter than A. (POE-RJW_student)

“c- Akım her noktada dirence uğrar. O yüzden giderek azalır...-The currents encounters with resistance at every point. Therefore, it gradually decreases...” (POE_student)

“c- $i_1 > i_2 > i_3$ olması lazım. Ampullerden geçen akım azalır...- it should be $i_1 > i_2 > i_3$. The current flowing through the bulbs decreases...” (TI_student)

Q13 was another current flow question. Yet, at this time, students were required to rank the currents at different points of parallel connected bulbs in a circuit (see Appendix G). From the pre to post-EMCT, the number of students who incorrectly responded to both tiers in Q13 diminished for all three groups (POE-RJW: 80% to 46%, POE: 71% to 54%, TI: 60% to 22%). However, the number for both POE-EJW (46%) and POE (54%) groups were still high, demonstrating that the students in these groups had *no understanding* about the concept in the post-EMCT. On the other hand, the number of students scoring “3” point was greater on the POE-RJW group (36%) compared to the POE (17%) and TI (27%) group on the post-EMCT. The students dominantly selected choice E in Q13 both on the pre-EMCT and also on the post-EMCT (POE-RJW: 26% and 41%, POE: 16% and 40%, TI: 18% and 11%, respectively). In this framework, the explanations written to the second tier of this question can be considered as alternative conceptions of students. Predominantly, the alternative conception that “the current is everywhere, and it is the same in parallel connected circuits”, can be seen in students’ explanations from all three groups on the pre-EMCT as in the following excerpts:

“e- Paralel bağlamada herhalde her yerde akım eşit oluyordu.- In parallel connection, presumably, the current was the same everywhere.” (POE-RJW_student)

“e- Çıkan akım her yere eşit dağılır.-The current is distributed everywhere the same.” (POE_student)

“e- Akım paralel düzeneklerde eşit geçer. The current flows equally in parallel circuits (TI_student)

Similar to the explanations on the pre-EMCT, on the post-EMCT, many students held onto their alternative conceptions about the distribution of current in a parallel circuit as can be seen in the following excerpts:

“e- Paralel bağlı devrelerde akım eşit dağılır. Böylece akım hepsinde aynı hesaplanır- In parallel connected circuits, the current is distributed uniformly. So, the current is calculated as the same in all of them.” (POE-RJW_student)

“e- Akım bir azalmaya uğramaz, eşittir-The current does not diminish, it is equal.”(POE_student)

“e- Akım aynıdır, değişmez.-The current is the same, it does not change.”
(TI_student)

Q19 intended to detect students’ conceptions about how the brightness of bulbs differs in a parallel connected circuit. Although the students in all three groups improved their understandings from the pre to post-EMCT, the percentage of the POE-RJW students (28%) who showed *complete conceptual understanding* was greater than the POE (9%) and TI group (3%).

The last question assessing “electric current” concept was Q20 which provided insights into students’ understandings of the electric current passing through the series connected resistors. The number of students who scored “0” point in this question was very high for all three groups on the pre-EMCT (POE-RJW: 74% POE: 85%, and TI: 89%). Similarly, after the instructions, the number of students exhibiting *no understanding* was also high on the post-EMCT (POE-RJW: 59% POE: 73%, and TI: 57%). The incorrect choice marked by the students was the choice B with a high ratio both on the pre and post-EMCT (POE-RJW: 44% and 21%, POE: 40%, and 46%, TI: 52% and 28%, respectively). Choice B states that the magnitude of the current on each series connected bulb is inversely proportional to the magnitude of their resistance. Although this idea is true in terms of Ohm’ law (the greater the resistance, the less the current), it was not applicable for the series connected bulbs. In this context, the students’ explanations to the second tier of this question can be seen in the following excerpts.

“b-Direnci az olana, akım daha çok gider.- The current goes much more to the one which has less resistance.(POE-RJW_student)

“b-Direnci küçük olanın akımı daha fazla olur.- The less resistance one has, the more current it has.”(POE-RJW_student)

“b- Akım direnci az olan yerden daha fazla geçer.-The current passes through much more from the low resistance.” (POE_student)

“b-Direnç küçükse, akım fazla geçer- If the resistance is low, more current passes through.” (POE_student)

“b-Akımlar dirençlerle ters orantılı olduğu için sıralamalar bu şekilde olur.-Since there is a inverse proportion between the currents and resistors, the ranking will be like that.”(TI_student)

“b-Direnç artarsa akım azalır.- If the resistance increases, the current decreases.”(TI_student)

In order to recognize students’ understanding of the “electric current” concept as a whole in EMCT, the average of percentage values for the set of Q7, Q11, Q12, Q13, Q19, and Q20 were calculated. As shown in Table 4.17, there was an improvement in terms of understanding the “electric current” concept. When the percentages of three groups were taken into account, the percentage of students showing *complete understanding* on the post-EMCT was greater in the POE-RJW (29%) group compared to the POE (12%) and TI (15%) group.

4.3.7. Concept 7: Electrical Resistance

Question 8 (Q8) in EMCT addressed the variables affecting the electrical resistance. On the pre-EMCT, high percentage of students in all the three groups scored “0” (POE-RJW: 82%, POE: 85% and TI: 92% respectively) in this question showing *no understanding* about the “electrical resistance” concept (see Table 4.18). After the instructions, the percentage of students scoring “0” point decreased nearly in the same ratio (about 30 %) for the students in POE-RJW (82% to 51%) and POE (85 % to 51%) group. However, the decrease in percentage ratio was about 20% for the TI group. Although a few number of students among from both the POE-RJW (5%) and the POE (12%) group scored “3” points in Q7, there was no student getting “3” points in this question in the TI group.

Table 4.18. Frequencies and percentages of the questions related to concept 7 for the three instruction groups in the pre and post-EMCT.

Concept 7	Q#	Pre-EMCT						Post-EMCT						
		POE-RJW (n=39)		POE (n=59)		TI (n=37)		POE-RJW (n=39)		POE (n=59)		TI (n=37)		
		f	%	f	%	f	%	f	%	f	%	f	%	
Electrical Resistance	Q8	0	32	82	50	85	34	92	20	51	30	51	27	73
		1	4	10	7	12	1	3	12	31	18	31	10	27
		2	1	3	1	2	1	3	5	13	4	7	0	0
		3	2	5	1	2	1	3	2	5	7	12	0	0

On the pre-EMCT, a considerable number of students from all the groups selected choice E (POE-RJW: 58%, POE: 63% and TI: 68%), which states that immediately after

the switch is opened, the resistance goes to zero. The resistance of the bulb is affected by three variables including the total length of the wire, cross-sectional area of the wire and the material that a wire is made of. But, all of these variables remained same in the wire of the bulb when switch is opened, indicating that the resistance also remains same, not goes to zero. Similarly the number of students selecting this choice was also large on the post-EMCT for all the three groups (POE-RJW: 37%, POE: 40% and TI: 73%). In other words, the majority of the students perceived the resistance as a direct function of both current and potential difference. For that reason, the explanations given to the second tier of Q8 can be considered as alternative conceptions. The students in all three groups wrote similar explanations regarding the change in the electrical resistance:

“e- Akım kesileceğinden sıfırlanır.- Since the current will be cut off, the resistance goes to zero.”(TI_student)

“e- Anahtar kapalıyken akım olmadığı için lambanın etkin bir direnci yoktur. Ancak anahtar açıldıktan sonra otomatik olarak direnç ortaya çıkar.- Since there is no current when the switch is closed, the bulb does not have an active resistance. But, just after the switch is opened, the resistance automatically appears.”(POE_student)

“e- Devreden akım geçmeyeceği için lamba bir direnç uygulamaz.- Since there is no current flow in the circuit, the bulb does not apply a resistance.” (POE-RJW_student)

4.3.8. Concept 8: Electric Potential Difference

On the EMCT, “electric potential difference” was assessed by the questions comprising question 9 (Q9), question 14 (Q14), and question 15 (Q15). Q9 involved the potential difference between the two terminals of a battery; requiring students consider how it is affected when one more resistor connected to the circuit (see Appendix G). On the pre-EMCT, the number of students scoring “0” in Q9 was very high for all three groups (POE-RJW: 62%, POE: 70 % and TI: 78%). Expectedly, these numbers exhibiting *no understanding* decreased after the instructions (POE-RJW: 36%, POE: 59 % and TI: 27%). The percentage of the POE-RJW students scoring “3” points (33%) in Q9 was greater than the POE (12%) and the TI (24%) groups. The number of students selecting choice B totally was 66 (50% of whole students) on the pre-EMCT. Similarly, choice B was again the most selected choice by the students (30% of all students) on the post-EMCT. Therefore, it can be inferred that the explanations composed to the second tier of Q9 can be assumed as

alternative conceptions. Here are some excerpts from the post-EMCT revealing alternative conceptions:

“b- Normalde şekil I’de bir lamba kullanırken, şekil II’de iki lamba kullanacağından pilin potansiyel farkı azalacaktır.- Normally, while one bulb use up the voltage in figure I; in figure II two bulbs will use up the potential difference indicating that it will decrease.”(POE_student)

“b-Azalur çünkü direnç artar.- It decreases because the resistance increases.”(POE_student)

“b- Çünkü devreden geçen direnç artar bu yüzden potansiyel fark azalur.-Since the resistance in the circuit increases, the potential difference decreases.” (POE_student)

“b-...yeni bir direncin gelmesi...potansiyel fark sadece pil daha fazla harcama yapığı için azalur.-... one more connected resistor...potential difference decrease because only the battery will consume much more.”(POE-RJW_student)

Q14 also assessed students’ understanding of “potential difference”. They were asked to rank the potential difference between two different points in three different connected circuits (see Appendix G). Although none of the students in all of the groups scored “3” points in pre-EMCT, it was remarkable that the number of students showing *complete understanding* was greater for the POE-RJW (31%) compared with the POE (12%) and the TI (3%) groups on the post-EMCT. The most selected choice on the pre-EMCT was choice E (POE-RJW: 41%, POE: 39%, and TI: 50% = 42% of all students) that revealed some alternative conceptions. On the post-EMCT, the most selected incorrect choice was again choice E (28 % of whole students). It seemed that the explanations given to the second tier of Q14 included some alternative conceptions. Below are the students’ responses that show the alternative conceptions about potential difference between any two different points in circuits after the instructions:

“e- Devre II ve III’te 2 pile 2 lamba düşüyor o yüzden.-“In circuit II and III, there are two bulbs per two batteries so.”(POE_student)

“e- II. ve III. devrelerde 2 üreteç, 2 lamba olduğundan birbirlerine eşittir (potansiyel fark). I’in ise daha azdır.- In the circuits II and III, since there are two batteries and two light bulbs they are equal (potential difference). However, I is lesser.” (POE-RJW_student)

The last question assessing the “electric potential difference” was Q15; requiring students’ understandings about determining the equivalent voltage across the components of the given circuits (see Appendix G). As can be seen in Table 4.19, the students in all of the three groups showed a progression in understanding this concept. But at the post-EMCT, in terms of scoring “3” points, the percentage of POE-RJW students (31%) was greater than the POE (20%) and the TI (3%) students. Examination of cross-tabulation between the groups and this question on the pre-EMCT revealed that 29 of 135 (22%) students selected the choice A. This led to the inference that students’ explanations to the second tier of Q15 can be thought as alternative conceptions. Here are two sample excerpts from students’ explanations on the post-EMCT:

“a-I’ de iki üretecin yönü aynı, II de bir üreteç var, III’te üreteçlerin yönü birbirine zıt. Bu yüzden $I > II > III$. – In circuit I, the direction of the batteries are equal. In II there exists one battery. In the circuit III, the directions of batteries are opposite to each other. So, $I > II > III$.” (POE_student)

“a- I’de pil fazla direnç az. II’de pil ve direnç birbirleriyle dengede. III’te paralel bağlı piller vardır.- In I, there exists more batteries, the resistance is low. In II, the battery and resistors are in equilibrium. In III, there exist parallel connected batteries. In I, $V_{total} = 2V$; in II, $V_{total} = V$; in III, $V_{total} = V/2$.”(TI_student)

To identify students’ understanding of the “electric potential difference” concept in EMCT, the average of percentage values for Q9, Q14 and Q15 were calculated. As can be seen in Table 4.19, all of the three groups improved their understandings in relation to the concept. When the students who scored at least two points on average in this concept were examined, the percentage of POE-RJW (49%) students were much greater than the POE(27%) and TI (24%) groups.

Table 4.19. Frequencies and percentages of the questions related to concept 8 for the three instruction groups in the pre and post-EMCT.

Concept 8	Q#	Pre-EMCT						Post-EMCT						
		POE-RJW (n=39)		POE (n=59)		TI (n=37)		POE-RJW (n=39)		POE (n=59)		TI (n=37)		
		f	%	f	%	f	%	f	%	f	%	f	%	
Electric Potential Difference	Q9	0	24	62	41	70	29	78	14	36	35	59	10	27
		1	9	23	15	25	6	16	7	18	14	24	18	49
		2	2	5	0	0	0	0	5	13	3	5	0	0
		3	4	10	3	5	2	5	13	33	7	12	9	24
	Q14	0	33	85	43	73	26	70	19	49	32	54	14	38
		1	5	13	10	17	9	24	4	10	15	25	15	41
		2	1	3	6	10	2	5	4	10	5	9	7	19
		3	0	0	0	0	0	0	12	31	7	12	1	3
	Q15	0	17	44	21	36	14	38	4	10	18	31	9	24
		1	10	26	27	46	15	41	12	31	16	27	19	51
		2	12	31	11	19	8	22	11	28	13	22	8	22
		3	0	0	0	0	0	0	12	31	12	20	1	3
Total (Average)	0		63		59		62		32		48		30	
	1		21		29		27		20		25		47	
	2		13		10		9		17		12		14	
	3		3		2		2		32		15		10	

4.3.9. Concept 9: Magnetic Field

The ninth concept aimed to be assessed in EMCT was “magnetic field” and it was assessed by the combination of the questions 16 (Q16), 17 (Q17) and 18 (Q18). Q16 was asked to identify the understandings of students about the direction of the magnetic field produced by a bar magnet around it (see Appendix G). As can be seen in Table 4.20, based on the results of the pre-EMCT, a large number of students from the POE-RJW, the POE and the TI groups scored “0” for Q6 showing *no understanding* regarding the “magnetic field” concept (74%, 51% and 70% respectively). In other words, a noticeable percentage of students seemed to be confused about how the direction of magnetic field vector is drawn around the bar magnet. Although they were not expected to have high level of understanding about this concept on the pre-EMCT, the number of students having no understanding on the pre-EMCT was supposed to decrease on the post-EMCT. However, the number of students getting “0” point interestingly increased from the pre to the post-EMCT for the POE (51% to 68%) and the TI (70% to 87%) groups. Exclusively, the number of students getting “0” point on the pre-EMCT showed a substantial decrease for the POE-RJW group after instruction (74% to 21%).

Table 4.20. Frequencies and percentages of the questions related to concept 9 for three of the instruction groups in pre and post EMCT.

Concept 9	Q#	Pre-EMCT						Post-EMCT						
		POE-RJW (n=39)		POE (n=59)		TI (n=37)		POE-RJW (n=39)		POE (n=59)		TI (n=37)		
		f	%	f	%	f	%	f	%	f	%	f	%	
Magnetic Field	Q 16	0	29	74	30	51	26	70	8	21	40	68	32	87
		1	9	23	29	49	11	30	10	26	13	22	5	14
		2	0	0	0	0	0	0	13	33	5	9	0	0
		3	1	3	0	0	0	0	8	21	1	2	0	0
	Q 17	0	1	3	1	2	2	5	0	0	0	0	1	3
		1	2	5	7	12	6	16	6	15	5	9	5	14
		2	2	5	12	20	4	11	2	5	5	9	4	11
		3	34	87	39	66	25	68	31	80	49	83	27	73
	Q 18	0	20	51	19	32	10	27	4	10	7	12	12	32
		1	12	31	24	41	21	57	8	21	22	37	12	32
		2	7	18	15	25	5	14	23	59	19	32	9	24
		3	0	0	1	2	1	3	4	10	11	19	4	11
Total (Average)	0		43		28		34		10		27		41	
	1		20		34		34		21		23		20	
	2		8		15		8		32		16		12	
	3		30		23		23		37		34		28	

On the pre-EMCT, for Q16, the majority of students in all the groups considered that the direction of the magnetic field vector would be same on each of the points entering to the two different poles (Choice C was marked by 44% of POE-RJW, 30% of POE and 49% of the TI students). After the instructions, likewise, choice C was the most selected choice for the POE (48%) and the TI (64%) group students. Therefore, explanations written to the second tier of choice C can be interpreted as alternative conceptions about the “magnetic field” concept. The following excerpt from the students’ explanations in the second tier represents examples of these alternative conceptions:

“c- Zıt kutupların tersi istikamette olacağı için c yönü doğru yöndür.- Since the opposite pole will be on the different direction, c will be the correct direction.”(POE_student)

“c- Simetrik olmalıdır.-It would be symmetrical.”(TI_student)

“c- Diğer taraf a ise, zıt kutbu da c gösterir.-If the other side is a, c shows the opposite pole.” (TI_student)

Q17 investigated the attraction and repulsion forces between the opposite poles of a bar magnet. It is notable that Q17 had the best pre and post-EMCT correct answer

percentages for all the three groups. As can be seen in Table 4.20, the number of students displaying *complete conceptual understanding* on the post-EMCT for this question was very high (POE-RJW: 80%, POE: 83 % and TI: 73 %).

From the pre to the post-EMCT, while the percentage of students who scored “0” point at Q18 reduced for the POE-RJW (51% to 10%) and the POE (32% to 12%) groups, it surprisingly increased for the TI group (27% to 32%). In addition, the percentage of students getting at least “1” point on the post-EMCT was nearly the same for as the POE-RJW (90%) and the POE (88%) groups but was different for the TI (68%) group.

In addition to the percentage values of Q16, Q18 and Q18 separately, the average percentage of these set of questions were calculated so as to realize students’ understandings about “magnetic field” concept. On the post-EMCT, 10% of POE-RJW students, 27% of the POE students and 41% of the TI students scored “0” point showing that they had *no understanding* pertaining to “magnetic field” concept. It was evident that a high percentage of the TI students displayed *no understanding* (41%).

4.4. Findings Related to the Research Question 4

- Research Question 4: How does the motivation to learning physics differ from pre to posttest for the three groups of Grade 10 students who engaged in POE-RJW Instruction, POE Instruction, or TI?
- Null Hypothesis 4: There is no statistically significant mean difference in each group of Grade 10 students’ motivation to learning physics before and after the instructions of POE-RJW, POE, and TI.

Students’ motivation to learning physics was measured through the instrument named as “Physics Motivation Questionnaire” (PMQ). The PMQ included 22 Likert-type items ranging from 1 (never) to 5 (always). Four of the items were reversed. Therefore, the maximum score that can be taken from PMQ was 110 and the lowest score was 22. The data from the PMQ was coded and analyzed. For the statistical analysis, a paired sample t-test was conducted on each group of students' PMQ scores to evaluate the impact of the

three different instructions, namely POE-RJW instruction, POE instruction, and Traditional instruction, on students' scores on the PMQ.

4.4.1. Comparison of the Pre and Post-PMQ Scores of the POE-RJW Group

The pre and the posttest mean scores of the students who engaged in the POE-RJW instruction are demonstrated in Table 4.21. The mean of the POE-RJW group students' scores on the pre-PMQ was found to be $M=66.56$ ($SD=12.40$), while the mean of their post-PMQ was found to be $M=82.43$ ($SD=11.37$). As it can be easily realized, the post-PMQ scores of the POE-RJW group students were higher than their scores on the pre-PMQ. The highest score of the pre-PMQ was 87, and the lowest one was 45. On the other hand, the highest score of the post-PMQ was 102, and the lowest one was 59.

Table 4.21. The mean of the pre and the post-PMQ scores of the POE-RJW group.

	Mean	N	Std. Deviation	Highest Score	Lowest Score
Pre-PMQ	66.56	39	12.40	87	45
Post-PMQ	82.43	39	11.37	102	59

To identify whether there was a statistically significant difference in the mean scores of the pre and post-PMQ for the POE-RJW group students, a paired sample t-test was used. Based on the paired sample t-test results (see Table 4.22), it can be concluded that there was a statistically significant difference in the PMQ scores of the POE-RJW group students from the pre-PMQ ($M=66.56$, $SD=12.40$) to the post-PMQ ($M=82.43$, $SD=11.37$), $t_{(38)} = -4.82$, $p < 0.05$. The mean difference in the PMQ scores was 16.33 with a 95% confidence interval ranging from -22.52 to -9.21. Since the calculated p value ($t_{(38)} = -4.82$, $p < 0.05$) was lower than the critical p value of 0.05; the null hypothesis was rejected for the POE-RJW group.

Table 4.22. Results of the paired sample t-test on the pre-post PMQ mean scores of the POE-RJW group.

	Mean	Std. Deviation	t	df	Sig.(2-tailed)
Pre-PMQ Post-PMQ	-15.87	20.53	-4.82	38	.000

4.4.2. Comparison of the Pre and Post-PMQ Scores of the POE Group

The pre and the posttest mean scores of the students who engaged in POE instruction are demonstrated in Table 4.23. The mean of the POE students' scores on the pre-PMQ was found to be $M=71.47$ ($SD=11.58$), while the mean of their post-PMQ was found to be $M=71.42$ ($SD=14.21$). As it can be clearly realized, the post-PMQ scores of the students in the POE group were very close to the scores in the pre-PMQ. The highest score of the pre-PMQ was 101, and the lowest one was 47. On the other hand, the highest score of the post-PMQ was 99, and the lowest one was 37.

Table 4.23. The mean of the pre and post-PMQ scores of the POE group.

	Mean	N	Std. Deviation	Highest Score	Lowest Score
Pre-PMQ	71.47	39	11.58	101	47
Post-PMQ	71.42	39	14.21	99	37

Based on the paired sample t-test results (see Table 4.24), it can be concluded that there was not a statistically significant difference in the PMQ scores of the POE group students from the pre-PMQ ($M=71.47$, $SD=11.58$) to the post-PMQ ($M=71.42$, $SD=14.21$), $t(58) = .20$, $p < 0.05$. The mean difference in the PMQ scores was 0.05 with a 95% confidence interval ranging from -5.07 to 5.17. Since the calculated p value ($t(58) = 0.20$) was not lower than the critical p value of 0.05; the null hypothesis was not rejected for the POE group.

Table 4.24. Results of the paired sample t-test on the pre-post PMQ mean scores of the POE group.

	Mean	Std. Deviation	t	df	Sig.(2-tailed)
Pre-PMQ Post-PMQ	.50	19.65	.20	58	.984

4.4.3. Comparison of the Pre and Post-PMQ Scores of the TI Group

The mean scores of the TI group students on the pre and the posttest are demonstrated in Table 4.25. The mean of the TI group students' scores on the pre-PMQ was found to be $M=72.78$ ($SD=12.08$), while the mean of their post-PMQ was found to be $M=72.45$ ($SD=14.45$). That is, the post-PMQ scores of the TI group students were very

close to the scores in the pre-PMQ. The highest score of the pre-PMQ was 95, and the lowest one was 33. Similarly, the highest score of the post-PMQ was 95, and the lowest one was 36.

Table 4.25. The mean of the pre and post-PMQ scores of the TI group.

	Mean	N	Std. Deviation	Highest Score	Lowest Score
Pre-PMQ	72.78	39	12.08	95	33
Post-PMQ	72.45	39	14.45	95	36

Based on the paired sample t-test results (see Table 4.26), it can be concluded that there was not a statistically significant difference in the PMQ scores of the TI group students from the pre-PMQ (M=72.78, SD=12.08) to the post-PMQ (M=72.45, SD=14.45), $t_{(36)} = .113$, $p < 0.05$). The mean difference in the pre-post PMQ scores was 0.32 with a 95% confidence interval ranging from -5.47 to 6.12. Since the calculated p value ($t_{(36)} = 0.113$) was not lower than the critical p value of 0.05; the null hypothesis was not rejected for the TI group.

Table 4.26. Results of the paired sample t-test on the pre-post PMQ mean scores of the TI group.

	Mean	Std. Deviation	t	df	Sig.(2-tailed)
Pre-PMQ Post-PMQ	.32	17.83	.113	36	.910

$p < 0.05$

The results showed that only the POE-RJW group students' motivation to learning physics increased from the pre to the posttest. However, this result does not provide information about the magnitude of the instruction effect. Thus, an effect size was calculated for each group by obtaining eta squared value. As shown in Table 4.27, the effect size for the POE-RJW instruction is 0.38; the effect size for the POE instruction and the Traditional instruction is 0.00. Cohen (1988) divided effect size values into three categories which are (1) values $< .06$ as small effect, (2) values in the range between 0.06 and 0.13 as moderate effect and (3) values $> .14$ as large effect. Based on the Cohen's guidelines to interpret the values, it can be concluded that the POE-RJW instruction produced a large effect on students' motivation to learning physics. However, the eta squared statistic indicated a small effect size for the POE (.00) and the TI (.00).

Table 4.27. Effect size of the interventions on the PMQ scores for the paired sample t-test.

	POE-RJW	POE	TI
Eta squared	.38	.00	.00

4.5. Findings Related to the Research Question 5(a) and 5(b)

4.5.1. Comparison of the Pre-PMQ Scores between Three Instruction Groups

- Research Question 5(a): Are there any difference among the three groups of Grade 10 students in terms of their motivation to learning physics before engaging in POE-RJW Instruction, POE Instruction, or TI?
- Null Hypothesis 5(a): There is no statistically significant mean difference between the three groups of Grade 10 students' pretest scores in terms of motivation to learning physics before engaging in POE-RJW Instruction, POE Instruction, or TI.

A one-way ANOVA was conducted to determine if the motivation to learning physics (pre-PMQ scores) was different across the three groups who engaged in POE-RJW Instruction, POE Instruction, or TI. Participants were divided into three groups with respect to their instruction types: POE-RJW (n=39), POE (n=59) and Traditional instruction (n=37). The assumption of homogeneity of variances was met as it was assessed by Levene's test of homogeneity of variances ($p = .369$) (see Table 4.28).

Table 4.28. Test of homogeneity of variances for the pre-PMQ scores.

Levene's Statistic	df1	df2	Sig.
1.025	2	132	.369

The pre-PMQ score decreased from the TI group ($M=72.78$, $SD=12.08$) to the POE group ($M=71.47$, $SD=11.58$), to the POE-RJW group ($M=66.56$, $SD=12.40$), respectively, but the differences between these instruction groups was not statistically significant, $F(2,132) = 2.978$, $p=.054$ (see Table 4.29).

Table 4.29. One-Way ANOVA results for the pre-PMQ scores.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	852.198	2	426.099	2.978	.054
Within Groups	18888.572	132	1143.095		
Total	19740.770	134			

Since the mean scores across the three groups were not statistically different ($p > 0.05$), we could not reject the null hypothesis.

4.5.2. Comparison of the Post-PMQ Scores between Three Instruction Groups

- Research Question 5(b): Are there any difference among the three groups of Grade 10 students in terms of their motivation to learning physics after engaging in POE-RJW Instruction, POE Instruction, or TI?
- Null Hypothesis 5(b): There is no statistically significant mean difference between the three groups of Grade 10 students' posttest scores in terms motivation to learning physics after engaging in POE-RJW Instruction, POE Instruction, or TI.

For the analysis of the post-PMQ scores, a one-way ANOVA was also conducted. As can be seen in Table 4.30, the assumption of homogeneity of variances was met, as it was assessed by Levene's test of homogeneity of variances ($p = 0.306$).

Table 4.30. Test of homogeneity of variances for the post-PMQ scores.

Levene's Statistic	df1	df2	Sig.
1.195	2	132	.306

There was a statistically significant difference at the 0.05 level of significance in the post-PMQ scores for the three instruction groups, $F(2,132) = 8.600$ (see Table 4.31). The effect size, calculated using eta squared, was 0.115 which shows a medium effect. Post Hoc comparisons using the Tukey HSD test indicated that the mean score for the POE-RJW group ($M=82.43$, $SD=11.37$) was significantly different from both the POE group ($M=71.42$, $SD=14.21$) and the TI group ($M=72.45$, $SD=14.45$). The POE group ($M=71.42$, $SD=14.21$) did not differ significantly from the TI group ($M=72.45$, $SD=14.45$) in terms of their motivation to learning physics.

Table 4.31. One-Way ANOVA table for the post-EMCT scores.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3148.148	2	1574.074	8.600	.000
Within Groups	24161.186	132	183.039		
Total	27309.333	134			

Because the mean scores of PMQ across the groups were statistically different ($p < .05$), we rejected the null hypothesis and accepted the alternative hypothesis.

5. DISCUSSION AND CONCLUSION

There were two main purposes of the current study. The first one was to investigate the effectiveness of “Predict-Observe-Explain instruction coupled with Reflective Journal Writing” (POE-RJW instruction) over both “POE instruction” and “Traditional instruction” (TI) in terms of improving Grade 10 students’ conceptual understanding of electricity and magnetism. The second one was to investigate the effectiveness of the POE-RJW instruction over the POE instruction and the TI in terms of increasing students’ motivation to learning physics. To reach these two essential goals, a quasi-experimental control group design with a pre and posttest was conducted including three groups of students who engaged in three types of instructions: POE-RJW, POE, and TI. This section presents the conclusions and the related interpretations of the results in relation to the research questions. Then, recommendations and implications for further research will be discussed.

Conclusion 1: From pre to post-instruction, the POE-RJW, the POE, and the TI group students’ conceptual understanding of electricity and magnetism improved but the students in the POE-RJW group demonstrated a much more progression in terms of understanding the concepts of electricity and magnetism compared to the POE and the TI group.

The three different groups of students participated in a 10-week period of instruction including two hours of lessons per week. Thus, in total, they involved in 20 hours-lessons on electricity and magnetism unit. The electricity and magnetism conceptual test (EMCT) was administered to the three groups before and after the interventions. While the mean score of pre-EMCT for the POE-RJW instruction group was 12.92, the post-EMCT one was 29.25. On the other hand, the mean score of the POE group on the pre and post-EMCT was 12.15 and 21.00, respectively. The means of the TI group was 11.29 and 19.48 on the pre and post-EMCT. Paired sample t-test was conducted to identify the progression on conceptual understanding of each group. When the effect sizes of the three types of instructions were calculated, the eta squared value of the POE-RJW group (0.69) was found to be higher than the eta squared value of the POE (0.52) and the TI (0.52) group.

Therefore, it can be inferred that the POE-RJW instruction had a substantial effect on students' conceptions of electricity and magnetism ($t=9.76$, $p<0.05$) when compared to the POE and the TI. The extensive improvement of conceptual understanding of the POE-RJW group compared to the other two groups might be due to its having the combination of two instructional approaches in the context of constructivist view of learning: POE instruction and journal writing.

In relation to POE instruction, several studies in the literature aimed to investigate the effectiveness of POE on students' science conceptual understandings or the conceptual change learning in science (Crouch *et al.*, 2004; Searle and Gunstone, 1990; Yavuz and Çelik, 2013; Tao and Gunstone, 1999; Zacharia, 2005; Zacharia *et al.*, 2008). Yet, whether POE instruction has a positive impact on conceptual understanding or on the conceptual change learning is still a controversial issue. Coştu *et al.* (2009) designed a PDEODE (Predict-Discuss-Explain-Observe-Discuss-Explain) instruction, which is a modified version of POE strategy, on the basis of students' alternative conceptions to promote conceptual change. Findings from this particular study suggested that POE strategy assisted the 52 freshmen in a primary science education department to achieve a better conceptual understanding in the evaporation concept and promoted conceptual change. However, different from the present study, there was no control group to compare the effectiveness of PDEODE instruction with any other instructional strategy in their study.

Besides the POE learning/teaching model, in the current study, the POE tasks integrated with computer-based simulations or virtual manipulatives might also have a positive impact on the effectiveness of the POE-RJW instruction in terms of fostering students' conceptual understanding of electricity and magnetism. The 12 of 14 POE activities performed in the context of the POE-RJW instruction were supported by computer-based simulations, and such an addition might have also contributed to the conceptual understanding of the POE-RJW students. This interpretation is in line with the results of Zacharia (2005) who suggested that combining POE model with the computer simulations was an effective strategy in terms of improving students' conceptual understanding. In addition, there existed several studies which aimed to explore the effectiveness of computer simulations in fostering conceptual change (e.g., Zietsman and Hewson, 1986; White and Horwitz, 1988; McDermott, 1990; Gorsky and Finegold, 1992).

For example, Zacharia *et al.* (2008) found that students using physical manipulatives and virtual manipulatives together in the context of POE experiments showed more scientific conceptual understandings than the students using only physical manipulatives in their experiments. The difference between these two groups' understandings of the concepts was attributed to the use of virtual manipulatives. Similarly, Finkelstein *et al.* (2005) emphasized the importance of computer simulations. They compared the two groups of students, those who used computer simulations and those who used real laboratory equipment, in terms of their conceptual understandings of heat and temperature. Results indicated that students who used computer simulations performed significantly better than the students in real equipment group on the measure of conceptual understanding test. Similar to the current study, Finkelstein *et al.* also used the computer simulations from the PhET (The Physics Education Technology) Website of Colorado University. These simulations probably provided students such an engaging learning environment in which they can freely manipulate the variables, collect data, rerun the experiment, reflect on their ideas, and share their ideas with their friends and the teacher. As previous studies suggested, in the current study, computer simulations used throughout the POE-RJW instruction might be one of the important element in fostering students' mastery of concepts concerning the electricity and magnetism.

In addition to the contribution of POE instruction, the effectiveness of POE-RJW instruction on conceptual understanding can be associated with the use of journal writing as a significant tool integrated in POE strategy. Neither students in the POE group nor students in the TI group wrote physics learning journals, but students in the POE-RJW group wrote down at least 10 physics learning journals. Perhaps, the POE-RJW group students' progression toward more scientific understandings of electricity and magnetism compared to the POE and the TI group might be due to the use of learning journals. Many research studies have long been interested in whether writing learning journals (logs) increase science conceptual understanding or not (Dianovsky and Wink; 2012; Kalman, 2011; Klein 2000; Mason and Boscolo, 2000). Although some studies (e.g., McCrindle and Christensen, 1995) showed that journal writing enhances conceptual growth and promotes conceptual change, Klein's (2000) study indicated that only a small portion of students who engaged in journal writing activity improved their learning (10 of 36 students for buoyancy concept and 5 of the 36 students for balancing concept). Wallace (2004)

explained the reason of conceptual growth for only a few students in Klein's study with students' unawareness about two important learning strategies: cognitive and metacognitive learning strategies. In addition, Wallace claimed that learners have to be taught how and when to use these strategies so as to foster learning. In a similar vein, Galbraith (2015) asserted that, writing activity has to engage the students in a mental process in which both cognitive and metacognitive mechanisms have to be activated through the act of writing. In this context, many researchers did not ask students to write freely; instead they prepared structured journals in which various appropriate *prompts* were provided to induce cognitive and metacognitive strategies in the course of writing (e.g., Berthold *et al.*, 2007; Glogger *et al.*, 2012; Hübner *et al.*, 2010; Schmidt *et al.*, 2012). Consistent with the findings of the current study, in their meta-analysis Bangert-Drowns *et al.* (2004) investigated the use of metacognitive prompts in writing to learn activities, and they found that engaging students in reflections on their pre-knowledge, understanding their conceptual difficulties and learning processes were the best predictors that enhance effect size (the extent of academic performance progression) on fostering learning compared to the writing activities without such prompts. In addition, in one of their longitudinal study, Wäschle (2015) found that students who were required to write prompted journals (including cognitive and metacognitive prompts) outperformed the students who completed other homework assignments in terms of improving comprehension on biology concepts. In the light of these findings, it can be inferred that the efficacy of learning journals depends on its potential to trigger such mechanisms in the learners' minds throughout the act of writing so that it promotes deep conceptual understanding. As a result, based on the evidence emerging from these studies, the current study also presents a powerful evidence that journal writing in science, particularly prompted journal writing, which includes cognitive and metacognitive prompts, can enhance students' conceptual understanding in science and it can be used as a beneficial tool to promote conceptual change. The following excerpts from the "Journal Writing Survey" (JWS) provided some evidence:

"Günlük yazarak fizik kavram ve konularını daha kolay ve kalıcı bir şekilde öğrendim- By means of journal writing, I learnt the physics subjects and concepts easily and in an unforgettable manner."

"Fizik günlüğü sayesinde fizikte işlediğimiz konuları ve kavramları normal derse göre çok daha rahat anlıyorum. Ve anlamadığım yerleri ... arkadaşlarımla

tartışabiliyorum. - By means of physics journals, I understand the concepts and subjects easier than a normal lesson. And the points which I did not understand ... I can discuss with my friends.”

“Günlükleri dersten sonra tekrar şeklinde yazdığımızdan dolayı ...fizik konu ve kavramlarımı daha iyi öğreniyoruz.-Since we wrote the journals after the lesson as a review process, we learn the physics concepts and subjects better.”

Furthermore, different from the POE and the TI groups, written feedbacks given to the students’ journals by the teacher might have also contributed to the effectiveness of the POE-RJW instruction and empower the impact of journal writing on students’ understanding. Although the meta-analysis of Bangert-Drowns *et al.* (2004) surprisingly suggested that the feedbacks given to the students on their writing did not exhibit significant relationship with the effect size for writing to learn, in the study of Butler and Nisan (1986), they found that students who were provided informative feedbacks on their written work scored significantly higher on the performance task than the students who did not receive feedback. Therefore, the provision of feedback throughout the POE-RJW instruction might have a positive impact on students’ learning. To support this idea, some excerpts from JWS written by the students in the POE-RJW group can be stated as follows:

“...Günlüğü yazdıktan sonra kontrol edilmiş bir şekilde elime alıyordum ve bu da konuyu daha iyi anlamamı sağlıyordu.- After writing the journal, I was taking the checked form of it and this provided me to better understand ...”

“...Dönüt geldiğinde yanlış anladığımız yerleri arkadaşlarımızla tartışarak doğrusunu öğrendik.- when feedback was provided, we learnt the points which we misunderstood by means of discussing with our friends.”

“...geri dönüt alıp hatalı olduğumuz konulara tekrar çalışıp yazıyoruz.- By taking feedback and by studying the subjects which we had wrong ideas, we study again and write one more.”

Moreover, the notes which were taken by the POE-RJW students throughout the lessons might have promoted better learning and also better retention of the concepts addressed in the class. Actually, this assumption is consistent with the findings of several studies, asserting that taking notes during class contributes to the retention of knowledge by triggering cognitive operations in the note-takers’ mind (e.g., Piolat, 2007; Piolat *et al.*, 2003). Note taking can be considered as taking notes so as to compile a written record of information students will use later, not copying the writings on the board directly or

transferring what the teacher says (Piolat, 2007). For instance, some students specified in their JWS that they started to take notes throughout the lessons so as to use these notes while writing their journals. Some excerpts from the POE-RJW group students follow:

“Fizik günlükleri sayesinde dersi derste anlamaya daha çok önem verdim. Konuyu daha dikkatli dinleyerek, not almamı bu sayede akşam günlüğü yazarken bu notlar aracılığıyla günlüğü daha kolay yazdım- Along with writing physics journals, I paid more attention to understand the topics in the lesson. By listening the lesson more carefully, I took notes, thus by means of these notes I wrote down more easily to the journal.”

“...Ayrıca derste notlar da tutuyordum...-Also I was taking notes in the lesson.”

“...derste not tuttuğumuz hem de dersten sonra o notları düzenleyerek günlük yazdığım için dersin konuları kalıcı olarak aklımda kalıyor- Since we took notes and also I wrote the journal by organizing these notes, the topics of the lessons was much more long lasting in my mind.”

The effectiveness of the POE-RJW instruction might also be associated with the theoretical framework. As specified in the second chapter, the current study takes its roots from constructivist view of learning. The POE-RJW instruction was specifically designed by receiving inspiration from the constructivist view of learning in which understanding can be seen as a self-regulatory process of struggling with the conflict between pre-existing conceptions and discrepant new insight (Fosnot, 2005). Understanding can also be seen as the potential of the learners to use the knowledge and make connections between the related ideas (Entwistle and Ramsden, 1983; Stevens *et al.*, 2010). In this framework, the POE-RJW instruction was designed to promote students' conceptual understanding of electricity and magnetism. Besides, the students' learning was examined from the viewpoint of conceptual understanding and conceptual change (Driver, 1989; Smith 1991). Based on the several theoretical views of writing to learn discussed in the second chapter, the current study suggested that writing can be seen as a mode of learning (Emig, 1977) whereby cognitive processes are activated in the learners' mind (Flower and Hayes, 1981). The effectiveness of POE-RJW instruction might have also been associated with engaging students in such writing to learn activity proposed by these theories. Additionally, in line with the Keys' (1999) explanations about science learning in association with the *knowledge-transforming model* of Bereiter and Scardamalia (1987), it proved to be successful in the current research to engage students in their *content space* (including prior

knowledge, new data and inferences), which was achieved by structured journals. The opportunity for *rhetorical space* (selecting appropriate language) also provided students freedom for selecting the suitable language they wanted to use and by asking them to write with their own words in their journals. In relation to this consideration some sample excerpts from the students' JWS follow:

“Derste öğrendiğimiz konuları kendi cümlelerimizle, kendi anladığımız şekilde günlüğe yazdığımızda, hem bu konuları tekrar etmiş oluyoruz hem de konuyu kendi yorumumuzla yazdığımız için daha iyi unutulmayacak şekilde öğrenmiş oluyoruz.- When we wrote the journals with our own sentences based on how we understood; we can go over the subjects and also we can learn the subjects in an unforgettable manner since we wrote them by using our own interpretations.”

“...kendi yazdıklarımı (benim için kendi dilimden yazdıklarım daha öğretici ve anlaşılırdır) dersten sonra daha iyi kavradım. I comprehended my own writings (according to me the writings in which I use my own words and understandings were more instructive and understandable) better following the instruction.”

“...kendi cümlelerimizle yazmamız akılda kalıcılığı artırıyor.- writing with our own sentences can be remembered easily.”

As a result, in line with several models and theories proposed in the literature, this study showed that writing can enhance students' learning (Britton, 1970; Emig, 1977; Flower and Hayes, 1980, 1981; Bereiter and Scardamalia, 1987), particularly their science conceptual understanding (Prain and Hand, 1996; Keys, 1999).

Conclusion 2(a): Before the intervention, the students in the three different types of instruction groups (POE-RJW, POE and TI) showed similar but insufficient conceptual understanding about the electricity and magnetism concepts in a way that they possessed predominantly nonscientific ideas regarding the different concepts of electricity and magnetism.

Students in all three groups started the instructions with similar but low level of scientific understandings of electricity and magnetism; however they dominantly demonstrated nonscientific understandings of the topic. When the pre-EMCT scores of the three groups were taken into account, it was seen that these scores were very low but very close to each other. The mean scores for the three groups, (1) POE-RJW, (2) POE and (3) TI, were 12.92, 12.15, and 11.29, respectively. The maximum score that could be taken

from the pre-EMCT was 60. Therefore, the mean scores of these three groups indicated that they all had inadequate conceptual understandings regarding the electricity and magnetism concepts. Within the context of this very low level of conceptual understanding, a huge number of alternative conceptions were identified in their answers to the second tier of the pre-EMCT in which they explained their reasons for their choice in the first tier. Although these students studied the basic electricity and magnetism concepts throughout their middle school years, their alternative conceptions remained the same, exhibiting insufficient conceptual understandings of electricity and magnetism. As previous studies suggested, even after being taught in school, students keep on their nonscientific conceptions (Vosniadou, 1994; Lee and Law, 2001) since they are very robust to change (Driver, 1985). In relation to these alternative conceptions, several research studies have been conducted within the last 30 years, and they addressed that these alternative conceptions were independent from grade level and academic success (Bornes and Gilbert, 1999, Fredette and Locheard, 1980; Osborne and Freyberg, 1985) across different countries with different educational programs (Shipstone *et al.*, 1988; Tsai *et al.*, 2007; Liégeois and Mullet, 2002). In particular, Tsai *et al.* (2007) investigated the high school students' conceptual understanding in electric circuits by using a two-tier diagnostic instrument. The results of the nationwide survey, which was applied to 7,145 Taiwanese students in Grades 8 and 9, and 2,857 students in Grade 11, showed that these students held many alternative conceptions concerning electricity concepts including "consumption of current", "current and energy in the circuit", and "voltage in series and parallel circuits" those of which are similar to the concepts assessed in EMCT. Therefore, taking all these literature findings into account, it can be concluded that the insufficient conceptual understanding of the Grade 10 students about electricity and magnetism concepts in the pre-EMCT shows a congruency with the past research findings. In other words, the results of the similar studies in the literature are consistent with the findings of the current study.

Conclusion 2(b.1): After the instructions, the students in the POE and the TI groups showed similar conceptual understanding about the electricity and magnetism but the POE-RJW students showed more scientific conceptual understandings about the electricity and magnetism concepts compared to the POE and the TI students.

The conceptual understandings of all the three groups were similar based on the pre-EMCT results. According to the results from the ANOVA test conducted for the post-EMCT, the mean score for the POE-RJW instruction group ($M=29.25$, $SD=9.80$) was significantly different from both the POE group ($M=21.00$, $SD=7.41$) and the TI group ($M=19.48$, $SD=6.46$). This result clearly indicated that the POE-RJW instruction was more effective than the POE and the TI in terms of increasing students' conceptual understanding about the electricity and magnetism. The reasons what makes the POE-RJW instruction better than POE and TI may be similar as discussed for *Conclusion 1*. Specifically, what makes the POE-RJW instruction better than the POE can be seen as the journal writing approach in which students involved in a writing to learn assignment that foster conceptual understanding.

Conclusion 2(b.2): After the instruction, the POE and the TI group students demonstrated similar conceptual understanding about the electricity and magnetism concepts. These students demonstrated similar progression from the pre to the post-EMCT in terms of understanding the concepts of electricity and magnetism.

On the pre-EMCT, the mean scores of the POE and the TI groups were 12.15 and 11.29, respectively. That is to say, before the interventions, the students in both groups showed similar but a lack of conceptual understanding on the pre-EMCT. On the post-EMCT, while the mean score of POE group was 21, the mean score of TI group was 19.48. Although the mean score of the POE group was greater than the TI group, they statistically displayed similar level of conceptual understanding at the end of the instructions based on the ANOVA results. That is to say, the students engaged in the POE instruction could not perform better than the students in the TI group on the measures of EMCT. It is interesting to note that the POE students' conceptual growth was not statistically significant than the the TI students. Actually, this finding was not an expected outcome of the current study since it contradicts with the findings of the study conducted by Yavuz and Çelik (2013). They found that the students in the POE group outperformed the students who involved in the traditional instruction in terms of learning the concept of gases. Additionally, consistent with their study, Akgün *et al.*, (2013) compared the POE instruction with traditional instruction, and they suggested that the students in the POE groups gained better conceptual understandings than the TI group. However, the finding of the current study

revealed that the POE instruction is not superior to the TI in terms of fostering students' conceptual understanding. Comparing the findings of the present study with the considerations of Haysom and Bowen (2010), there is no guarantee that a POE instruction would strongly promote conceptual understanding or conceptual change. Instead, they suggested that POE can be a valuable starting point to trigger the conceptual change process. For instance, Tao and Gunstone (1999) designed a computer-supported instruction including 46 POE tasks as a means to explore the students' process of conceptual change. Grade 10 students worked in pairs together and conducted POE tasks on computer along with the worksheets they were provided with. The findings showed that few students (6 of 14) demonstrated substantial conceptual change. Similarly, many studies addressed that cognitive conflict instructional strategies, one of which is POE strategy, may not always strongly promote conceptual change or conceptual understanding since the alternative conceptions held by students are very robust to change (e.g., Limon, 2001; Lee and Law, 2001; Searle and Gunstone, 1990). Taking all these studies into account, effectiveness of POE on conceptual change and its superiority over the TI in terms of increasing conceptual understanding necessitates a further research. The results of the present study showed that the POE instruction alone may not be more effective than the TI in terms of improving students' conceptual understanding.

Another reason for the ineffectiveness of the POE instruction over the TI might stem from not offering POE activity sheets for students to write down during the POE tasks. Instead, students wrote the questions and their answers in their notebooks. As Haysom and Bowen (2010) and also Liew (2010) suggested, the students have to be provided a teacher-prepared worksheets in order to increase student engagement where the POE strategy would be more effective for learning. However, in the current study, since there was no activity sheets for students. Thus, perhaps, students might have only verbalized their responses instead of writing them down in their notebooks. Besides, the teacher did not check the students one by one whether they wrote down the POE questions and answers in their notebooks, due to the time limitation.

Conclusion 3: From the pre to the posttest, the conceptual understandings of the associated concepts of electricity and magnetism mostly showed a better progression for the POE-RJW group than the POE and the TI.

The frequency and percentage values were calculated for each of the associated nine concepts both for the pre-EMCT and the post-EMCT one by one for the three groups of Grade 10 students who engaged in the POE-RJW instruction, POE instruction, or TI. A student's success on a conventional multiple choice test may not be effective to detect his or her conceptual understanding, even s/he gets high scores. Accordingly, Adadan and Savasci (2012) specified that science teachers should use such assessment tools like two-tier multiple choice tests instead of traditional multiple choice tests so as to identify students' conceptual understanding. In line with their suggestions, in the current study, the two-tier EMCT was used to recognize the students' conceptual growth. To do this, the explanations written to the second tier of the questions provided plenty of information in relation to students' comprehension about the associated concepts. In this framework, rather than the percentage of students who got 1 point (indicating the correctness of the first-tier), the percentage of students who got "2" points (indicating *partial conceptual understanding*) or who got "3" points (indicating *complete conceptual understanding*), for each associated concept was much more valuable for the aims of the current study. Therefore, the sum of percentage values of "2" and "3" points was calculated (from the tables presented in the previous chapter) for each group in order to identify understandings of the associated concepts. The sums are labeled as CUP, which means *conceptual understanding percentage*. To identify the conceptual progression for each concept, the gains (difference of the CUP values) from the pre to the post-EMCT was found (see Table 5.1).

Students' understandings of nine associated concepts of electricity and magnetism were assessed by EMCT. When understandings of nine concepts were examined for each group in terms of the increase in CUP values from the pre to the posttest, in two of them (Concept 1: conductors and Concept 7: electrical resistance) all three groups showed no considerable progression. For the Concept 3 (Coulomb force), only the TI group showed a considerable progression. For the remaining six concepts, namely insulators, electric field, electric circuit, electric current, potential difference and magnetism, the POE-RJW students, compared to the POE and the TI students, exhibited a substantial progression.

Table 5.1. The sum of conceptual understanding percentage values for each group on the pre and the post-EMCT.

	Pre %	Post %	Gain	Pre %	Post %	Gain	Pre %	Post %	Gain
	C1: Conductors			C2: Insulators			C3: Coulomb force		
POE-RJW	10	26	16	5	36	31	24	50	26
POE	0	14	14	2	27	27	20	42	22
TI	0	3	3	14	11	- 3	8	46	38
	C4: Electric Field			C5: Electric Circuit			C6: Electric Current		
POE-RJW	3	33	30	23	63	40	10	45	35
POE	0	2	2	15	43	28	8	24	16
TI	0	3	3	15	34	19	8	26	18
	C7: Electrical Resistance			C8: Potential Difference			C9: Magnetic Field		
POE-RJW	8	18	10	16	49	33	38	69	31
POE	4	19	15	12	27	15	38	50	12
TI	6	0	- 6	11	24	13	31	40	9

The first concept assessed by EMCT was “conductors”, and all three groups showed no substantial progression for this particular concept. The CUP value of the POE-RJW group for this concept was “10%” on the pre-EMCT, whereas it was “26%” on the post-EMCT. The CUP value was calculated as “0%” and “14%” for the POE group, and for the TI group, it was “0%” and “3%” on the pre and the post-EMCT, respectively. Although the conceptual progressions (gains) of the POE-RJW (16%) and the POE (14%) groups were better than the TI group (3%), there was no considerable progression on understanding the concept of conductors for the three groups. It can be deduced that all the three instructions failed to improve students’ understanding in conductors. This can be due to the students’ pre-conceptions which are very difficult to change about this concept. Comparing the findings of this study to the findings of Maloney *et al.* (2001), there was no difference in the finding that many students confused about how charges are distributed on conductors. They also found a similar gain (24%) from the pre to the posttest in relation to the concept of conductors. Although students in both the POE-RJW and the POE groups engaged in the POE activity (Task 3) about the distribution of charges on a human body (see Table 3.4), they still had confusion on understanding this concept.

The other associated concept showing no definite progression for all three groups was “electrical resistance”. The CUP value of the POE-RJW group for this concept increased from 8% to 18% from the pre to the posttest. However, the similar values for the POE group were 4% and 19%, and for the TI they were 6% to 0%. It was found that there was no substantial increase in the CUP values of both the POE RJW group (10%) and the POE group (15%). Interestingly, the CUP value decreased for the TI group. Based on the results, it can be concluded that none of the instructions was successful to improve the understanding in “electrical resistance” concept. This can be due to the insufficient time shared by the teacher to the POE task in relation to this concept. In addition to the concept of “electrical resistance”, the concept of “Ohm’s law” was also addressed in the same lesson (see Table 3.4). Most probably, the teacher hurried up to teach both concepts in the same lesson. Thus, students might have not properly engaged in the POE task, which was directly related to the electric resistance concept.

It is noteworthy that the comprehension in the “coulomb force” concept, the TI group students showed a considerable progression. Although the POE-RJW and the POE groups improved their understanding on this concept (gains of 26% and 22%, respectively), the progression of the TI was greater in terms of understanding the concept of “coulomb force”. The reason behind this can be explained by such a learning environment of the TI in which students were required to solve so many numeric problems about the Coulomb force. Because the question assessing this concept (Q3) could be solved by using mathematical formulations, it was probable that students in the TI group solved this problem by using such equations. On the other hand, students in the POE-RJW group and the POE group did not solve so many problems about this concept throughout the instructions.

Based on the evidence emerging from the findings, the POE-RJW group showed a fairly strong improvement for the remaining six concepts. The gains of these six concepts were as follows: (1) Concept 2 (Insulators): 31%, (2) Concept 4 (Electric field): 30%, (3) Concept 5 (Electric Circuit): 30%, (4) Concept 6 (Electric current): 40%, (5) Concept 8 (Potential Difference): 33 % and (6) Concept 9 (Magnetic field): 31% (see Table 5.1). All of the gains for these associated concepts were higher than 30 percent, indicating a substantial progression in students’ understanding of such concepts. The reason that caused

this difference might be related to the journal writing activity by which students improved their conceptual understanding. This finding is in line with the findings of several studies (e.g., Mason and Boscolo, 2000; McCrindle and Christensen, 1995).

Conclusion 4: From the pre to the post-instruction, while the POE and the TI group students demonstrated no increase in their motivation to learning physics, the POE-RJW students showed a substantial increase in their motivation to learning physics.

All of the groups began the instructions with similar level of motivation to learning physics as analyzed statistically for the pre-PMQ scores. The maximum score that could be taken from the PMQ was 110. The mean score of the POE group on the pre-PMQ and the post-PMQ was 71.47 and 71.42, respectively, whereas the mean score of the TI group on the pre and the post-PMQ was 72.78 and 72.45, respectively. From the pre to the posttest, based on the results obtained from the paired sample t-test, neither the POE nor the TI group showed progression in their motivation to learning physics. On the other hand, the mean scores of the POE-RJW group on the pre and the post-EMCT was 66.56 and 82.43, respectively, exhibiting that there was a statistically significant difference in the mean scores. In other words, the present finding suggests that the POE-RJW instruction can be used to increase students' motivation to learning physics. The reason why the POE-RJW was effective to increase students' motivation towards learning physics might be due to the amalgamation of POE instruction and journal writing, each of which has discussed in several studies whether they have a positive impact on students' motivation to learning physics or not.

Previous studies in relation to the POE instruction have indicated a sound increase in students' motivation and attitude towards science (Kırıkkaya and Vurkaya, 2011; Köseoğlu *et al.*, 2002; Palmer, 1995). Therefore, the POE instruction might have played a critical role in increasing the POE-RJW students' motivation to learning physics in the present study. Here are some sample excerpts from JWS to support this claim:

“Öncelikle tahmin yaparken yaptığımız tahminler ve sorduğumuz sorular bize konuyu daha ilgi çekici hale getiriyor.- First of all, while predicting, the predictions and the questions that we asked make the subject more interesting.”

“... önce konu hakkında tahminlerde bulunduk ve ilgi çekici oldu.-...firstly we predicted about the subjects and this was interesting.”

Another reason for the increase in motivation might have been related to the learning journals which students wrote down throughout the POE-RJW instruction. Since one of the important way of increasing students' learning motivation is to make them recognize the relevance of a topic (Pintrich, 2004), learning journals can be a promising *writing to learn* tool for students whereby they can reflect their ideas regarding a topic in a free manner. This interpretation, and also conclusion, aligns well with the past research on journal writing in science education (Çardak, 2010; Schmidt *et al.*, 2012, Waschle *et al.*, 2015). Although Nückles *et al.* (2010) found that students' motivation for writing the learning journal decreased over a longer period of time, Schmidt *et al.* (2012) found that journal writing is a useful strategy to enhance students' motivation to learn. In a similar vein, the journals used in the POE-RJW instruction might have contributed to increase in students' motivation to learn. The following excerpt from Journal Writings Survey can be seen as an evidence to support this idea:

“Öğrenme günlükleri sayesinde derse olan ilgimiz arttı çünkü...- By means of learning journals, our interest increased towards the lesson...”

In addition to the possible positive effects of POE instruction and journal writing on students' motivation, feedbacks given to the students' learning journals might have also contributed to enhance students' motivation. Several studies showed that continuous and regular feedback to students' performance can have a positive influence on intrinsic motivation (e.g., Butler and Nisan, 1986, Deci, 1971) and motivation towards learning physics as well (e.g., Changeiywo *et al.*, 2010). An informative feedback, which focuses on what students did well, where they showed incomplete understanding and how they can improve their learning, allows students acquire satisfaction in completing the assignments fruitfully (Deci, 1971, Froschauer and Bigelow, 2012). In the present study, the teacher not only graded the journals but also provided appropriate written feedback to each student in the POE-RJW group. In harmony with the findings of the previous studies, the feedbacks given to the POE-RJW students in the current study might have improved students' motivation to learning physics.

As a summary for *Conclusion 4*, the current study is an example where students benefit from the opportunity to write about their learning in the context of a POE instruction in a physics class. Besides, this study was the first study which combined the POE instruction and journal writing in a physics class on electricity and magnetism concepts. Consistent with the study of Changeiywo *et al.* (2010), teaching methods in which students engage actively can enhance the motivation of secondary school students. Therefore, the present study presented that the POE-RJW instruction is a useful method to increase students' motivation to learning physics.

Conclusion 5(a): Before the instruction, the students in the POE-RJW, the POE and the TI groups showed similar level of motivation to learning physics in a way that they all had nearly high level of motivation to learning physics.

The pre-PMQ mean scores of the POE-RJW, the POE and the TI groups were 66.56, 71.47 and 72.78 respectively and there was no significant difference between these three groups in terms of motivation to learning physics. Over 110 points, these means indicated that the students in all three groups had nearly high level of motivation to learning physics. The assessment criterion for being "high" was based on the study of İlhan, Yıldırım and Yılmaz (2012) from which the PMQ was adapted in the present study. In their study, they specified that while the points between 44 and 65 shows middle motivation level, the points between 66 and 87 indicates high level of motivation towards learning. Actually, the finding of the current study in relation to high motivation was not an expected outcome. There exist several studies addressing that students' motivation towards learning physics is very low and the number of students motivated to follow physics courses is decreasing dramatically (e.g., Baumer, Schmitz, Sang, and Roeder, 1987; Changeiywo *et al.*, 2010; Fisher and Horstendahl, 1997), particularly in secondary schools (Osborne *et al.*, 2003; Schumm and Bogner, 2016). For example, in a recent study, Schumm and Bogner (2016) found that tenth grade students' self-determination, which is an essential aspect of motivation, were very low. Different from this study, although the mean scores of the three groups in the current study are very close to the upper limit of medium motivation level, the findings of the current study exhibited that Grade 10 students' motivation towards learning physics can be considered as high. Although it seemed to be high, the students' motivation towards physics might be on the verge of decreasing.

Conclusion 5(b.1): After the instruction, the POE and the TI group demonstrated a similar level of motivation to learning physics, but the POE-RJW group showed a better progression in their level of motivation to learning physics compared to the POE and the TI group.

Although there was no significant mean differences between the three groups of Grade 10 students' pretest scores in terms of their motivation to learning physics before instruction, ANOVA results for the post-PMQ indicated that the mean score for the POE-RJW group ($M=82.43$, $SD=11.37$) was significantly different from the POE group ($M=71.42$, $SD=14.21$) and the TI group ($M=72.45$, $SD= 14.45$). The reasons what makes the POE-RJW group better than the POE and the TI group in relation to motivation towards physics may have been the similar reasons discussed for *Conclusion 4*. What appears interesting in the context of *Conclusion 5(b.1)* is that while the POE students showed lower motivation in comparison to the POE-RJW students, their motivation level was similar to the TI students. This finding shows that solely POE instruction may not be sufficient to make students' motivation higher than the motivation of the TI students; instead journal writing has to be coupled with POE instruction in order to overcome this problem.

Conclusion 5(b.2): After the instruction, the POE and the TI group students demonstrated similar level of motivation to learning physics and also from pre to post-PMQ students in the two different groups demonstrated similar progression in terms of motivation to learning physics.

Based on the ANOVA results for the post-PMQ, the POE group ($M=71.42$, $SD=14.21$) did not differ significantly from the TI group ($M=72.45$, $SD= 14.45$) in terms of their motivation to learning physics. Actually, this result was not an expected outcome for the current study. Previous studies comparing the POE instruction and traditional instruction have indicated that the POE instruction is better than traditional instruction in terms of increasing students' motivation level (Kırıkkaya and Vurkaya, 2011; Köseoğlu *et al.*, 2002; Mısır and Saka, 2011; Palmer, 1995). Motivation towards science learning is mainly dependent on the quality and type of instruction (Krapp and Prenzel, 2011). Contrary to the traditional teaching strategies in which students almost passive in class, the

POE instruction provides students more engaging learning environment in which they actively take place in several processes such as predicting, observing, sharing their ideas with their friends. However, findings of the present study showed that, the POE instruction and traditional instruction are similar to each other in terms of increasing students' motivation level. This finding is in line with the findings of Akgün *et al.* (2013) that they also did not find significant difference between the POE and traditional instruction with regard to increase in students' attitudes towards science which is a related motivational concept (Krapp and Prenzel, 2011, p. 30).

In summary, all these conclusions confirm the idea that "Predict-Observe-Explain instruction coupled with Reflective Journal Writing" (POE-RJW instruction) can be a fruitful constructivist method to foster conceptual understanding in science, particularly in physics, and also contribute to increase in motivation to learning to physics.

5.1. Limitations

Despite the encouraging findings of the current study, there are also some limitations. The first limitation was the use of convenience sampling, which is a type of nonrandom sampling. Since the design of this study was quasi-experimental, it did not include the use of random assignment. In this study, 7 pre-existing classes were selected randomly among 17 Grade 10 classes. However, rather than assigning participants randomly, selecting whole classes to the experimental groups (POE-RJW and POE) and control group (TI), results in limitations. In spite of the fact that the differences between the groups were controlled by using the results of ANOVA on the pre-tests, it is also probable that other uncontrolled extraneous variables had an effect on the outcome. Therefore, this study might be replicated by such experimental designs in which participants are selected randomly.

Another limitation of the present study can be the deficiency of interviews as a data collection method. In addition to the subject-completed instruments such as EMCT, PMQ and JWS; interviews, by which students are required to clarify and expand their answers that are particularly significant, could be used to identify students' conceptual

understanding, motivations towards learning and thoughts about their experiences on journal writing.

5.2. Recommendations for Further Research and Implications

Although the present study provided many important educational insights, it also generated a number of questions that remain unanswered. (1) What can be the impact of learning journals without any prompts on students' conceptual understanding in POE instruction-classes? In this study, physics learning journal included cognitive and metacognitive prompts and also, the POE-RJW instruction combined the prompted journal writing with POE tasks that students' conceptual understanding increased. Future studies may examine if learning journals which do not include such prompts (or unstructured journal having solely blank pages) might have an impact on students' conceptual growth in science. (2) Rather than the *rhetorical space*, the prompts used in the learning journals concentrated on the *content space*. For instance, the prompts such as "What have you learnt today? Explain in details (with scientific explanations and the answers of why and how questions)" and "Which issues/concepts haven't you understood in class today?" were used in the current study. Yet, the journals did not include prompts such as "How can you organize the content for a reader (different from the teacher)?" According to the *knowledge-transforming* writing model of Bereiter and Scardamalia (1987), learning throughout writing depends on the dynamic relationship between content and rhetorical space. In this context, a goal of future research would be to use such learning journals in which the prompts focusing on the rhetorical space placed in the journals in order to identify the growth of science conceptual understanding. In addition, the same prompts can still exist in the journals but students can be asked to write the journals, rather than to the teacher, to the different audiences such as younger students, peers, or parents. (3) Another significant question refers to the use of learning journals not only with POE instruction, but combining it with several constructivist instructional strategies. In this framework, future research can focus on the combination of such strategies (for example, 5E model) with learning journals so as to detect whether the amalgamation of learning journal with different teaching strategies enhance conceptual understanding or not. (4) Finally, another goal of future research would be to recognize the impact of learning journals in traditional-instruction classes. In the current study, learning journals was used along with POE

instruction. However, in future studies, traditional instruction and traditional instruction coupled with journal writing can be compared in terms of their effects on students' conceptual understanding in science and motivation to learning.

The results of the present study suggest significant implications. Wallace *et al.* (2004) specified the necessity of future research on more advanced research questions of the impact of the instructional tasks on writing to learn, rather than the question of whether writing promotes science learning. Keys (1999) suggested for a similar further research which answers the question of "What types of classroom activities may be developed to support integrated inquiry and science writing" (p.128). In this study, the POE tasks were used as a classroom activity to support science writing that enhanced learning. Therefore, the current study presented promising findings to these questions.

Another implication can be stated for the teaching in science, particularly in physics. Wallace, Hand and Prain (2004) specified that "links between writing and specific types of learning have not been well understood" (p.5). This study was the first one in which students' conceptual understanding was increased by means of combining the POE instruction with reflective learning journals in a physics instruction on the topic of electricity and magnetism. In this context, the findings of the current study indicated that writing is able to promote conceptual understanding. Therefore, science teachers should consider the use of such writing types to enable students to learn science concepts better. In addition, the contribution of the POE-RJW instruction was encouraging to increase students' motivation to learning physics. Therefore, science teachers can use such instructional strategies in which POE and journal writings are combined to increase motivation towards physics lessons. As a result, the findings of the current study indicated that writing may promote science conceptual understanding and increase motivation towards physics.

Finally, the EMCT instrument in its present form is a useful tool for teachers and researchers to assess students' conceptual understanding and to reveal students' alternative conceptions in relation to electricity and magnetism concepts.

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APPENDIX A: POE AND POE-RJW INSTRUCTION LESSON SLIDES

LESSON 1:

TASK 1: Sweater and Balloon

Concept(s): Electric Charges and Electric Force

Time: 80 minutes







<p>Ünite 2: Elektrik ve Manyetizma</p>  <p>Konu 1: Elektrik Yükleri</p>	 <p>(Java) Deney gözlemlerinizi yazınız ve nedenini açıklayınız</p>
<p>Slide 1</p>	<p>Slide 4</p>
<p>Etkinlik 1: Kazak ve Balon</p>  <p>Tahmin et</p> <p>Gözlem/Deney Yap</p> <p>Açıkla (izah et)</p>	 <p>Gözlem</p> <p>Tahmin</p>  <p>Gözlem ve tahminlerinizi karşılaştırın? Aynı mı yoksa farklı mı? Nedenleriyle açıklayınız</p>
<p>Slide 2</p>	<p>Slide 5</p>
<p>Balonu kazığa <u>sürtelim</u> ve biraz uzaklaştıralım. Acaba ne olur?</p>  <p>Defterinize <u>tahmininizi</u> yazınız ve nedenini <u>açıklayınız.</u></p>	<p>Keşfedilecek Sorular?</p> <ol style="list-style-type: none"> 1. Nötr bir cisim ne demektir? 2. Elektriklenmeyi sağlayan temel parçacık hangisidir? 3. Elektrik yüklü cisim ne demektir? 4. Sürtünme miktarı ile elektrikle yüklenme nasıl arasında nasıl bir ilişki vardır? 5. Bir cismin elektrik yükü hangi değerlerde olabilir? Neden? 6. Elektrik yükleri korunur mu?
<p>Slide 3</p>	<p>Slide 6</p>

Figure A.1. Slides of lesson 1.

LESSON 1: (cont.)


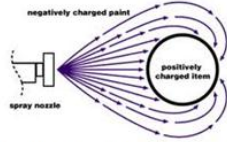

<p>Elektrostatik Boya Sistemi Nasıl Çalışır?</p> 	<p>Elektrostatik Boya Sistemi</p>  <ul style="list-style-type: none"> • Normal bir spreysel tabancası ile yapılan boyama işleminde boyalar tekrar kullanılmadığı için ziyan olur. • Bu sistemde ise ziyan olan boyama miktarı çok azdır. • Boyama eksikliğiyle, uygulama yüzeyi ise artı yüklerle yüklenir. • Böylelikle kolayca yüzeye yapışır.
<p>Slide 7</p>	<p>Slide 10</p>
<p>Acaba Bilim insanları nasıl açıklamışlar?</p> <ol style="list-style-type: none"> 1. Elektriklenmeyi sağlayan temel parçacık elektrondur. 2. Elektronlar, cisimler arasında alınıp verilebilir. Nötr bir cisim elektron alırsa negatif, verirse pozitif yüklenir. Atomun çekirdeğindeki pozitif yükler (protonlar) hareket etmez, bir cisimden diğerine geçmez. 3. Elektronun yükü bölünemez ve en küçük yüktür. Bu nedenle bir cismin yükü elektronun yükünün tam katları olabilir, kesirli katları olamaz. Bu özelliğe yüklerin tanecikli yapısı denir. 	
<p>Slide 8</p>	
<ol style="list-style-type: none"> 4. Doğada iki cins elektrik yükü vardır. Elektronun yükü eksi, protonun artı işaretlidir. 5. Proton ve elektronun yük değerleri eşittir. 6. Nötr cisimler dışarıya karşı herhangi bir elektriksel etki göstermez. Yüklü cisimler birbirine elektriksel kuvvet uygular. Bir başka ifadeyle elektrik yükleri elektriksel kuvvetin nedenidir. 7. Elektrik yüklerinin önemli özelliklerinden birisi de korunumlu olmalarıdır. 	
<p>Slide 9</p>	

Figure A.1. Slides of lesson 1. (cont.)

LESSON 2:

TASK 2: Balloon and Wall

Concept(s): Electric Force

Time: 80 minutes

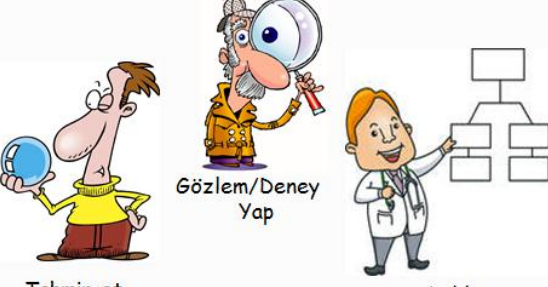




<p>Etkinlik 2: Balon ve Duvar</p>  <p>Tahmin et</p> <p>Gözlem/Deney Yap</p> <p>Açıkla (izah et)</p>	 <p>Gözlem</p> <p>Tahmin</p> <p>Gözlem ve tahminlerinizi karşılaştırın? Aynı mı yoksa farklı mı? Nedenleriyle açıklayınız</p>
<p>Balonu kazağa sürttükten sonra duvara yaklaştırsak acaba ne olur?</p>  <p>Defterinize tahmininizi yazınız ve nedenini açıklayınız.</p>	<p>Keşfedilecek Sorular?</p> <ol style="list-style-type: none"> 1. Elektrik yüklü bir cisim nötr bir cisme yaklaştırılırsa ne olur? 2. Cisimleri hangi yollarla elektrik yükleyebiliriz? 3. Sürtünme ile elektrikleme nedir? 4. Etki ile elektrikleme nasıl olur? 5. Dokunma ile elektrikleme nasıl olur?
 <p>(Java) Deney gözlemlerinizi yazınız ve nedenini açıklayınız</p>	<p>Streç filmler saklama kaplarını sıkıca sarar? Ama bu nasıl oluyor?</p> 
<p>Slide 1</p>	<p>Slide 4</p>
<p>Slide 2</p>	<p>Slide 5</p>
<p>Slide 3</p>	<p>Slide 6</p>

Figure A.2. Slides of lesson 2.

LESSON 3:

TASK 3: John Travolta

Concept(s): Conductors and Insulators

Time: 80 minutes

<p>Etkinlik 3: John Travolta</p>  <p>Tahmin et</p> <p>Gözlem/Deney Yap</p> <p>Açıkla (izah et)</p>	<p>Gözlem</p> <p>Tahmin</p>  <p>Gözlem ve tahminlerinizi karşılaştırın? Aynı mı yoksa farklı mı?Nedenleriyle açıklayınız</p>
<p>Travolta'nın ayağını yere sürtelim? Acaba ne olur?(Yük dağılımı nasıl olur?)</p>  <p>Defterinize tahmininizi yazınız ve nedenini açıklayınız.</p>	<p>Keşfedilecek Sorular?</p> <ol style="list-style-type: none"> 1. İletken nedir? 2. İletkenlerde yüklü parçacıklar nasıl dağılır? 3. İletkenin şekli yüklerin dağılımını nasıl etkiler? 4. Yıldırım ve şimşek nasıl oluşur? 5. Paratoner nedir?Neden sivri uçlu olur? 6. Yalıtkan nedir? 7. Yalıtkanlarda yüklü parçacıklar nasıl dağılır? 8. Hem iletken hem de yalıtkanlar atomdan oluştuğu halde neden yalıtkanlar da iletkenler gibi elektriği iletmezler? 9. Topraklama nedir?
<p>(Java) Deney gözlemlerinizi yazınız ve nedenini açıklayınız</p> 	<p>Yıldırım ve Şimşek Nasıl Oluşur?</p> 
Slide 1	Slide 4
Slide 2	Slide 5
Slide 3	Slide 6

Figure A.3. Slides of lesson 3.

LESSON 4:

TASK 4: Electric Force

Concept(s): Electric Force

Time: 50 minutes

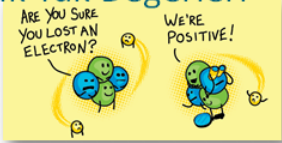


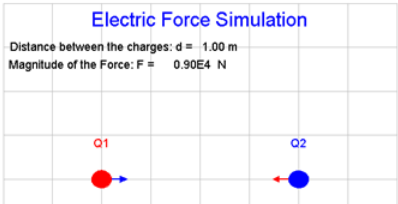
<h3>Elektrik Yük Değerleri</h3>  <ul style="list-style-type: none"> Elektriklenmeyi pozitif veya negatif taneciklerin fazlalığı oluşturduğuna göre, yük miktarının ölçülebilmesi, ölçme için de bir birimin olması gerekir. Uluslararası Birim Sisteminde (SI) yükün birimi coulomb (kulom)dur ve C simgesiyle gösterilir. Yapılan ölçmeler doğadaki en küçük elektrik yükünün elektronun yükü olduğunu göstermiştir. Bu nedenle bir elektronun yüküne temel yük ya da elementer yük (ey) denir. Bir elektronun yükünün değeri $1,6 \cdot 10^{-19}$ C'tur. 	<h3>Elektrik Yük Değerleri</h3> <table border="1"> <thead> <tr> <th>Cisim</th> <th># fazlalık elektron/proton sayısı</th> <th>Cismin Coulomb cinsinden elektrik yük değeri</th> </tr> </thead> <tbody> <tr> <td>A</td> <td>1×10^6 fazlalık elektron</td> <td>-1.6×10^{-13} C</td> </tr> <tr> <td>B</td> <td>1×10^6 fazlalık proton</td> <td>$+1.6 \times 10^{-13}$ C</td> </tr> <tr> <td>C</td> <td>2×10^{10} fazlalık elektron</td> <td>-3.2×10^{-9} C</td> </tr> <tr> <td>D</td> <td>3.5×10^8 fazlalık proton</td> <td>$+5.6 \times 10^{-11}$ C</td> </tr> <tr> <td>E</td> <td>4.67×10^{10} fazlalık elektron</td> <td>-7.5×10^{-9} C</td> </tr> </tbody> </table>	Cisim	# fazlalık elektron/proton sayısı	Cismin Coulomb cinsinden elektrik yük değeri	A	1×10^6 fazlalık elektron	-1.6×10^{-13} C	B	1×10^6 fazlalık proton	$+1.6 \times 10^{-13}$ C	C	2×10^{10} fazlalık elektron	-3.2×10^{-9} C	D	3.5×10^8 fazlalık proton	$+5.6 \times 10^{-11}$ C	E	4.67×10^{10} fazlalık elektron	-7.5×10^{-9} C			
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Slide 3	Slide 6																					

Figure A.4. Slides of lesson 4.

LESSON 4: (cont.)

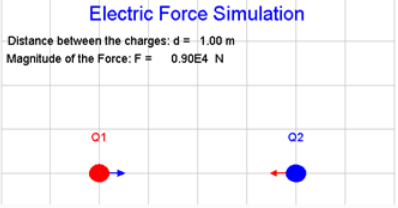
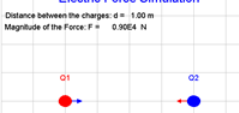
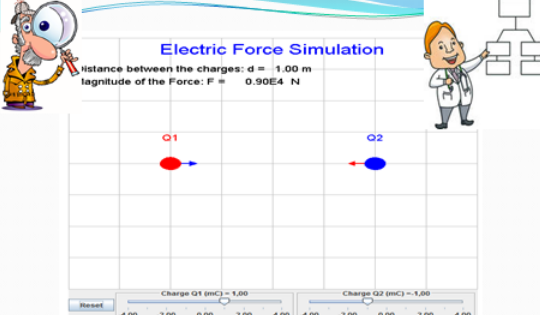
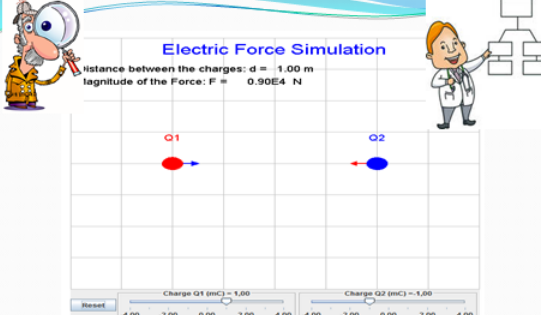


<p>Şekildeki (+) ve (-) yüklerin birbirlerine uyguladıkları çekim kuvveti arasında nasıl bir ilişki vardır?</p> <p>Electric Force Simulation</p> <p>Distance between the charges: $d = 1.00 \text{ m}$ Magnitude of the Force: $F = 0.90E4 \text{ N}$</p>  <p>Defterinize tahmininizi yazınız ve nedenini açıklayınız.</p>	<ol style="list-style-type: none"> Şekildeki (+) yüklü Q1 yükünün yük miktarı ile F (Elektriksel kuvvet) arasında nasıl bir ilişki vardır? Şekildeki (-) yüklü Q2 yükünün yük miktarı ile F (Elektriksel kuvvet) arasında nasıl bir ilişki vardır? Yükler arasındaki mesafe ile F (Elektriksel kuvvet) arasında nasıl bir ilişki vardır? Yükler arasına konulan bir madde (havadan farklı) ile F (Elektriksel kuvvet) arasında nasıl bir ilişki vardır? <p>Electric Force Simulation</p> <p>Distance between the charges: $d = 1.00 \text{ m}$ Magnitude of the Force: $F = 0.90E4 \text{ N}$</p>  <p>Defterinize tahminlerinizi yazınız ve nedenini açıklayınız.</p>
Slide 7	Slide 10
<p>Electric Force Simulation</p> <p>Distance between the charges: $d = 1.00 \text{ m}$ Magnitude of the Force: $F = 0.90E4 \text{ N}$</p>  <p>(Java) Deney gözlemlerinizi yazınız ve nedenini açıklayınız</p>	<p>Electric Force Simulation</p> <p>Distance between the charges: $d = 1.00 \text{ m}$ Magnitude of the Force: $F = 0.90E4 \text{ N}$</p>  <p>(Java) Deney gözlemlerinizi yazınız ve nedenini açıklayınız</p>
Slide 8	Slide 11
<p>Gözlem</p> <p>Tahmin</p> <p>Electric Force Simulation</p> <p>Distance between the charges: $d = 1.00 \text{ m}$ Magnitude of the Force: $F = 0.90E4 \text{ N}$</p>  <p>Gözlem ve tahminlerinizi karşılaştırın? Aynı mı yoksa farklı mı? Nedenleriyle açıklayınız</p>	<p>Gözlem</p> <p>Tahmin</p> <p>Electric Force Simulation</p> <p>Distance between the charges: $d = 1.00 \text{ m}$ Magnitude of the Force: $F = 0.90E4 \text{ N}$</p>  <p>Gözlem ve tahminlerinizi karşılaştırın? Aynı mı yoksa farklı mı? Nedenleriyle açıklayınız</p>
Slide 9	Slide 12

Figure A.4. Slides of lesson 4. (cont.)

LESSON 4: (cont.)


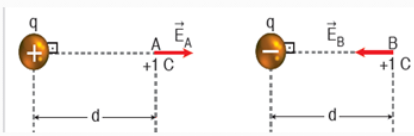

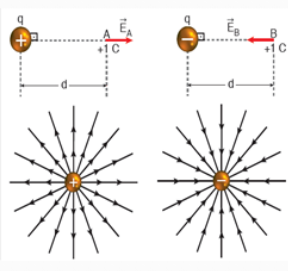
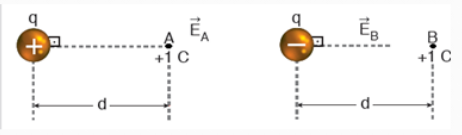
<p>Acaba Bilim insanları nasıl açıklamışlar?</p> <p>Bu soruların cevabı Fransız fizikçisi Charles Augustin Coulomb tarafından 18. yüzyılda yapılan deneysel çalışmalarla verildi.</p> <p>Coulomb, elektrik yüklerinin birbirine etkisini de kendi adıyla anılan bir yasa biçiminde şöyle ifade etmiştir:</p> <p>“Noktasal iki yükün birbirine etkisi yüklerin her biriyle doğru, aralarındaki uzaklığın karesiyle ters orantılıdır. Ayrıca bu etki aralarındaki ortama da bağlıdır.”</p>  <p><small>Resim 2.23: Charles Augustin Coulomb (1736-1806)</small></p>	<p>Elektrik Alan Vektörü</p> <ul style="list-style-type: none"> Uzayın herhangi bir noktasındaki elektriksel alan vektörü, o noktaya konulan +1 C'lik deneme yüküne etkileyen elektriksel kuvvet vektörüdür. 
Slide 13	Slide 16
<p>Acaba Bilim insanları nasıl açıklamışlar?</p> <p>Bu ifade ile anlatılan şey fizikte Coulomb Yasası olarak bilinir. Bu yasanın matematiksel ifadesi:</p> $F = k \cdot \frac{q_1 \cdot q_2}{d^2}$ <p>şeklinde dir. Burada;</p> <p>F : Newton (N) olarak elektriksel itme ya da çekme kuvvetinin büyüklüğü,</p> <p>q_1 ve q_2 : Coulomb (C) olarak noktasal yüklerin değeri,</p> <p>d : Metre (m) olarak noktasal iki yük arasındaki uzaklık,</p> <p>k : İki yükü arasındaki ortamla ilgili bir kat sayıdır.</p> <p>Yukarıdaki birimler SI birim sistemindeki birimlerdir. Buna göre, q_1 ve q_2'nin birimi C, r'nin birimi m olunca F'nin biriminin N olarak çıkması için k'nin birimi $\frac{N \cdot m^2}{C^2}$ olmak zorundadır. Boşluk için,</p> $k = 9 \cdot 10^9 \frac{N \cdot m^2}{C^2}$ <p>olduğu bilinmektedir. Yükler arasındaki ortam değişince k'nin, dolayısıyla elektriksel kuvvetin büyüklüğünün değişeceği açıktır.</p> 	<p>Elektriksel Alan</p> <ul style="list-style-type: none"> Noktasal q yükünden d kadar uzaklıktaki elektriksel alanın büyüklüğü şöyle olur: $E = \frac{k q}{d^2}$ 
Slide 14	Slide 17
<p>Elektriksel Alan</p> <ul style="list-style-type: none"> Bir elektrik yükü, çevresinde yüklü parçacıklara kuvvet uyguladığı bir bölge yaratır. Bu bölge o yükün elektriksel kuvvet etkisini gösterdiği alandır. Herhangi bir noktada duran +1 C'lik deneme yükünü bir elektriksel kuvvet etkiliyorsa o noktada bir elektrik alanı bulunduğu söylenebilir. 	<p>Elektriksel Alan</p> <ul style="list-style-type: none"> Elektriksel alan vektörü, +1 C'lik yüke etkileyen kuvvet vektörü olarak tanımlandığına göre elektriksel alan vektörünün E" olduğu bir noktada q C'lik yüke alan tarafından etkileyen kuvvet şöyle olur: $\vec{F} = q \cdot \vec{E}$ <ul style="list-style-type: none"> F'nin birimi newton (N), elektrik yükünün birimi coulomb (C) olduğundan, eşitliği sağlanması için elektriksel alan şiddetinin birimi newton/coulomb (N/C) olmak zorundadır.
Slide 15	Slide 18

Figure A.4. Slides of lesson 4. (cont.)

LESSON 4: (cont.)

TASK 5: Electric Field

Concept(s): Electric Field

Time : 30 minutes


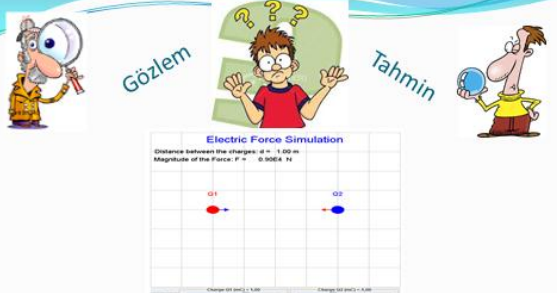
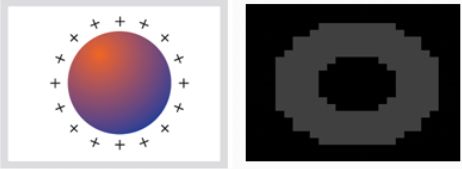


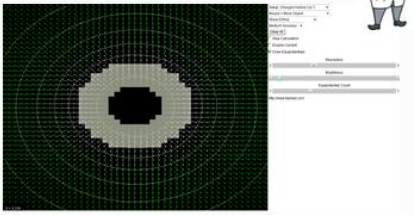


<p>Etkinlik 5: Elektriksel Alan</p>  <p>Tahmin et</p> <p>Gözlem/Deney Yap</p> <p>Açıkla (izah et)</p>	 <p>Gözlem</p> <p>Tahmin</p> <p>Electric Force Simulation</p> <p>Distance between the charges: $d = 1.00 \text{ m}$</p> <p>Magnitude of the Force: $F = 0.0024 \text{ N}$</p> <p>Gözlem ve tahminlerinizi karşılaştırın? Aynı mı yoksa farklı mı? Nedenleriyle açıklayınız</p>
Slide 19	Slide 22
<p>(+) yüklü içi boş iletken bir kürenin içindeki ve etrafındaki elektrik alan çizgileri acaba nasıl olur?</p>  <p>Defterinize tahmininizi yazınız ve nedenini açıklayınız.</p>	<p>Peki ama bu nasıl oluyor?</p> 
Slide 20	Slide 23
  <p>(Java) Deney gözlemlerinizi yazınız ve nedenini açıklayınız</p>	<p>Acaba Bilim insanları nasıl açıklamışlar?</p> <ol style="list-style-type: none"> 1. Kapalı bir yüzeye sahip olan iletken bir cisim elektrik alanı içerisine yerleştirildiğinde elektronlar, iletkenin içerisindeki elektrik alanı sıfırlanıncaya kadar hareket eder. 2. iletken yüzey sürekli olmak yerine, kafes şeklinde de imal edilebilir. 3. Öte yandan geometrinin küre olması şart değildir. Kapalı herhangi bir yüzey, kafes görevini yerine getirir. 4. Bu durumu ilk fark eden İngiliz Fizikçi Michael Faraday (Maykıl Faraday, Resim 2.17), "Faraday Kafesi" (Resim 2.18) denen buluşunu yapmıştır.  <p>Resim 2.17: Michael Faraday (1791-1867)</p>  <p>Resim 2.18: Faraday kafesi</p>
Slide 21	Slide 24

Figure A.4. Slides of lesson 4. (cont.)

LESSON 5:

TASK 6: Resistance of a Wire

Concept(s): Electric Resistance

Time: 50 minutes



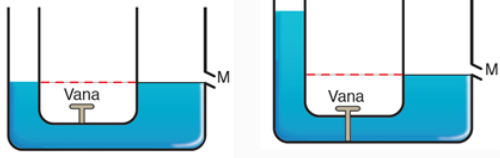
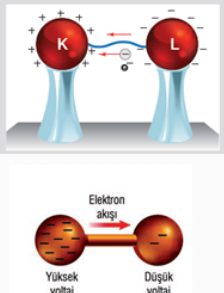

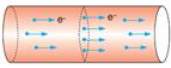
<p>Konu 2: Potansiyel Fark, Akım, Direnç</p>  <p>1752 Benjamin Franklin (Benjamin Franklin) Yıldırımın elektrik enerjisi boşalması olduğunu gösterdi.</p> <p>1800 Alessandro Volta (Alessandro Volta) Devrelere gerilim sağlayan pili buldu.</p> <p>1820 André-Marie Ampère (André Mari Amper) Elektrik akımı ile ilgili çalışmalar yaptı.</p> <p>1826 George Simon Ohm (Georg Simon Ohm) Gerilim/Akım oranının devredeki dirence eşit olduğunu gösterdi.</p>	<p>Elektriksel Potansiyel Fark</p> <ul style="list-style-type: none"> Biri (+) diğeri (-) yüklü iki cismin arasında elektriksel potansiyel farkı veya gerilim vardır. Birim hacimdeki elektron sayıları farklı cisimlerin elektriksel potansiyelleri farklıdır. V ile gösterilir ve birimi "volt" tur. 
Slide 1	Slide 4
<p>Potansiyel Fark</p>  <ul style="list-style-type: none"> Vana açılırsa su akışı olur mu? Neden? Vana açılırsa su akışı olur mu? Neden? 	<p>Elektrik Akımı</p> <ul style="list-style-type: none"> K ve L iletken cisimler arasında potansiyel farkı olduğundan iki cisim iletkenle birleştirilirse birinden diğeri elektron geçişi, bir başka ifadeyle elektrik akımı oluşur. Buna göre, iletkenin herhangi bir kesitinden birim zamanda geçen toplam yük miktarına akım şiddeti denir. 
Slide 2	Slide 5
<p>Potansiyel Fark</p>  <ul style="list-style-type: none"> Potansiyel fark sıvı akışına sebep olur. 	<p>Elektrik Akımı</p> <p>Buna göre, iletkenin herhangi bir kesitinden birim zamanda geçen toplam yük miktarına akım şiddeti denir. Akım şiddeti i sembolü ile gösterilir. Tanıma göre;</p> $\text{Akım şiddeti} = \frac{\text{Yük}}{\text{Zaman}} \text{ dir.}$ <p>(yük : q, zaman : t olduğundan)</p> $i = \frac{q}{t} \Rightarrow q = i \cdot t \text{ olur.}$ <p>Bağlantıdaki q : coulomb ; t : saniye olmak üzere akım şiddetinin birimi,</p> $\frac{\text{coulomb}}{\text{saniye}} = \text{Amper dir.}$ 
Slide 3	Slide 6

Figure A.5. Slides of lesson 5.

LESSON 5: (cont.)

Elektrik Akımı

Akım şiddetinin yönü, (-) kutuptan çıkıp (+) kutba gelen elektronların hareketine zıt yöndedir. Yani üreticinin (+) kutbundan (-) kutbuna yöneliktir. Akım şiddeti ampermetre ile ölçülür. Ampermetre, akım şiddeti ölçülecek devre elemanı ile seri bağlanır.

Slide 7

Bir akvaryum su filtre sistemini bir elektrik devresine benzeticek olursak....

Analoji-Su Filtreleme Sistemi	Hedef-Basit Elektrik Devresi
Su	?????
İlerleyen (Akan) Su	?????
Suyu Taşıyan Borular	?????
Su pompası	?????
Pompadaki Su basıncı	?????
Filtre (suyun akışına direnç)	?????
Su kaybı olmaz	?????

Slide 10

Direnç

- İletkenlerin akımı oluşturan serbest elektronların hareketlerine gösterdiği güçlük veya kolaylık maddelerin gösterdiği dirençle ilgilidir.
- Elektrik akımına karşı gösterilen zorluğa **direnç** denir.
- Direnç R ile sembolize edilir ve birimi "ohm" dur ve Ω (omega) ile gösterilir.

RESISTOR

Slide 8

Analoji-Su Filtreleme Sistemi	Hedef-Basit Elektrik Devresi
Su	Elektrik
İlerleyen (Akan) Su	Elektrik Akımı
Suyu Taşıyan Borular	Elektrik Telleri
Su pompası	Üreteç (Pil)
Pompadaki Su basıncı	Üreticinin Voltajı
Filtre (suyun akışına direnç)	Direnç
Su kaybı olmaz	Akım Korunur

Slide 11

Akvaryum Filtre Sistemi Analogisi

Electrical Filter

Slide 9

Etkinlik 6: İletken Telin Direnci

Tahmin et

Gözlem/Deney Yap


Açıkla (izah et)

Slide 12

Figure A.5. Slides of lesson 5. (cont.)

LESSON 5: (cont.)

Şekildeki iletken telin direnci ile
1.uzunluğu
2.Telin kesit alanı
arasında nasıl bir ilişki vardır?



Defterinize tahmininizi yazınız ve nedenini açıklayınız.

Keşfedilecek Sorular?

1. İletken telin boyu ile direnci arasında nasıl bir ilişki vardır?
2. İletken telin kesit alanı ile direnci arasında nasıl bir ilişki vardır?
3. İletken telin türünün telin direncine etkisi var mıdır?
4. Telin sıcaklığının direncine etkisi nasıldır?

Slide 13

Slide 16

Acaba Bilim insanları nasıl açıklamışlar?

Metali tellerin direnci;
I. Telin boyu ile doğru orantılıdır.
II. Telin kesit alanı ile ters orantılıdır.
III. Metalin türüne bağlıdır.
 Bu nedenle bir metal telin direnci matematiksel olarak

$$R = \rho \frac{L}{A}$$

eşitliği ile anlatılabilir.
 R direnç, ohm, (Ω)
 l telin uzunluğu, (metre)(m)
 A kesit alanı (A = π.r²)(m²)
 ρ (rho) telin yapıldığı metalin türü ile ilgili bir sabit olup adına öz direnç denilmektedir.
 Boyu ve kesit alanı 1 birim olan telin direncine **öz direnç** denir.
Öz direnç maddeler için ayırt edici özelliktir.

Slide 14

Slide 17

Gözlem **Tahmin**

Gözlem ve tahminlerinizi karşılaştırın? Aynı mı yoksa farklı mı? Nedenleriyle açıklayınız

• Öz dirençler madde türüne bağlı olduğu gibi maddenin sıcaklığına da bağlıdır.
 • Öz direnç sıcaklığa bağlı ise maddelerin direnci de sıcaklığa bağlı demektir.
 • En iyi iletken hangisidir? Neden?

Madde adı	Öz direnç (Ω · m)
Gümüş	1,6 · 10 ⁻⁸
Bakır	1,7 · 10 ⁻⁸
Altın	2,4 · 10 ⁻⁸
Tungsten	5,6 · 10 ⁻⁸
Demir	9,7 · 10 ⁻⁸
Nikrom	150 · 10 ⁻⁸
Karbon	3.500 · 10 ⁻⁸
Kâğıt	1
Porselen	10 ⁹
Sert plastik	10 ⁹
Tahta	10 ⁸ – 10 ¹¹
Cam	10 ¹⁰ – 10 ¹⁴

Tablo : Bazı maddelerin ota sıcaklığındaki öz dirençleri

Slide 15

Slide 18

Figure A.5. Slides of lesson 5. (cont.)

LESSON 5: (cont.)

• Elektrik enerjisinin taşınmasında hangi telleri kullanmalıyız? Neden?



Madde adı	Öz direnç ($\Omega \cdot m$)
Gümüş	$1,6 \cdot 10^{-8}$
Bakır	$1,7 \cdot 10^{-8}$
Altın	$2,4 \cdot 10^{-8}$
Tungsten	$5,6 \cdot 10^{-8}$
Demir	$9,7 \cdot 10^{-8}$
Nikrom	$150 \cdot 10^{-8}$
Karbon	$3.500 \cdot 10^{-8}$
Kâğıt	1
Porselen	10^3
Sert plastik	10^3
Tahta	$10^8 - 10^{11}$
Cam	$10^{10} - 10^{14}$

Tablo : Bazı maddelerin ortalama sıcaklıktaki öz dirençleri

• Elektrik enerjisinin ısıya dönüşmesini istiyorsak hangi tip telleri kullanmalıyız?



Madde adı	Öz direnç ($\Omega \cdot m$)
Gümüş	$1,6 \cdot 10^{-8}$
Bakır	$1,7 \cdot 10^{-8}$
Altın	$2,4 \cdot 10^{-8}$
Tungsten	$5,6 \cdot 10^{-8}$
Demir	$9,7 \cdot 10^{-8}$
Nikrom	$150 \cdot 10^{-8}$
Karbon	$3.500 \cdot 10^{-8}$
Kâğıt	1
Porselen	10^3
Sert plastik	10^3
Tahta	$10^8 - 10^{11}$
Cam	$10^{10} - 10^{14}$

Tablo : Bazı maddelerin ortalama sıcaklıktaki öz dirençleri

Slide 19
Slide 20


Figure A.5. Slides of lesson 5. (cont.)

TASK 7: Ohm's Law

Concept(s): Ohm's Law

Time: 30 minutes

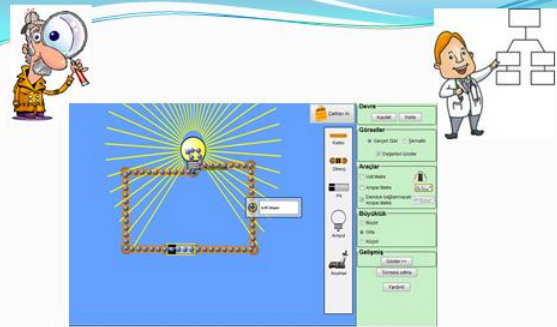
Etkinlik 7: Ohm Kanunu



Tahmin et

Gözlem/Deney Yap

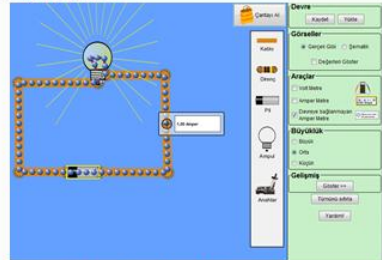
Açıkla (izah et)




(Java) Deney gözlemlerinizi yazınız ve nedenini açıklayınız

Slide 21
Slide 23

Şekildeki devrede V(potansiyel fark) ile akım arasında nasıl bir ilişki vardır?

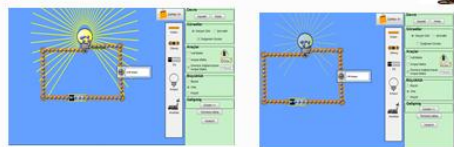


Defterinize tahmininizi yazınız ve nedenini açıklayınız.



Gözlem

Tahmin



Gözlem ve tahminlerinizi karşılaştırın? Aynı mı yoksa farklı mı? Nedenleriyle açıklayınız

Slide 22
Slide 24

Figure A.5. Slides of lesson 5. (cont.)

LESSON 5: (cont.)







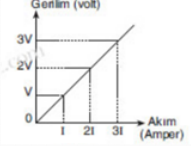




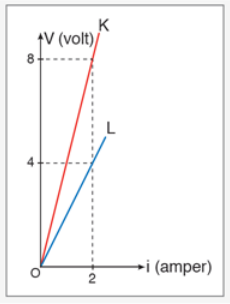
<p> Keşfedilecek Sorular?</p> <ol style="list-style-type: none"> 1. Devredeki potansiyel fark ile akım arasındaki ilişki nasıldır? 2. Devrede potansiyel fark ile direnç arasındaki ilişki nasıldır? 3. Devrede akım ile direnç arasındaki ilişki nasıldır? 4. Lambanın parlaklığı ile akım arasındaki ilişki nasıldır? 	<p>Acaba Bilim insanları nasıl açıklamışlar?</p> <ul style="list-style-type: none"> • Gerilimin birimi volt, • akım şiddetinin birimi amper, • Direncin birimi "volt/amper" olur. Bu orana ohm denildiğini ve simgesinin Ω (omega) olduğunu biliyoruz. <p></p> <p>  </p> <p>$V = I \times R$ $I = \frac{V}{R}$ $R = \frac{V}{I}$</p>
Slide 25	Slide 28
<p>Acaba Bilim insanları nasıl açıklamışlar?</p> <ul style="list-style-type: none"> • Alman fizikçi George Simon Ohm (Corç Zimon Om) (1789-1854) tarafından keşfedildiği için fizikte "Ohm Yasası" olarak bilinir ve şöyle ifade edilir: • Sıcaklığı sabit kalmak koşuluyla, bir metal iletkenin uçlarındaki gerilimin, bu iletkeni geçen akım şiddetine oranı sabittir. • Bu sabit orana o iletkenin direnci denir. <p></p> <p></p>	<p>Örnek Soru 1:</p> <ul style="list-style-type: none"> • Bir ampulün uçlarına 6 voltluk gerilim uygulanınca 3 amper şiddetinde akım geçiyor. Bu ampulün direnci kaç ohmdur?
Slide 26	Slide 29
<p>Acaba Bilim insanları nasıl açıklamışlar?</p> <p>Buna göre, Ohm Yasası;</p> $\frac{\text{Gerilim}}{\text{Akım Şiddeti}} = \text{Direnç}$ <p>şeklinde ifade edilir. Bu ifadeye göre iletkenin direnci; gerilim veya akım şiddetine bağlı değildir. Gerilim V, akım şiddeti I, direnç R simgesi ile gösterildiğine göre Ohm Yasası'nın simgelerle ifadesi,</p> $\frac{V}{I} = R$ <p>  </p> <p>$V = I \times R$ $I = \frac{V}{R}$ $R = \frac{V}{I}$</p> <p></p>	<p>Örnek Soru 2:</p> <ul style="list-style-type: none"> • K ve L metal iletkenlerinden geçen akım şiddetinin uçlarındaki gerilime bağlı değişimi grafikteki gibidir. • Bu iletkenlerin dirençleri R_K ve R_L kaç ohmdur? <p></p>
Slide 27	Slide 30

Figure A.5. Slides of lesson 5. (cont.)

LESSON 6:

TASK 8: Rheostat

Concept(s): Rheostat

Time: 80 minutes

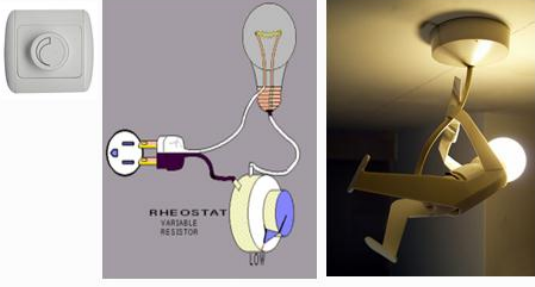
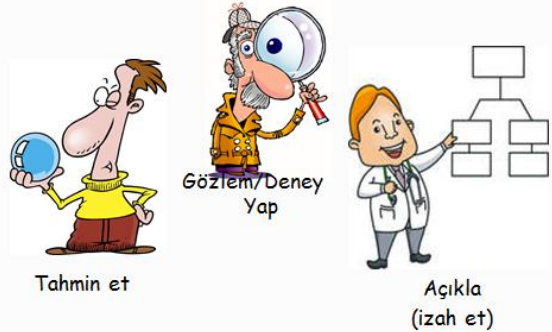
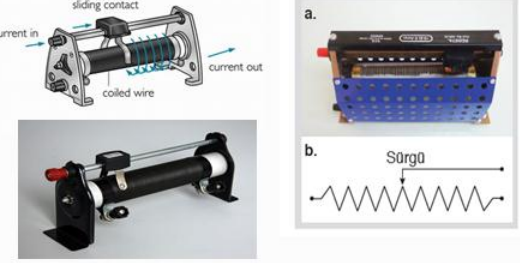
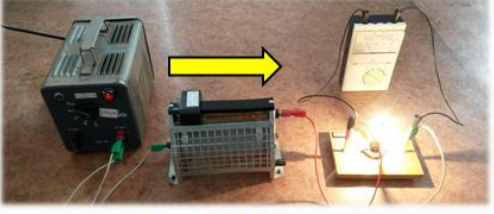
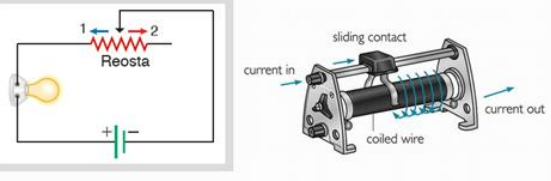

<p>Kademeli Elektrik Anahtarları Nasıl Çalışır?</p> 	<p>Etkinlik 8: Reosta</p> 
<p>Slide 1</p>	<p>Slide 4</p>
<p>Reosta</p>  <ul style="list-style-type: none"> • Reostalar devredeki değeri değiştirilebilir dirençlerdir. 	<p>Şekildeki devrede reostanın sürgüsü ok yönüne doğru sürülürse;</p> <ol style="list-style-type: none"> 1. devredeki lambadan geçen akım, 2. Lambanın parlaklığı, 3. Lamba üzerindeki potansiyel fark, nasıl değişir?  <p>Defterinize tahmininizi yazınız ve nedenini açıklayınız.</p>
<p>Slide 2</p>	<p>Slide 5</p>
<p>Reosta</p>  <p>Reostanın devrede simgesel gösterimi</p>	 <p>(Java) Deney gözlemlerinizi yazınız ve nedenini açıklayınız</p>
<p>Slide 3</p>	<p>Slide 6</p>

Figure A.6. Slides of lesson 6.

LESSON 6: (cont.)



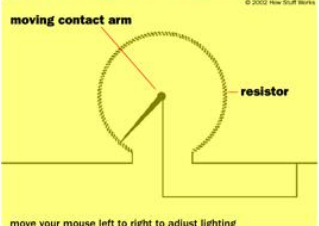
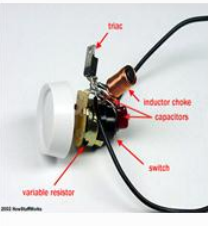
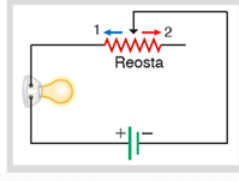
 <p>Gözlem ve tahminlerinizi karşılaştırın? Aynı mı yoksa farklı mı? Nedenleriyle açıklayınız</p>	<h3>Acaba Bilim insanları nasıl açıklamışlar?</h3> <p>DEĞİŞKEN DİRENÇ (Reosta)</p> <p>Bir iletken telin uzunluğunun değiştirilmesiyle devredeki direnç arttırıp azaltılabilir. İletkenin bu özelliklerinden yararlanılarak yapılan ve devredeki direnci arttırıp azaltmaya yarayan araçlara reosta (ayarlı direnç) denir.</p> <p>SÜRGÜ</p>  <p>Direnç artar ← → Direnç azalır</p> <p>DİRENÇ ARTARKEN LAMBANIN PARLAKLIĞI AZALIR; DİRENÇ AZALIRKEN LAMBANIN PARLAKLIĞI ARTAR.</p>
<p>Slide 7</p>	<p>Slide 9</p>
<h3>Dimmer Anahtar</h3>  <p>© 2002 Hewlett-Packard</p> <p>moving contact arm</p> <p>resistor</p> <p>move your mouse left to right to adjust lighting</p>  <p>slider</p> <p>variable resistor</p> <p>inductor choke</p> <p>capacitors</p> <p>switch</p> <ul style="list-style-type: none"> • Evlerimizdeki kademeli elektrik düğmeleri aynen reostanın devrede yaptığı görevi yapar. 	<h3>Örnek Soru</h3>  <p>1 2</p> <p>Reosta</p> <ul style="list-style-type: none"> • Yandaki şekilde reostanın sürgüsü 2 yönünde çekilirse lambanın parlaklığı nasıl değişir? Neden?
<p>Slide 8</p>	<p>Slide 10</p>

Figure A.6. Slides of lesson 6. (cont.)

LESSON 7:

TASK 9: Series connected Resistors

Concept(s): Resistors in Series

Time: 80 minutes


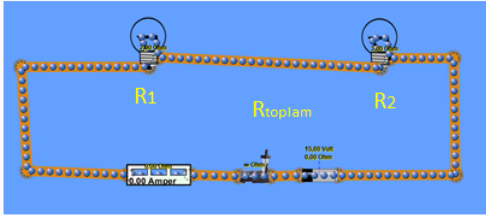

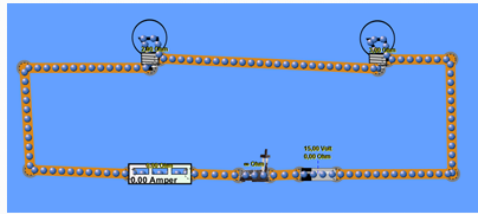
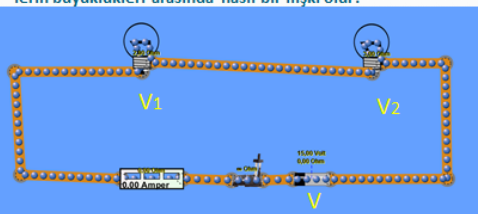

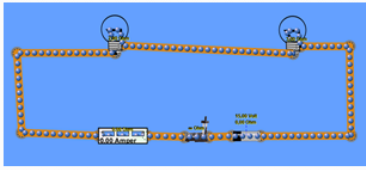
<p>Etkinlik 9: Seri Bağlı Dirençler</p>  <p>Tahmin et</p> <p>Açıkla (izah et)</p>	<p>Şekildeki devrede anahtar kapatıldığında ; 3. Devredeki R_1, R_2 ve toplam direnç (R_{toplam}) arasındaki ilişki nasıl olur?</p>  <p>Deferinize tahmininizi yazınız ve nedenini açıklayınız.</p>
<p>Şekildeki devrede anahtar kapatıldığında ; 1. Üreteçten (ana koldan) geçen akım (i) lamba 1 den geçen akım (i_1) lamba 2 den geçen akım (i_2) ların büyüklükleri arasında nasıl bir ilişki olur?</p>  <p>Deferinize tahmininizi yazınız ve nedenini açıklayınız.</p>	<p>Şekildeki devrede anahtar kapatıldığında ; 4. Lamba 1 ve lamba 2'nin yanına bir lamba daha seri bağlanırsa parlaklıkları nasıl değişir? Neden?</p>  <p>Deferinize tahmininizi yazınız ve nedenini açıklayınız.</p>
<p>Şekildeki devrede anahtar kapatıldığında ; 2. Üretecin (pilin) gerilimi (V) lamba 1 'in uçları arası gerilim (V_1) lamba 2 den uçları arası gerilim (V_2) lerin büyüklükleri arasında nasıl bir ilişki olur?</p>  <p>Deferinize tahmininizi yazınız ve nedenini açıklayınız.</p>	  <p>(Java) Deney gözlemlerinizi yazınız ve nedenini açıklayınız</p>
Slide 3	Slide 6

Figure A.7. Slides of lesson 7.

LESSON 7: (cont.)


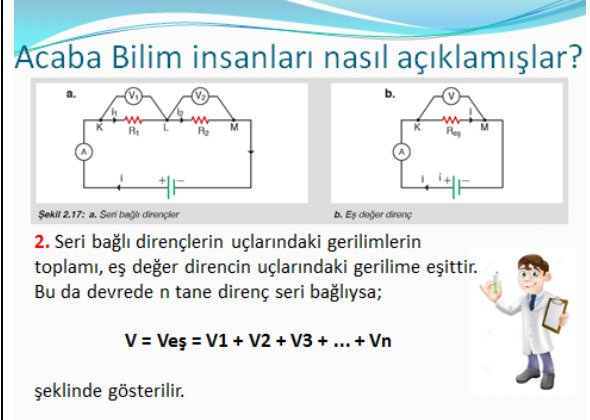

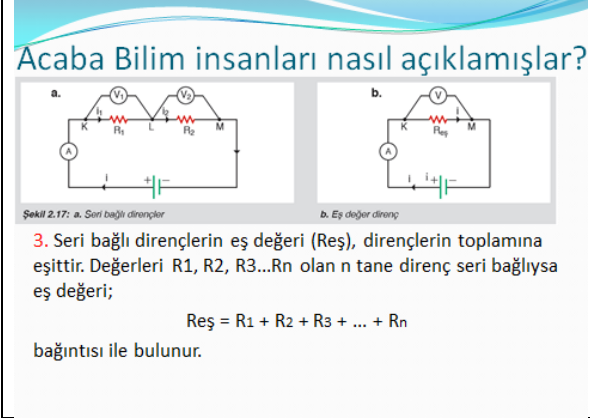
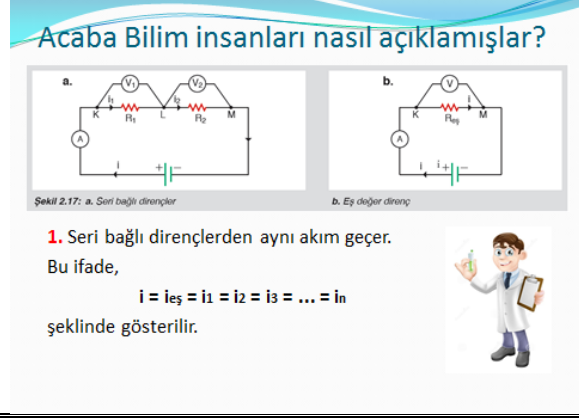
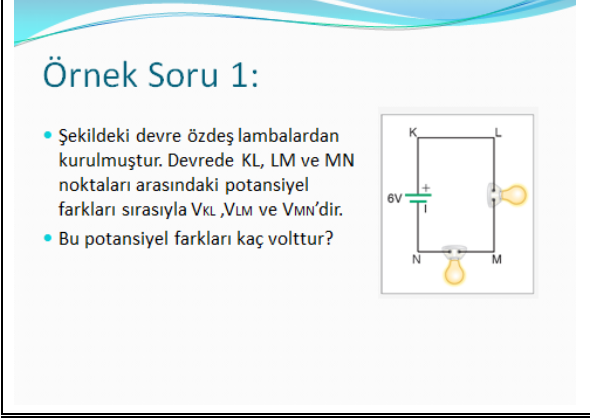
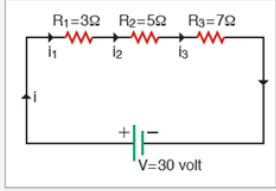
 <p>Gözlem ve tahminlerinizi karşılaştırın? Aynı mı yoksa farklı mı? Nedenleriyle açıklayınız</p>	<p>Acaba Bilim insanları nasıl açıklamışlar?</p>  <p>2. Seri bağlı dirençlerin uçlarındaki gerilimlerin toplamı, eş değer direncin uçlarındaki gerilime eşittir. Bu da devrede n tane direnç seri bağlıysa;</p> $V = V_{eş} = V_1 + V_2 + V_3 + \dots + V_n$ <p>şeklinde gösterilir.</p>
Slide 7	Slide 10
<p>Acaba Evlerimizdeki elektrikli aletler seri mi bağlı mıdır? Neden?</p> 	<p>Acaba Bilim insanları nasıl açıklamışlar?</p>  <p>3. Seri bağlı dirençlerin eş değeri ($R_{eş}$), dirençlerin toplamına eşittir. Değerleri $R_1, R_2, R_3 \dots R_n$ olan n tane direnç seri bağlıysa eş değeri;</p> $R_{eş} = R_1 + R_2 + R_3 + \dots + R_n$ <p>bağıntısı ile bulunur.</p>
Slide 8	Slide 11
<p>Acaba Bilim insanları nasıl açıklamışlar?</p>  <p>1. Seri bağlı dirençlerden aynı akım geçer. Bu ifade,</p> $i = i_{eş} = i_1 = i_2 = i_3 = \dots = i_n$ <p>şeklinde gösterilir.</p>	<p>Örnek Soru 1:</p> <ul style="list-style-type: none"> Şekildeki devre özdeş lambalardan kurulmuştur. Devrede KL, LM ve MN noktaları arasındaki potansiyel farkları sırasıyla V_{KL}, V_{LM} ve V_{MN}'dir. Bu potansiyel farkları kaç voltur? 
Slide 9	Slide 12

Figure A.7. Slides of lesson 7. (cont.)


LESSON 7: (cont.)

Örnek Soru 2:

- Şekildeki dirençleri R_1 , R_2 ve R_3 olan ampullerin uçları arasındaki potansiyel farklarının V_1 , V_2 ve V_3 değerleri kaç voltur?



Hortumdaki Fiskiyeler-Seri Bağlı Lambalar Analojisi

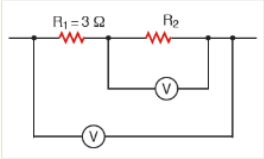


Analog: Hortumdaki Fiskiyeler	Hedef: Seri Bağlı Lambalar
Her bir fiskiye	Her bir lamba
Dışarı püsküren su	??????????????
Püsküren suyun yüksekliği	??????????????
Fiskiye ekleme, püskürme yüksekliğinin azalması	??????????????
Fiskiyeler su akıntısından yararlanır	??????????????

Slide 13

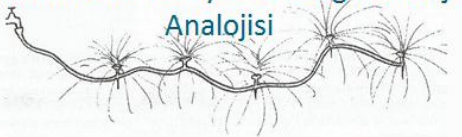
Slide 15

Örnek Soru 3:



- Şekildeki devre parçasında voltmetrelerden birisi 8V diğeri 12 V gösterdiğine göre R_2 direnci kaç Ω 'dur?

Hortumdaki Fiskiye-Seri Bağlı Direnç Analojisi



Analog: Hortumdaki Fiskiyeler	Hedef: Seri Bağlı Lambalar
Her bir fiskiye	Her bir lamba
Dışarı püsküren su	Parlayan lamba
Püsküren suyun yüksekliği	Lambanın Parlaklığı
Fiskiye ekleme, püskürme yüksekliğinin azalması	Lamba ekleme, Lambaların parlaklığının azalması
Fiskiyeler su akıntısından yararlanır	Lambalar elektrik akımından yararlanır

Slide 14

Slide 16

Figure A.7. Slides of lesson 7. (cont.)

LESSON 8:

TASK 10: Parallel Connected Resistors

Concept(s): Resistors in Parallel

Time: 80 minutes

<p>Hatırlatma Sorusu:</p> <ul style="list-style-type: none"> Şekildeki elektrik devresinde, <ol style="list-style-type: none"> Ampermetre, ampulden geçen akım şiddetini ölçer. Voltmetre, ampulün uçlarındaki gerilimi ölçer. Ampulün uçlarındaki gerilim üretcin uçlarındaki gerilimden büyüktür. <p>Yargılardan hangisi ya da hangileri doğrudur? A) Yalnız I B) Yalnız II C) I ve II D) I ve III E) II ve III</p>	<p>Birden çok ışık kaynağı kullanarak; ışık kaynaklarının bir tanesi çıkarıldığında ya da bozulduğunda diğer ışık kaynaklarının ışık verebilmesi için nasıl bir devre tasarlarsınız?</p> <p>Edison'un notlarından uyarlanarak çizilmiş seri bağlama tasarımı</p>
Slide 1	Slide 4
<p>Acaba ne olur?</p> <ul style="list-style-type: none"> Yukarıdaki devrede lambalardan birinin iki ucunu, direnci önemsiz bir tel ile birleştirecek acaba ne olur? 	<p>Etkinlik 10: Paralel Bağlı Dirençler</p> <p>Gözlem/Deney Yap</p> <p>Tahmin et</p> <p>Açıkla (izah et)</p>
Slide 2	Slide 5
<p>Kısa Devre</p> <ul style="list-style-type: none"> Lambanın üzerinden akımın geçemediği, akımın direcsiz yolu tercih ettiği böyle durumlara kısa devre denir 	<p>Şekildeki devrede anahtar kapatıldığında;</p> <ol style="list-style-type: none"> Üreteçten (ana koldan) geçen akım (i) lamba 1 den geçen akım (i_1) lamba 2 den geçen akım (i_2) <p>ların büyüklükleri arasında nasıl bir ilişki olur?</p> <p>Değerlerinize tahmininizi yazınız ve nedenini açıklayınız.</p>
Slide 3	Slide 6

Figure A.8. Slides of lesson 8.

LESSON 8: (cont.)

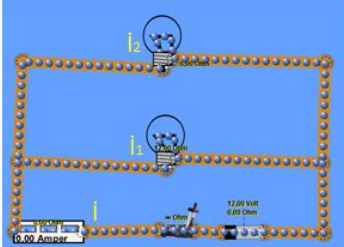


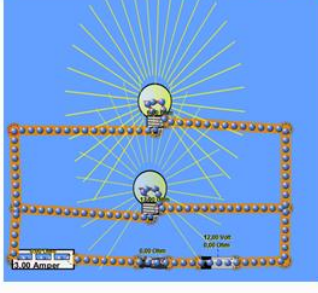
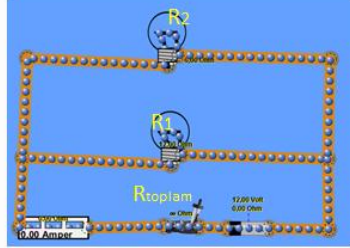
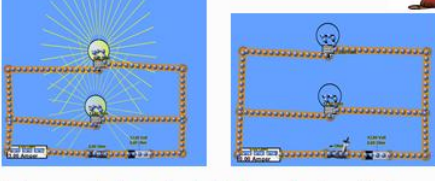
<p>Şekildeki devrede anahtar kapatıldığında ;</p> <p>1. Üreteçten (ana koldan) geçen akım (I) lamba 1 den geçen akım (I_1) lamba 2 den geçen akım (I_2) ların büyüklükleri arasında nasıl bir ilişki olur?</p>  <p>DeFTERİNİZE tahmininizi yazınız ve nedenini açıklayınız.</p>	<p>Şekildeki devrede anahtar kapatıldığında ;</p> <p>4. lamba 1 ve lamba 2'nin yanına bir lamba daha seri bağlanırsa parlaklıkları nasıl değişir? Neden?</p>  <p>DeFTERİNİZE tahmininizi yazınız ve nedenini açıklayınız.</p>
Slide 7	Slide 10
<p>Şekildeki devrede anahtar kapatıldığında ;</p> <p>2. Üretecin (pilin) gerilimi (V) lamba 1 'in uçları arası gerilim (V_1) lamba 2 den uçları arası gerilim (V_2) lerin büyüklükleri arasında nasıl bir ilişki olur?</p>  <p>DeFTERİNİZE tahmininizi yazınız ve nedenini açıklayınız.</p>	 <p>(Java) Deney gözlemlerinizi yazınız ve nedenini açıklayınız</p>
Slide 8	Slide 11
<p>Şekildeki devrede anahtar kapatıldığında ;</p> <p>3. Devredeki R_1, R_2 ve toplam direnç (R_{toplam}) arasındaki ilişki nasıl olur?</p>  <p>DeFTERİNİZE tahmininizi yazınız ve nedenini açıklayınız.</p>	 <p>Gözlem ve tahminlerinizi karşılaştırın? Aynı mı yoksa farklı mı? Nedenleriyle açıklayınız</p>
Slide 9	Slide 12

Figure A.8. Slides of lesson 8. (cont.)

LESSON 8: (cont.)


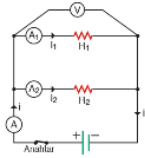

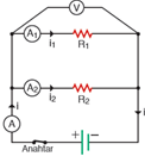

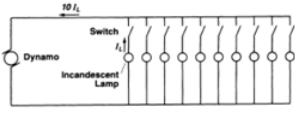

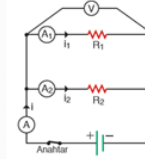

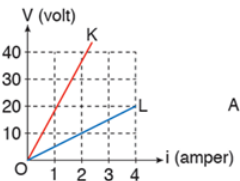
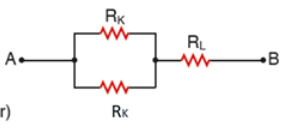
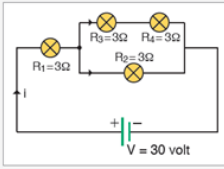
<p>Acaba evlerimizdeki elektrikli aletler paralel mi bağlı mıdır? Neden?</p> 	<p>Acaba Bilim insanları nasıl açıklamışlar?</p>  <p>4. Paralel bağlı ampullerden direnci çok olanın parlaklığı azdır. Özdeş ampullerin dirençleri eşit olduğundan üzerinden geçen akım şiddeti, dolayısıyla uçlarındaki gerilimi çok olan ampul parlak yanar.</p> 
Slide 13	Slide 16
<p>Acaba Bilim insanları nasıl açıklamışlar?</p>  <p>1. Paralel bağlı dirençlerden geçen akım şiddetlerinin toplamı ana koldan geçen akım şiddetine eşittir. n tane paralel bağlı direnç için akım şiddeti; $i = i_1 + i_2 + i_3 + \dots + i_n$</p> 	<p>Birden çok ışık kaynağı kullanarak; ışık kaynaklarının bir tanesi çıkarıldığında ya da bozulduğunda diğer ışık kaynaklarının ışık verebilmesi için nasıl bir devre tasarlırsınız?</p>  <p>Edison'un notlarından uyarılarak çizilmiş seri bağlama paralel bağlama tasarımı</p> <ul style="list-style-type: none"> Edison paralel bağlı lambalar kapsamında ilk gösterisini Amerika'da Menlo Park'taki elektrik santraline 30 lambayı paralel bağlayarak gerçekleştirdi. Her hangi bir lamba kapatıldığında bir diğerini etkilemiyordu. 
Slide 14	Slide 17
<p>Acaba Bilim insanları nasıl açıklamışlar?</p>  <p>2. Paralel bağlı dirençlerin uçları arasındaki gerilimleri eşittir. Devrede n tane direnç paralel bağlıysa; $V = V_{eş} = V_1 = V_2 = V_3 = \dots = V_n$</p> 	<p>Örnek Soru 1:</p>   <ul style="list-style-type: none"> Bir elektrik devresindeki K ve L dirençlerinin gerilim-akım grafiği verilmiştir. <p>AB noktaları arasında iki tane R_k, bir tane R_L direnci şeklindeki gibi bağlanırsa eş değer direnç kaç Ω olur?</p>
Slide 15	Slide 18

Figure A.8. Slides of lesson 8. (cont.)

LESSON 8: (cont.)

Örnek Soru 2:



• Şekildeki gibi bağlanmış özdeş ampullerin her birinin direnci 3Ω 'dur. Devrede i ile gösterilen ana koldaki akım şiddeti kaç amperdir?

Okulun Spor Salonu- Paralel Bağlı Lambalar Analojisi

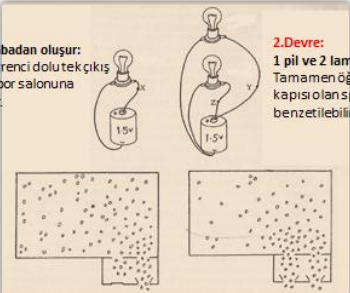
Analog: Öğrencilerin salonu boşaltmaları	Hedef: Paralel Bağlı Lambalar
Öğrencilerle dolu spor salonu	Tamamen Dolu üreteç (pil)
Tek kapıdan çıkan öğrenciler	Devredeki tek lamba
İki kapıdan çıkan öğrenciler	Devredeki paralel bağlı iki lamba
Her kapıdan çıkışın aynı hızdadır	Her lambanın aynı üzerindeki akım ve voltajı aynıdır
İki kapısı açık salon iki kat daha hızlı sürede boşalır	Paralel bağlı iki lambalı devrede pilli iki kat hızlı süredetükenir

Slide 19

Slide 22

Okulun Spor Salonu- Paralel Bağlı Lambalar Analojisi

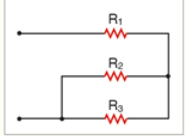
1.Devre:
1 pil ve 1 lambadan oluşur:
Tamamen öğrenci dolu tek çıkış kapısı olan spor salonuna benzetilebilir.



2.Devre:
1 pil ve 2 lambadan oluşur:
Tamamen öğrenci dolu iki çıkış kapısı olan spor salonuna benzetilebilir.

Kavrama Sorusu 1:

Bir elektrik devresindeki K ve L noktaları arasında R_1 , R_2 ve R_3 dirençleri şekildeki gibi bağlanmıştır. Bu dirençlerin bağlanış şekilleri ile ilgili olarak aşağıdakilerden hangisi doğrudur?



A) Üçü de birbirine paralel bağlıdır.
B) Üçü de birbirine seri bağlıdır.
C) R_1 ve R_2 seri, R_3 onlara paralel bağlıdır.
D) R_2 ve R_3 paralel, R_1 onlara seri bağlıdır.
E) R_2 ve R_3 seri, R_1 onlara paralel bağlıdır.

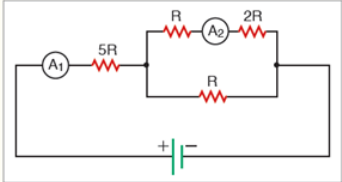
Slide 20

Slide 23

Okulun Spor Salonu- Paralel Bağlı Lambalar Analojisi

Analog: Öğrencilerin salonu boşaltmaları	Hedef: Aynı voltajı ve akımı paylaşan paralel bağlı lambalar
Tamamen öğrencilerle dolu spor salonu	Tamamen Dolu üreteç (pil)
Tek kapıdan çıkan öğrenciler	????????????????
İki kapıdan çıkan öğrenciler	????????????????
Her kapıdan çıkışın aynı hızdadır.	????????????????
İki kapısı açık salon iki kat daha hızlı sürede boşalır	????????????????

Kavrama Sorusu 2:



Şekildeki devrede A_1 ampermetresinin gösterdiği değerin A_2 ampermetresinin gösterdiği değere oranı kaçtır?

A) 2 B) 3 C) 4 D) 5 E) 6

Slide 21

Slide 24

Figure A.8. Slides of lesson 8. (cont.)

LESSON 9:

TASK 11: Series Connected Batteries

Concept(s): Batteries in Series

Time: 40 minutes

<p>Etkinlik 11: Üreteçlerin Seri Bağlanması</p> <p>Tahmin et</p> <p>Gözlem/Deney Yap</p> <p>Açıkla (izah et)</p>	<p>Gözlem</p> <p>Tahmin</p> <p>Gözlem ve tahminlerinizi karşılaştırın? Aynı mı yoksa farklı mı? Nedenleriyle açıklayınız</p>
<p>Şekildeki devreye bir üreteç (pil) daha seri olarak bağlanırsa;</p> <ol style="list-style-type: none"> 1. Devredeki eşdeğer gerilim V_{KL}, V_1 ve V_2 arasındaki ilişki nasıl olur? 2. Pillerden geçen akımlar I_1 ve I_2 arasındaki ilişki nasıl olur? 3. Lambanın parlaklığı nasıl değişir? 4. Pilin ömrü (tükenme süresi) nasıl değişir? <p>Defterinize tahmininizi yazınız ve nedenini açıklayınız.</p>	<p>Acaba Bilim insanları nasıl açıklamışlar?</p> <p>a.</p> <p>b.</p> <p>1. 3 adet pil seri bağlanırsa KL noktaları arasındaki eşdeğer gerilim (V_{KL});</p> $V_{KL} = V_1 + V_2 + V_3$ <p>kadar olur.</p>
<p>(Java) Deney gözlemlerinizi yazınız ve nedenini açıklayınız</p>	<p>Acaba Bilim insanları nasıl açıklamışlar?</p> <p>a.</p> <p>b.</p> <p>2. Lambanın direnci R ise devrede dolaşan akımın şiddeti (i), Ohm Yasası'na göre,</p> $V_{KL} = i \cdot R$ <p>bağıntısı ile hesaplanır.</p> <p>Seri bağlı pillerin her birinden eşit miktarda akım geçer.</p>
Slide 3	Slide 6

Figure A.9. Slides of lesson 9.

LESSON 9: (cont.)

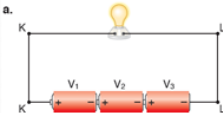
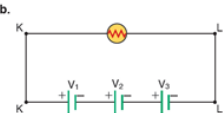

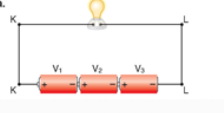
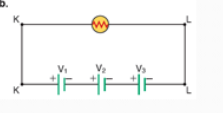

<p>Acaba Bilim insanları nasıl açıklamışlar?</p> <p>a. </p> <p>b. </p> <p>3. Seri bağlı pil sayısı arttıkça lambanın uçları arasındaki potansiyel farkı dolayısıyla lambadan geçen akım şiddeti de artar. Sonuçta seri bağlı pil sayısının artması lambanın parlaklığını artırır.</p> <p></p> <p>Slide 7</p>	<p>Acaba Bilim insanları nasıl açıklamışlar?</p> <p>a. </p> <p>b. </p> <p>4. Bir üretcin ömrü ya da tükenme süresi, yapılış anındaki boyutlarına, yapısını oluşturan maddelerin cinsine bağlıdır. • Özdeş üretçilerin yapıları aynı olduğundan, bunların tükenme süresi üretçten çekilen akım şiddetine bağlıdır. • Öyleyse, piller seri bağlandıkça pillerden geçen akım şiddeti artar, dolayısıyla ömürleri azalır.</p> <p></p> <p>Slide 8</p>
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Figure A.9. Slides of lesson 9. (cont.)

TASK 12: Parallel Connected Batteries

Concept(s): Batteries in Parallel

Time: 40 minutes



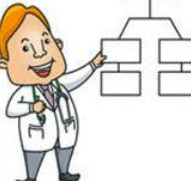

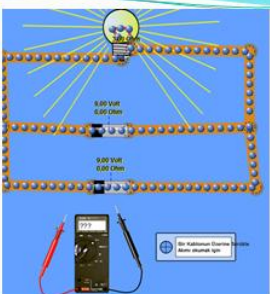

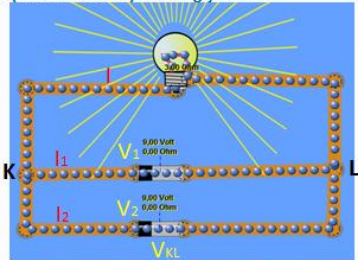



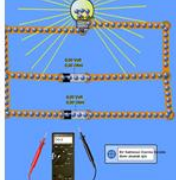

<p>Etkinlik 12: Üreteçlerin Paralel Bağlanması</p> <p> Tahmin et</p> <p> Gözlem/Deney Yap</p> <p> Açıkla (izah et)</p> <p>Slide 9</p>	<p>  </p> <p>(Java) Deney gözlemlerinizi yazınız ve nedenini açıklayınız</p> <p>Slide 11</p>
<p>Şekildeki devreye bir üretç(pil) daha paralel olarak bağlanırsa; 1. Devredeki eşdeğer gerilim V_K, V_1 ve V_2 arasındaki ilişki nasıl olur? 2. Pillerden ve lambadan geçen akımlar I_1, I_2 ve I arasındaki ilişki nasıl olur? 3. Lambanın parlaklığı nasıl değişir? 4. Pilin ömrü (tükenme süresi) nasıl değişir?</p> <p></p> <p>DeFTERİNİZE tahmininizi yazınız ve nedenini açıklayınız.</p> <p>Slide 10</p>	<p> Gözlem  Tahmin </p> <p> </p> <p>Gözlem ve tahminlerinizi karşılaştırdınız mı? Aynı mı yoksa farklı mı? Nedenleriyle açıklayınız</p> <p>Slide 12</p>

Figure A.9. Slides of lesson 9. (cont.)

LESSON 9: (cont.)

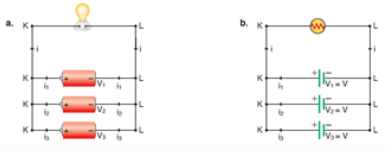
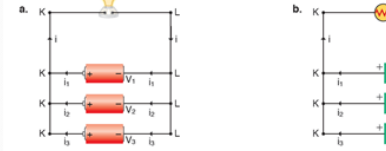
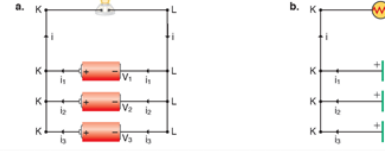
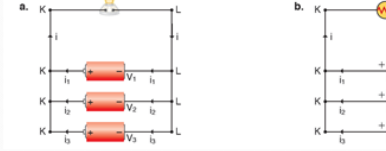
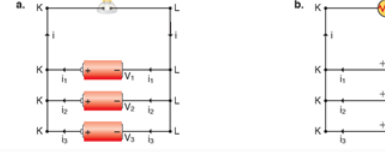


<p>Acaba Bilim insanları nasıl açıklamışlar?</p>  <ul style="list-style-type: none"> Piller (+) kutupları bir noktada (-) kutupları ise başka bir noktada olacak şekilde yapılan bağlamaya "paralel bağlı piller" denir. Paralel bağlı piller özdeş olmalıdır. Üreteçler paralel bağlı olduğundan uçları arasındaki potansiyel farkı eşitleninceye kadar birinden diğerine yük geçişi olur. Bu durum zamanla pillerin tükenmesine neden olur. 	<p>Acaba Bilim insanları nasıl açıklamışlar?</p>  <p>3. Direnci R olan lambadan geçen akım şiddeti (i), Ohm Yasası'na göre,</p> $i = \frac{V_{KL}}{R} = \frac{V}{R}$ <p>eşitliği ile hesaplanır.</p> <p>Lambadan geçen akım şiddeti değişmediği için lambanın parlaklığı değişmez.</p>
Slide 13	Slide 16
<p>Acaba Bilim insanları nasıl açıklamışlar?</p>  <p>1. KL noktaları arasındaki eş değer gerilim (V_{KL}),</p> $V = V_{KL} = V_1 = V_2 = V_3$	<p>Acaba Bilim insanları nasıl açıklamışlar?</p>  <p>4. Özdeş üreteçlerin yapılan aynı olduğundan, bunların tükenme süresi üreteçten çekilen akım şiddetine bağlıdır.</p> <p>Paralel bağlı pil sayısı arttıkça her pilden geçen akım şiddeti azalır, ömürleri artar.</p>
Slide 14	Slide 17
<p>Acaba Bilim insanları nasıl açıklamışlar?</p>  <p>2. Bu durumda lamba üzerinden geçen akım şiddeti,</p> $i = i_1 + i_2 + i_3$ <p>eşitliği ile hesaplanır.</p> <p>Piller özdeş olduğundan;</p> $i_1 = i_2 = i_3 = i/3$ <p>olur.</p>	<p>Pilin Keşfi</p>  <p>Luigi Galvani (1737-1798) "Hayvan Elektrikçi"</p>  <p>Alessandro Volta (1745-1827) "Temas Potansiyeli"</p> <p>• https://www.youtube.com/watch?v=e1BVeO71_jY</p>
Slide 15	Slide 18

Figure A.9. Slides of lesson 9. (cont.)

LESSON 9: (cont.)


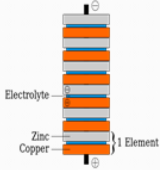
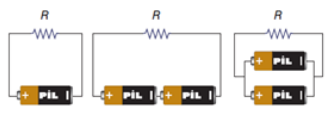
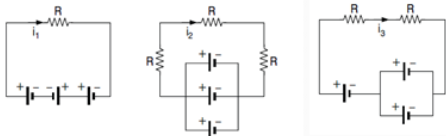
<h3>Volta Pili</h3> <ul style="list-style-type: none"> Potansiyel farkını arttırmak için yaptığı ilk çalışmada çinko ve gümüş metal çiftlerini üst üste koyarak bir sütun oluşturdu. Metaller arasındaki elektriklenmeyi arttırabilmek için mükemmel iletken olarak nitelendirdiği asit çözeltisi ile nemlendirdiği kâğıt parçalarını kullanarak bir metal çiftini diğer bir metal çiftinden ayırdı  	<h3>Örnek Soru 2:</h3>  <p>Özdeş piller ve R dirençleriyle kurulmuş devrelerde pillerin tükenme süresi sırasıyla t_I, t_{II} ve t_{III} tür.</p> <p>Buna göre, bu süreler arasındaki ilişki nedir?</p> <p>A) $t_I = t_{II} = t_{III}$ B) $t_{III} < t_{II} < t_I$ C) $t_I < t_{II} < t_{III}$ D) $t_{II} < t_I < t_{III}$ E) $t_I < t_{III} < t_{II}$</p>
Slide 19	Slide 21
<h3>Örnek Soru 1:</h3>  <p>Özdeş dirençler ve iç direnci önemsiz olmayan özdeş üreteçlerle kurulmuş şekildeki elektrik devrelerinde dirençlerden geçen akım şiddetleri i_1, i_2, i_3 tür.</p> <p>Buna göre, i_1, i_2, i_3 arasındaki ilişki nedir?</p> <p>A) $i_1 < i_2 < i_3$ B) $i_2 < i_1 = i_3$ C) $i_2 < i_1 < i_3$ D) $i_1 = i_2 < i_3$ E) $i_1 = i_3 < i_2$</p>	
Slide 20	

Figure A.9. Slides of lesson 9. (cont.)

LESSON 10:

TASK 13: The Brightness of Bulbs

Concept(s): Electric Power

Time: 40 minutes



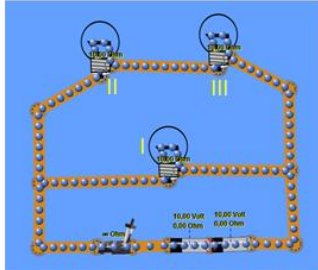
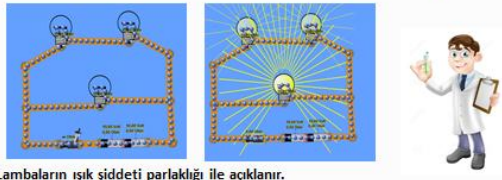
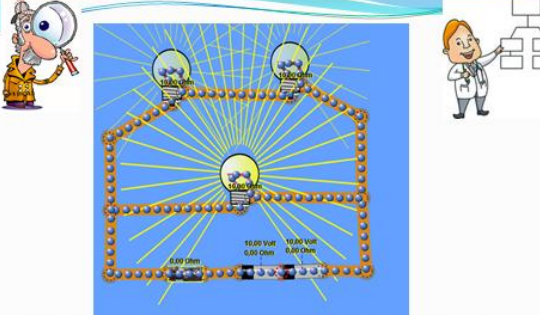
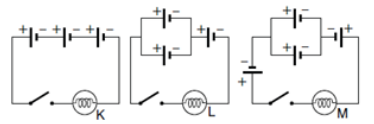
<p>Etkinlik 13:Lambaların Parlaklığı</p>  <p>Tahmin et</p> <p>Gözlem/Deney Yap</p> <p>Açıkla (izah et)</p>	 <p>Gözlem</p> <p>Tahmin</p> <p>Gözlem ve tahminlerinizi karşılaştırın? Aynı mı yoksa farklı mı?Nedenleriyle açıklayınız</p>
<p>Slide 1</p>	<p>Slide 4</p>
<p>Şekildeki devrede lambalar özdeşdir. Anahtar kapatılırsa, lambaların parlaklık sıralaması nasıl olur?</p>  <p>Defterinize tahmininizi yazınız ve nedenini açıklayınız.</p>	<p>Acaba Bilim insanları nasıl açıklamışlar?</p>  <ul style="list-style-type: none"> Lambaların ışık şiddeti parlaklığı ile açıklanır. Özdeş lambaların parlaklık sıralaması yapılırken akım veya gerilim incelenir: <ol style="list-style-type: none"> Akım: Lambaların parlaklığı, üzerinden geçen akım şiddeti ile doğru orantılıdır. Gerilim: Lambaların parlaklığı uçları arasındaki gerilim (potansiyel fark) ile doğru orantılıdır.
<p>Slide 2</p>	<p>Slide 5</p>
 <p>(Java) Deney gözlemlerinizi yazınız ve nedenini açıklayınız</p>	<p>Örnek Soru 1:</p>  <ul style="list-style-type: none"> İç dirençleri ihmal edilmiş, özdeş üreteç ve özdeş lambalarla kurulmuş devrelerde anahtarlar kapatıldığında lambaların ışık şiddetleri I_K, I_L, I_M oluyor. Buna göre, bu ışık şiddetleri arasındaki ilişki nedir?
<p>Slide 3</p>	<p>Slide 6</p>

Figure A.10. Slides of lesson 10.

LESSON 10: (cont.)

TASK 13: Relationship between Current and Magnetic Field

Concept(s): Magnetic Field of a Current Carrying Wire

Time: 40 minutes




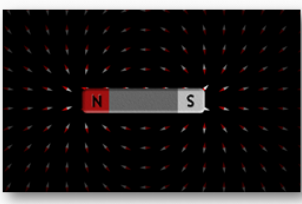
<p>Konu 3: Mıknatıslar</p> 	<p>Mıknatıs Nedir?</p> <ul style="list-style-type: none"> • Çevresinde statik(durgun) manyetik alan oluşturan nesne veya malzemeye mıknatıs denir. • Demir, nikel, kobalt gibi maddeleri çekme özelliği gösteren mıknatıslar, doğal olarak bulunabildikleri gibi yapay olarak da üretilebilir. • Sonradan etkileşim ile değişik şekillerde oluşturulabilen mıknatıslara yapay mıknatıs adı verilir. Doğal mıknatıslar uygun koşullar sağlanarak etkileştiğinde mıknatıs özelliği kazanırlar. 
<p>Slide 7</p>	<p>Slide 10</p>
<p>Etkinlik ile hedeflenen kazanım</p> <p>10.2.4.1. Mıknatısların manyetik özelliklerinin nedenlerini açıklar ve maddeleri manyetik özelliklerine göre sınıflandırır.</p> <p>a. Öğrencilerin deneyler yaparak ve simülasyonlar kullanarak manyetik alan kavramını açıklamaları sağlanır.</p> <p>b. Öğrencilerin bir mıknatısın manyetik alan kuvvet çizgilerinin mıknatısın farklı noktalarında nasıl değiştiğini görmeleri sağlanır.</p> <p>10.2.4.2. Mıknatıslar arasındaki itme ve çekme kuvvetini manyetik alan kavramını kullanarak açıklar ve bu kuvvetin bağlı olduğu değişkenleri analiz eder.</p> <p>a. Mıknatısların itme-çekme kuvvetleri ile ilgili matematiksel işlemlere girilmez</p> <p>b. Öğrenciler mıknatısları kullanarak günlük hayatta belirledikleri bir probleme çözüm önerisi üretmeleri sağlanır.</p> <ul style="list-style-type: none"> • NOT: Bu kısım gerçek (ders içi) sunuda bulunmamaktadır. 	<p>Her madde mıknatısla etkileşir mi?</p> <ul style="list-style-type: none"> • Mıknatıslardan etkilenecek mıknatıslık özelliği kazanabilen maddelere manyetik maddeler denir. • Bazı maddeler, doğal mıknatısla etkileşme yapamaz ve mıknatıs özelliği kazanamaz. Bu durumdaki maddelere manyetik olmayan maddeler denir. <p>Ör: Demir, Nikel, Kobalt</p> <p>Ör: Paladyum, manganez, Bizmut</p>
<p>Slide 8</p>	<p>Slide 11</p>
<p>Sorular soralım:</p> <ul style="list-style-type: none"> • Mıknatıs nedir? • Her madde mıknatısla etkileşir mi? • Mıknatısın manyetik alanı ne demektir? • Mıknatıs neden ve nasıl çeker? • Mıknatıslar arasındaki itme-çekme kuvveti nelere bağlı olabilir? • ???????? 	<p>Mıknatısın manyetik alanı ne demektir?</p> <ul style="list-style-type: none"> • Bir mıknatısın manyetik etkisini gösterdiği bölgeye o mıknatısın manyetik alanı denir. • «B» ile gösterilir. 
<p>Slide 9</p>	<p>Slide 12</p>

Figure A.10. Slides of lesson 10. (cont.)

LESSON 10: (cont.)

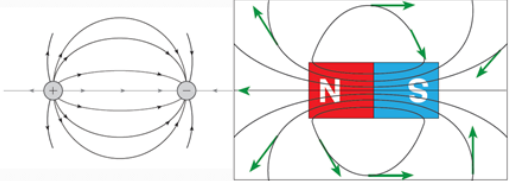
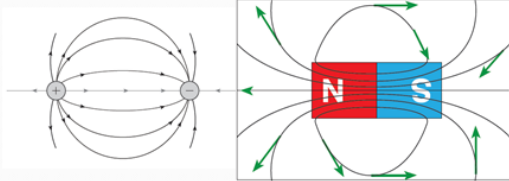
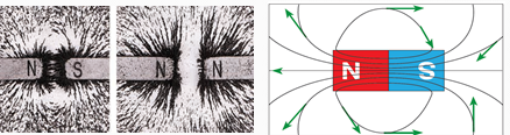
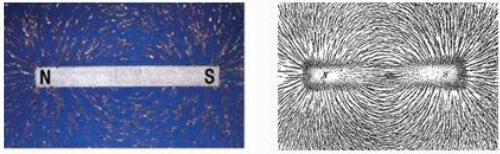
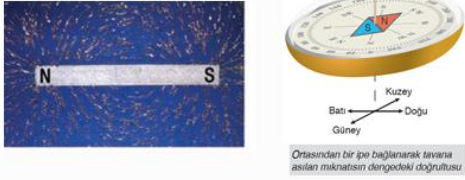

<p>Mıknatısın manyetik alanı ne demektir?</p> <ul style="list-style-type: none"> • Manyetik alanı açıklamak için manyetik alan çizgileri kullanılır. • Elektrik alanda olduğu gibi manyetik alan çizgileri de bir modeldir. • Gerçekte böyle çizgiler yoktur. 	<p>Mıknatısın manyetik alanı ne demektir?</p> <ul style="list-style-type: none"> • Birim yüzeyde dik olarak geçen çizgi sayısı, bu yüzey üzerindeki bir noktanın manyetik alan şiddetinin bir ölçüsü olarak alınabilir. • Bir noktadaki manyetik alan; doğrultusu, yönü ve şiddeti ile belirtilir. 
Slide 13	Slide 16
<p>Mıknatısın manyetik alanı ne demektir?</p> <ul style="list-style-type: none"> • Manyetik alan çizgilerinin yönü, alanı oluşturan mıknatısın N kutbundan çıkıp S kutbuna yönelen alan çizgilerinin yönü olur. • Manyetik alan şiddeti; alan çizgilerinin sık olduğu yerde büyük, seyrek olduğu yerde daha küçüktür. • Manyetik alan çizgilerinin başlangıcı ve sonu yoktur. Oysa elektriksel alan çizgileri artı işaretli yüklerden çıkıp eksi işaretli yüklerde son bulmaktadır 	<p>Mıknatısın manyetik alanı ne demektir?</p> <ul style="list-style-type: none"> • Çubuk şeklinde bir mıknatısın üzerine serpilmiş demir tozlarının yoğun bir şekilde mıknatısın uç kısımlarında toplandığı görülür. • Mıknatısın çekme özelliğinin en şiddetli olduğu bu bölgelere mıknatısın kutupları adı verilir. 
Slide 14	Slide 17
<p>Mıknatısın manyetik alanı ne demektir?</p> <ul style="list-style-type: none"> • Mıknatısların, mıknatıslık etkisinin kuvvetli olarak gözlemlendiği uçlarına kutup denir. • N kutbu kuzeyi, S kutbu ise güneyi temsil etmektedir. • Bu gösterim şekli yerin manyetik alanı göz önüne alınarak belirlenmiştir. 	<p>Mıknatısın manyetik alanı ne demektir?</p> <ul style="list-style-type: none"> • Çubuk şeklinde bir mıknatısı ikiye bölerek kutuplarının durumu sizce ne olur?  <ul style="list-style-type: none"> • Bir mıknatısın asla tek bir kutbu olmaz. • Mıknatıslar bölündükçe yeni mıknatıslar oluşur.
Slide 15	Slide 18

Figure A.10. Slides of lesson 10. (cont.)

LESSON 10: (cont.)

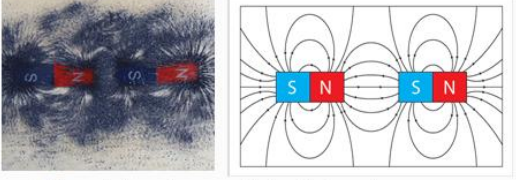
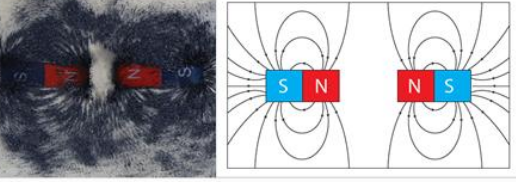
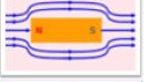
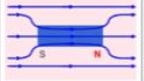
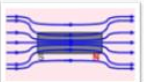
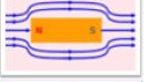
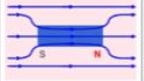
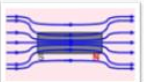
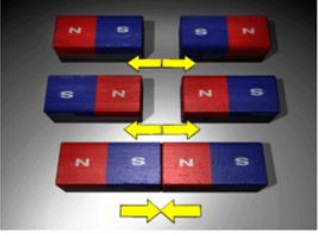
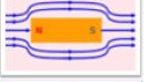
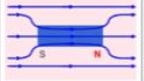
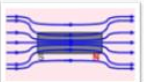
<h3>Manyetik Geçirgenlik</h3> <ul style="list-style-type: none"> • Bir mıknatıs oluşturduğu manyetik alan çizgilerinin sıklığı ya da seyrekliği, içinde bulunduğu ortama da bağlıdır. Bazı ortamlar, manyetik alan çizgilerini sıklaştırırken bazıları seyrekleştirir. • Maddelerin manyetik alan çizgilerini seyrekleştirme ya da sıklaştırma özelliğine o maddenin manyetik geçirgenliği denir. 	<h3>Mıknatıs neden çeker?</h3> <ul style="list-style-type: none"> • Resimleri inceleyelim!  <ul style="list-style-type: none"> • Zıt kutuplar karşı karşıya gelmişse bu kutupların çevresindeki manyetik alan çizgileri, âdeta mıknatısların zıt kutuplarını birbirine bağlayan bir bağ oluşturuyor. Bu bağ da sanki zıt kutupların birbirini çekmesini sağlıyor. 							
Slide 19	Slide 22							
<h3>Manyetik Geçirgenlik</h3> <ul style="list-style-type: none"> • Maddenin manyetik geçirgenliğinin boşluğun manyetik geçirgenliğine oranına bağlı manyetik geçirgenlik denir ve μ_b ile gösterilir. • μ_0 boşluğun, μ maddenin geçirgenlik katsayısı ise bağlı manyetik geçirgenlik, $\mu_b = \frac{\mu}{\mu_0}$ <p>bağıntısı ile bulunur.</p>	<h3>Mıknatıs neden çeker?</h3> <ul style="list-style-type: none"> • Resimleri inceleyelim!  <ul style="list-style-type: none"> • Eğer mıknatısların aynı kutupları karşı karşıya gelmişse bu kutupların yakınındaki manyetik alan çizgileri birbirine değmiyor. Birbirlerine değmemek için karşı karşıya gelen kutuplardan birinin kuvvet çizgileri diğerini itiyor. Dolayısıyla mıknatıslar da birbirini iter. 							
Slide 20	Slide 23							
<h3>Manyetik Geçirgenlik</h3> <ul style="list-style-type: none"> • Maddeler bağlı manyetik geçirgenliklerine göre üç grupta incelenir. <table border="1"> <tbody> <tr> <td rowspan="3">Maddeler</td> <td>Diyamanyetik Ör: Bizmut, Altın, Cam</td> <td></td> </tr> <tr> <td>Paramanyetik Ör: Alüminyum, platin, krom</td> <td></td> </tr> <tr> <td>Ferromanyetik Ör: Demir, nikel, kobalt</td> <td></td> </tr> </tbody> </table>	Maddeler	Diyamanyetik Ör: Bizmut, Altın, Cam		Paramanyetik Ör: Alüminyum, platin, krom		Ferromanyetik Ör: Demir, nikel, kobalt		<h3>Mıknatıslar arasındaki itme-çekme kuvveti nelere bağlı olabilir?</h3> <ul style="list-style-type: none"> • Peki, sizce mıknatısların manyetik alan aracılığı ile birbirlerine uyguladığı bu itme veya çekme kuvvetinin büyüklüğü nelere bağlıdır? 
Maddeler		Diyamanyetik Ör: Bizmut, Altın, Cam						
		Paramanyetik Ör: Alüminyum, platin, krom						
	Ferromanyetik Ör: Demir, nikel, kobalt							
Slide 21	Slide 24							

Figure A.10. Slides of lesson 10. (cont.)

LESSON 10: (cont.)

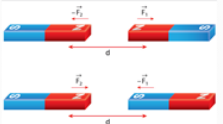











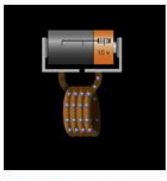


<p>Acaba Bilim insanları nasıl açıklamışlar?</p> <p>Coulomb Kanunu</p>  <ul style="list-style-type: none"> • İki mıknatıs kutbunun birbirine uyguladığı itme ya da çekme kuvvetinin büyüklüğü, 1. Mıknatısın kutuplarının şiddetiyle doğru, 2. Aralarındaki uzaklığın karesiyle ters orantılıdır. 3. Bu etki, kutuplar arasındaki ortamın türüne de bağlıdır. $\vec{F}_1 = -\vec{F}_2 \text{ ve } F_1 = F_2 = \frac{K \cdot P_1 P_2}{d^2}$	   <p>(Java) Deney gözlemlerinizi yazınız ve nedenini açıklayınız</p>
Slide 25	Slide 28
<p>Etkinlik 14: Akım-Manyetik Alan İlişkisi</p>  <p>Tahmin et</p>  <p>Gözlem/Deney Yap</p>  <p>Açıkla (izah et)</p>	 <p>Gözlem</p>  <p>Tahmin</p>    <p>Gözlem ve tahminlerinizi karşılaştırın? Aynı mı yoksa farklı mı? Nedenleriyle açıklayınız</p>
Slide 26	Slide 29
<p>Şekildeki devrede,</p> <ol style="list-style-type: none"> 1. Tel den geçen akım şiddeti ile pusulanın sapma miktarı 2. Tele uzaklık ile pusuladaki sapma miktarı 3. Tel ile pusula arasına bir madde koymamız ile pusuladaki sapma miktarı arasındaki ilişki nasıldır?   <p>Defterinize tahmininizi yazınız ve nedenini açıklayınız.</p>	 <p>Keşfedilecek Sorular?</p> <ol style="list-style-type: none"> 1. Devreden geçen akım ile akım ile manyetik alan şiddeti arasındaki ilişki nasıldır? Neden? 2. Tele olan uzaklık ile manyetik alan şiddeti arasındaki ilişki nasıldır? Neden? 3. Araya konulan bir madde manyetik alan şiddetini nasıl etkiler? 4. Akımın yönü değişirse manyetik alan nasıl etkilenir?
Slide 27	Slide 30

Figure A.10. Slides of lesson 10. (cont.)

LESSON 10: (cont.)




<p>Acaba Bilim insanları nasıl açıklamışlar?</p> <p>Manyetik alan şiddeti</p> <ul style="list-style-type: none"> akım şiddeti ile doğru, tele uzaklık ile ters orantılıdır. ortamın manyetik geçirgenliğine de bağlıdır. <p>• Akımın yönü ters dönünce manyetik alanın, dolayısıyla elektromanyetik kuvvetin yönü de ters dönüyor.</p> 	<p>Örnek Soru 2:</p> <p>Manyetik alan içinde akım taşıyan bir tele etkiyen manyetik kuvvetin artması için;</p> <p>I. Manyetik alan şiddetinin büyütülmesi, II. Telden geçen akım şiddetinin artırılması, III. Telin boyunun küçültülmesi</p> <p>işlemlerinden hangisi ya da hangileri yapılabilir?</p> <p>A) Yalnız I B) I ve II C) I ve III D) II ve III E) I, II ve III</p>																														
Slide 31	Slide 34																														
<p>Acaba Bilim insanları nasıl açıklamışlar?</p> <ul style="list-style-type: none"> İçinden akım geçen tellerin etrafında manyetik alan oluşmasına, akımın manyetik etkisi denir. Manyetik vinç, kapı otomati, hoparlör, bilgisayar vb. birçok araç akımın manyetik etkisinden yararlanarak çalışmaktadır. 																															
Slide 32																															
<p>Örnek Soru 1:</p>  <p>Şekildeki K, L ve M özdeş mıknatıslardan oluşmuş sistemde K ile M mıknatısları sabittir. L mıknatısının hareketsiz kalması için mıknatısların 1, 2, 3, 4 numaralı kutupları aşağıdakilerden hangisi olamaz? (Sürtünmeler önemsizdir.)</p> <table border="1"> <thead> <tr> <th></th> <th>1</th> <th>2</th> <th>3</th> <th>4</th> </tr> </thead> <tbody> <tr> <td>A)</td> <td>S</td> <td>S</td> <td>N</td> <td>S</td> </tr> <tr> <td>B)</td> <td>N</td> <td>S</td> <td>N</td> <td>N</td> </tr> <tr> <td>C)</td> <td>N</td> <td>N</td> <td>S</td> <td>N</td> </tr> <tr> <td>D)</td> <td>N</td> <td>N</td> <td>S</td> <td>S</td> </tr> <tr> <td>E)</td> <td>S</td> <td>N</td> <td>S</td> <td>S</td> </tr> </tbody> </table>		1	2	3	4	A)	S	S	N	S	B)	N	S	N	N	C)	N	N	S	N	D)	N	N	S	S	E)	S	N	S	S	
	1	2	3	4																											
A)	S	S	N	S																											
B)	N	S	N	N																											
C)	N	N	S	N																											
D)	N	N	S	S																											
E)	S	N	S	S																											
Slide 33																															

Figure A.10. Slides of lesson 10. (cont.)

APPENDIX B: PHYSICS REFLECTIVE JOURNAL WRITING GUIDELINES

“YANSITICI FİZİK ÖĞRENME GÜNLÜĞÜ” YAZIM REHBERİ

Yansıtıcı Fizik Öğrenme Günlüğü (YaFög) nedir ve Neden kullanmalıyım?

Öğrenme günlüğü yazma ve düşünme pratiği sağlayan etkin bir materyaldir. Öğrenme günlükleri, derslerde öğretmen tarafından tahtaya yazılanları pasif bir şekilde deftere aktarmış olduğunuz ders içi notlardan tamamen farklı bir özelliğe sahiptir. Öğrenme günlükleri derste sizin ne öğrendiğiniz veya öğrenemediğiniz üzerinde düşünerek sınıf içi kişisel deneyimlerinizi kayıt altına almanızı sağlar. Böylelikle; sizin öğrenmelerinize ilişkin görüşleriniz öğretmeninize yansıtılmış olur. Öğretmeninizin yazılan günlüğü okuyup sizlere gerekli geribildirimler vermesi, sizin süreç içerisinde gelişiminizin takip edilmesine olanak sağlar.

Öğrenme günlükleri ayrıca çok çeşitli katkılar sağlar:

- Kendi düşünceleriniz ile yüzleşmenizi sağlar.
- Bilgi ve düşüncelerinizin sentezi için bir platform oluşturur.
- Sizle öğretmeniniz arasında bir çeşit iletişim ve karşılıklı konuşma aracıdır.
- Derste size ilginç gelen ve zorlandığınız kısımların tespit edilmesine imkân sunar.
- Öğretmeniniz tarafından düzenli geri dönüt almanızı sağlar.
- Öğrenme düzeyiniz tespit edilerek yapılması gerekenler size yazılı olarak bildirilir.

Ne Yazmalıyım?

“Yansıtıcı Fizik Öğrenme Günlüğü” nde toplam 5 adet soruya cevap vermeniz beklenmektedir. İlk soruya cevap olarak, o gün işlenen konu ile ilgili daha önceki bilgilerinizi ve deneyimlerinizi aktarmanız beklenmektedir.

İkinci soruda sizden beklenen, işlediğimiz ders konusu ile ilgili derste ne anladıysanız üzerinde düşünerek ayrıntılı bir biçimde yazmanızdır. Bu bağlamda konu içi kavramlar, sınıf içi tartışmalar, gündelik hayat örnekleri, simülasyon deneyleri, gösteri deneyleri, laboratuvar etkinlikleri üzerinde düşünerek yazma içeriğinizi zenginleştirebilirsiniz.

Üçüncü soruda, derste size etkileyici ve ilginç gelen kısımları yazmanız beklenmektedir. Bu kapsamda derste sorulan bir sorunun cevabı, yapılan etkinliğin sonucu, izlediğiniz video vb. durumları düşünebilirsiniz.

Dördüncü soruda, derste size şaşırtıcı gelen kısımları yazmanız gerekmektedir. Şaşırtıcı kapsamında “Ben önceden bunu şöyle biliyordum, önceden şu şekilde düşünüyordum fakat şimdi anladım ki böyleymiş” gibi daha önceden bildiklerinizle yeni öğrendikleriniz arasında çelişki olduğunu gösteren yazımda bulunmanız beklenmektedir.

En son soruda ise işlediğimiz ders sonunda anlayamadığınız veya anlamakta güçlük çektiğiniz kısımları açıklamanız beklenmektedir.

Günlükleri ne zaman kullanmalıyım?

Doldurmuş olduğunuz ve öğretmeniniz tarafından geri dönüt verilmiş bütün günlüklerinizi bir port folyo hazırlayarak her derste yanınızda bulundurmanız gerekmektedir.

Nasıl Yazmalıyım?

Günlüklerinizi kendi el yazınız ile doldurmanız gerekmektedir. Önemli olan yazınızın açık, okunaklı ve anlaşılır olmasıdır. Bu şekilde ilerleyen haftalarda tekrar okumak istediğinizde rahatlıkla tekrar etme fırsatınız olacaktır.

Öğrenme günlükleriniz nasıl puanlandırılacak?

Yazdıklarınızın bilimsel olarak doğruluğu veya yanlışlığı değerlendirmeye alınmayacaktır. Ayrıca cümlelerinizi kurarken yapmış olduğunuz dilbilgisi, noktalama,

büyük harf, küçük harf gibi teknik hatalarınızdan da puan kırılmayacaktır. Önemli olan düşüncelerinizin ayrıntılı bir şekilde günlüklere aktarılması ve ne şekilde düşündüğünüzü tamamen kendi cümlelerinizle ifade edebilmenizdir. Özetle nasıl yazdığınızdan ziyade, nasıl düşündüğünüz değerlendirilmeye alınacaktır.

Bu kapsamda sizden beklenenler aşağıdaki tabloda belirtilmiştir.

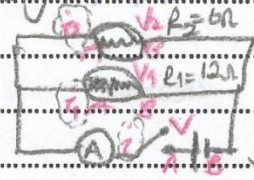
	Yüksek Düzeyde (4)	Yeterli Düzeyde (3)	Geliştirilmeli (2)	Zayıf (1)
Günlüklerin zamanında yazımı				
Açık ve anlaşılır yazım				
Düşüncelerin yansıtılması				
Dersle ve dersteki kavramlarla ilişkisi				
Özgün Yazım				

Not: Her bir günlük 20 puan üzerinden değerlendirilecektir. Toplamda 12 hafta boyunca günlük yazmanız gerekmektedir. Bunlar arasından en yüksek puanlı 10 tanesi değerlendirmeye alınacaktır.(20X10=200 puan üzerinden topladığınız puanlar daha sonra 100'lük sisteme dönüştürülecektir.)

APPENDIX C: EXAMPLES FROM STUDENTS' JOURNALS

2. Bugünkü derste neler öğrendiniz? Detaylı olarak (bilimsel açıklamalı, neden ve nasıl sorularının cevabını içerecek şekilde) açıklayınız.

Bugünkü derste Ohm kanununu yaptık. Jine her zaman ki gibi tahmin-gözetim ile gittik ve sonuçları öğrendik:



İlk önce i , i_1 ve i_2 nin oranlarını ve geçen akımın büyüklükten küçükçe sıralanmasını soruldu. Bu sıralanma $i > i_1 > i_2$ böyle olmasının sebebi i den geçen akım en büyük akım çünkü üretenden çıkan akımın tamamı önce o noktadan geçiyor. İkincinin i_2 olmasının sebebi ise akım geçmediği yoldan geçen olan maddeye olmasını ister o yüzden bizim akımımız dirençle orantılı bir şekilde paylaşılır ve toplam akımları değiştirmeden ikiye ayrılır. Direnç az olan yoldan daha çok akım geçer çok olan yerden daha az geçer ve bu yüzden i_2 ak i_1 akından küçük şekilde ayrılır. Bu yüzden sorularımızın $i > i_1 > i_2$ şeklinde olur. Diğer bir soru V , V_1 , V_2 arasındaki ilişki bu soruyu şöyle cevap verdik: i den emilen

Figure C.1. Examples from students' journals

4. Bugünkü derste size şaşırtıcı (kafa karıştırıcı) gelen şeyler nelerdi? Nedenleriyle açıklayınız. (Önceden farklı olan ama dersten sonra bilimsel yönde değiştirdiğiniz düşünceleriniz)

Bugünkü derste şaşırdığım şey etkinliğimizi yaparken ilk soruda bir tahmin yaptık benim tahminim $i = i_1 = i_2$ yönünde. Nite ki fakat götlem bölümünde oldukları bir hata yapmışım. O hatada i direncin ortak olduğu yerden a_2 a_1 olduğu yerden ortak akım geçer. Çünkü akım direnciye göre birleştiği için direnci a_2 olan yoldan ortak akım geçecek. O halde yere a_2 akım geçecektir. Bunu ben şaşırttı.

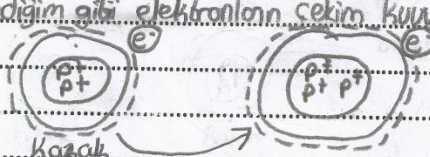
$\frac{1}{R_{es}} = \frac{1}{R_1} + \frac{1}{R_2}$ bu şekilde $R_{es} = 4$ $R_2 > R_1 > R_{es}$
 sıralanış bu şekilde dur. Bu formülü uygularsak
 $\frac{1}{R_{es}} = \frac{1}{6} + \frac{1}{12}$ $\frac{13}{12} = \frac{1}{R_{es}}$ $R_{es} = 4$ $R_1 = 6$ $R_2 = 12$
 (2) eşdeğer direnci her zaman devre direncinden düşük olur.

Figure C.1. Examples from students' journals (cont.)

APPENDIX D: EXAMPLES OF FEEDBACKS PROVIDED BY THE TEACHER

2. Bugünkü derste neler öğrendiniz? Detaylı olarak (*bilimsel açıklamalı, neden ve nasıl sorularının cevabını içerecek şekilde*) açıklayınız.

Dersimize ilk olarak Balon-Kazak başlığı altındaki bir etkinlikle başladık. İlk önce balonu kazığa sürttürdük acaba ne oldu? diye bir soru soruldu. Benim tahminim: Balonu kazığa sürttürdükten sonra kazak balonu çeker çünkü aralarında elektrik alışverişi olduğundan dolayı. Gözlemim ise: Balonu kazığa sürttürdükten sonra balondaki ve kazaktaki (+, -) yükler birbirleriyle etkileşime girdiği için kazak balonu çekti. Nasıl çekti diyecek olursak kazaktaki (+) yükler balona, balondaki (-) yükler ise kazığa geçtiğinden dolayı kazak balonu çekti. Daha sonra sorular soruldu ve cevaplandı. Mesela "Neden kazaktan balona (+) yükler gitti de balondan kazığa gitmedi?" bunun cevabını verecek olursak çünkü kazaktaki protonlar balona göre elektronlar daha az çekiyor bunun sebebi ise maddenin cinsine ve dediğim gibi elektronların çekim kuvvetine.



Kazığa balonu ne kadar çok sürttüncülse kazak balona daha çok yapışır yani sürtme miktarı ile çekme miktarı doğru orantılıdır.

Furkan! Kazaktaki + yükler balona geçti mi? Bu kısmı mutlaka otodoktrinle tartış! Mesela Fuat'la sorabilirsin!

Figure D.1. Examples of feedbacks provided by the teacher.

3. Bugünkü derste sizin için ilginç olan şeyler nelerdi? Nedenleriyle açıklayınız.

Neden sadece kazaktaki (-) yükler balona gitti de balondaki protonlar gitmedi. Bunun nedeni kazaktaki protonların elektronları balona göre daha az çektiği kısacası bunun nedeni maddenin hem cinsine bağlı, hem de elektronların protonlara olan çekim kuvvetine bağlı olduğu için. Bir de cismin cinsi değiştiği için de etkileşimi de değişti. Çünkü protonlar cismin cinsini belirlediğinden dolayı protonların çekme gücü de değişti. Bunlar bana ilginç geldi.

4. Bugünkü derste size şaşırtıcı (kafa karıştırıcı) gelen şeyler nelerdi? Nedenleriyle açıklayınız. (Önceden farklı olan ama dersten sonra bilimsel yönde değiştirdiğiniz düşünceleriniz).

Ben önceden yüksüz bir cismin elektron ve protonlara sahip olmadığını biliyordum fakat şimdi anladım ki her madde de proton ve elektron vardır. Yani proton ve elektron sayısı eşit de olsa bu cisim yüksüz bir cisim değildir sonuçta proton ve elektronları vardır. Ben önceden yüklü cisim denilince aklıma + yüklerin - yüklerin fazla olduğunu biliyordum fakat şimdi anladım ki elektron sayısı da proton sayısından fazla olursa bu cisim yüklü bir cisimdir. Bir de önceden protonların (H) hareket ettiğini biliyordum fakat şimdi anladım ki protonlar hareket etmez, elektronlar hareket eder çünkü elektronlar da protonlara çekildikleri için ⇒ (P)

Furkan tebrikler!
Nedenleriyle
ve bilimsel
derek
açıklaması
çok güzel
olmuş!

Figure D.1. Examples of feedbacks provided by the teacher. (cont.)

APPENDIX E: ITEM-OBJECTIVE TABLE

Soru No	Kazanım No	Kazanım
1	10.2.1.3.	Elektriklenen iletken ve yalıtkanlarda yüklü parçacıkların hareketini ve yük dağılımlarını karşılaştırır.
2	10.2.1.3.	Elektriklenen iletken ve yalıtkanlarda yüklü parçacıkların hareketini ve yük dağılımlarını karşılaştırır.
3	10.2.1.4.	Yüklü cisimler arasındaki etkileşimi açıklar.
4	10.2.1.4.	Yüklü cisimler arasındaki etkileşimi açıklar.
5	10.2.1.4.	Elektriklenen iletken ve yalıtkanlarda yüklü parçacıkların hareketini ve yük dağılımlarını karşılaştırır.
6	10.2.2.1.	Elektrik akımı, direnç ve potansiyel farkı kavramlarını açıklar.
7	10.2.3.1.	Akım, direnç ve potansiyel farkı kavramları aralarındaki ilişkiyi analiz eder.
8	10.2.2.1.	Elektrik akımı, direnç ve potansiyel farkı kavramlarını açıklar.
9	10.2.2.1.	Elektrik akımı, direnç ve potansiyel farkı kavramlarını açıklar.
10	10.2.3.1.	Akım, direnç ve potansiyel farkı kavramları aralarındaki ilişkiyi analiz eder.
11	10.2.3.1.	Akım, direnç ve potansiyel farkı kavramları aralarındaki ilişkiyi analiz eder.
12	10.2.3.1.	Akım, direnç ve potansiyel farkı kavramları aralarındaki ilişkiyi analiz eder.
13	10.2.3.1.	Akım, direnç ve potansiyel farkı kavramları aralarındaki ilişkiyi analiz eder.
14	10.2.3.2.	Günlük hayatta üreteçlerin seri ve paralel bağlanma gerekçelerini açıklar.
15	10.2.3.2.	Günlük hayatta üreteçlerin seri ve paralel bağlanma gerekçelerini açıklar.
16	10.2.4.1.	Mıknatısların manyetik özelliklerinin nedenlerini açıklar ve maddeleri manyetik özelliklerine göre sınıflandırır.
17	10.2.4.2.	Mıknatıslar arasındaki itme ve çekme kuvvetini manyetik alan kavramını kullanarak açıklar ve bu kuvvetin bağlı olduğu değişkenleri analiz eder.
18	10.2.5.1	Üzerinden akım geçen düz bir iletkenin oluşturduğu manyetik alanı etkileyen değişkenleri analiz eder.
19	10.2.3.1.	Akım, direnç ve potansiyel farkı kavramları aralarındaki ilişkiyi analiz eder.
20	10.2.3.1.	Akım, direnç ve potansiyel farkı kavramları aralarındaki ilişkiyi analiz eder.

	Kazanım No	Soru Adedi
1	10.2.1.3	2
2	10.2.1.4	3
3	10.2.2.1	3
4	10.2.3.1	7
5	10.2.3.2	2
6	10.2.4.1	1
7	10.2.4.2	1
8	10.2.5.1	1
Toplam		20

APPENDIX F: EMCT QUESTIONS AND ASSOCIATED CONCEPTS

Question	Master Concept(s)	Specific Concept(s)
1	Conductors	Distribution of charges on conductors
2	Insulators	Distribution of charges on insulators
3	Coulomb Force	Relationship between the amount of charge carried by the particle and Coulomb Force
4	Coulomb Force	Relationship between the amount of charge carried by the particle and Coulomb Force
5	Electric Field	Electric field at the center of a charged hollow metal sphere
6	Electric Circuits	The water circuit analogy for electric circuit
7	Electric Current	The effect of Rheostat in an electric circuit in association with Ohm's law
8	Electrical Resistance	Variables affecting electrical resistance
9	Electric Potential Difference	Factors affecting the potential difference
10	Electric Circuits	Parallel Connected Resistors
11	Electric Current	Electric current in series circuits
12	Electric Current	The brightness of identical lamps in association with the electric current in series circuits
13	Electric Current	Electric current in parallel circuits
14	Electric Potential Difference	Electric potential difference of the batteries connected in series and parallel
15	Electric Potential Difference	The brightness of identical lamps in association with the electric potential difference of batteries connected in series and parallel
16	Magnetic Field	Magnetic field lines of a magnet
17	Magnetic Field	Attraction and repulsion of magnets
18	Magnetic Field	Factors affecting the magnetic field of a current-carrying wire
19	Electric Current	The brightness of identical lamps in association with electric current in parallel and series connected resistors
20	Electric Current	Electric current in series circuits

APPENDIX G: ELECTRICITY AND MAGNETISM CONCEPTUAL TEST (EMCT)

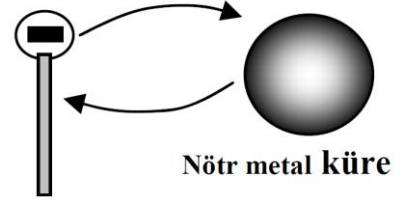
ELEKTRİK ve MANYETİZMA KAVRAM TESTİ

Sevgili Öğrenciler,

Bu test Elektrik ve Manyetizma ünitesi ile ilgili iki aşamalı 20 sorudan oluşan bir kavram testidir.

Testin sonuçları sizlere daha etkin bir fizik dersinin geliştirilmesine katkıda bulunabileceğinden önem taşımaktadır. Bu testte vereceğiniz cevaplar kesinlikle ders notunuzu etkilemeyecektir. Lütfen tüm soruları cevaplamaya çalışınız. Sınav süresi 45 dakikadır. Katılımınız için teşekkür ederim.

Soru 1: Elinizde içi oyuk **nötr metal bir küre** olduğunu varsayınız. Negatif yüklü bir cisim bu küreye yanda görüldüğü gibi dokundurulup uzak bir yere çekiliyor. Metal küre üzerindeki negatif yük dağılımı için aşağıda verilenlerden hangisi doğrudur?



- A) Yükler dokundurulan noktanın çevresinde kalır.
- B) Yükler kürenin dış yüzeyine eşit oranda dağılır.
- C) Yükler kürenin iç ve dış yüzeyine eşit oranda dağılır.
- D) Dokunma ile küre yüklenmemiştir.
- E) Verilenlerin hiçbirisi

Cevabınızın nedenini açıklayınız.

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Soru 2: Yalıtkan bir cisimle ilgili olarak verilen aşağıdaki durumlardan hangileri doğrudur?

- I. Bir yalıtıkandaki yükler serbestçe hareket edemez.
 - II. Yalıtkan bir madde yüklenemez.
 - III. Yalıtkan bir madde üzerindeki yüzey yükleri daima sıfırdır.
- A) Yalnız I B) Yalnız II C) I-II D) II-III E) I-II-III

Cevabınızın nedenini açıklayınız.

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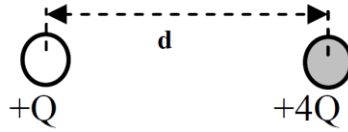
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Soru 3:

Her biri $+Q$ yüküne sahip iki noktasal cisim aralarında belli bir uzaklık varken birbirlerine F şiddetinde bir kuvvet uygulamaktadırlar. Bu cisimlerden birisinin yerine net yükü $+4Q$ olan başka bir noktasal cisim konuyor.



Bu durumda **$+Q$ yüküne** etki eden kuvvet ne olur?

- A) $16F$ B) $4F$ C) F D) $F/4$ E) hiçbiri

Cevabınızın nedenini açıklayınız.

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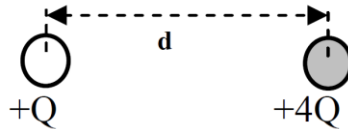
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Soru 4:

Her biri $+Q$ yüküne sahip iki noktasal cisim aralarında belli bir uzaklık varken birbirlerine F şiddetinde bir kuvvet uygulamaktadırlar. Bu cisimlerden birisinin yerine net yükü $+4Q$ olan başka bir noktasal cisim konuyor.



Bu durumda **$+4Q$ yüküne** etki eden kuvvet ne olur?

- A) $16F$ B) $4F$ C) F D) $F/4$ E) hiçbiri

Cevabınızın nedenini açıklayınız.

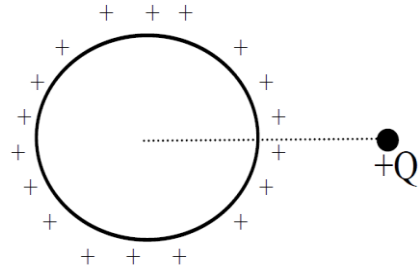
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Soru 5: Yanda, içi oyuk ve pozitif (+) yükler dış yüzeyine eşit oranda dağılmış bir iletken metal küre gösterilmiştir. Bu kürenin yakınına bir +Q yükü getiriliyor. +Q yükünün getirilmesi ile kürenin merkezindeki elektriksel alanın yönü nasıl olur?



- A) Sola doğru
 B) Sağa doğru
 C) Yukarı doğru
 D) Aşağı doğru
 E) Alan sıfırdır.

Cevabınızın nedenini açıklayınız.

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Soru 6: Yüksek yapılarda, kent suyunu üst katlara çıkarmak için kullanılan düzenekte:

- I. Su pompası,
 II. Su sayacı,
 III. Basınçölçer aygıtları vardır.

Bu düzenek bir elektrik devresine benzetilirse, yukarıdaki her bir aygıt, elektrik devresindeki aygıtların hangisinin yerini tutar?

- A) I. Üreteç, II. Direnç, III. Voltmetre
 B) I. Direnç, II. Voltmetre, III. Ampermetre
 C) I. Direnç, II. Ampermetre, III. Voltmetre
 D) I. Üreteç, II. Ampermetre, III. Voltmetre
 E) I. Üreteç, II. Ampermetre, III. Direnç

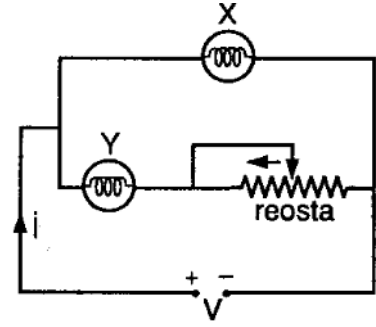
Cevabınızın nedenini açıklayınız.

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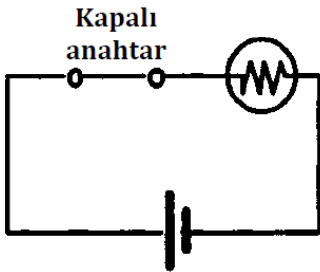
Soru 7: Şekildeki devrede reostanın sürgüsü ok yönünde çekilirse, X ve Y lambalarının parlaklığı ve i akımı nasıl değişir?

<u>X</u>	<u>Y</u>	<u>i akımı</u>
A) Artar	Azalır	Değişmez
B) Değişmez	Artar	Artar
C) Azalır	Azalır	Azalır
D) Azalır	Artar	Azalır
E) Değişmez	Azalır	Azalır



Cevabınızın nedenini açıklayınız.

Soru 8:

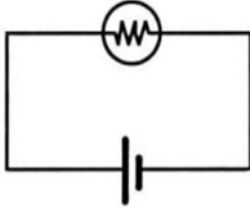


Yanda görülen devrede anahtar açıldıktan hemen sonra, lambanın direnci nasıl değişir?

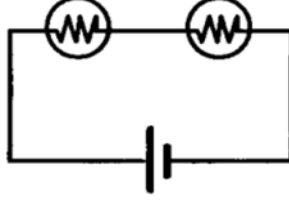
- A) Artar
- B) Azalır
- C) Değişmez
- D) Önce azalır, sonra artar
- E) Sıfırlanır

Cevabınızın nedenini açıklayınız.

Soru 9: Şekil I' de gösterilen elektrik devresine özdeş bir lamba daha eklenerek Şekil II' deki elektrik devresi oluşturuluyor. Buna göre üretcin uçları arasındaki potansiyel fark nasıl değişir?



Şekil I



Şekil II

- A) Artar
- B) Azalır
- C) Değişmez
- D) Önce azalır, sonra artar
- E) Sıfırlanır

Cevabınızın nedenini açıklayınız.

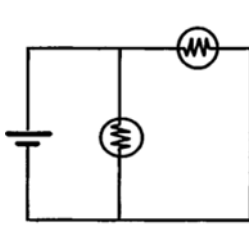
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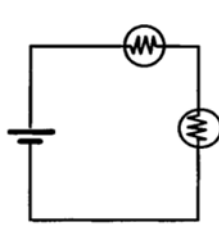
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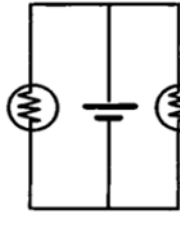
Soru 10:



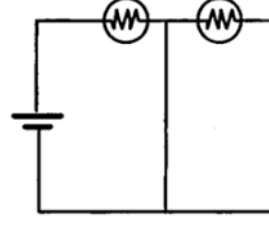
A



B



C



D

Yukarıdaki devreleri inceleyiniz. Bu devrelerden hangisi ya da hangileri bir üretçi ve paralel bağlı iki lambadan oluşur?

- A) A
- B) B
- C) C
- D) A ve C
- E) A, C ve D

Cevabınızın nedenini açıklayınız.

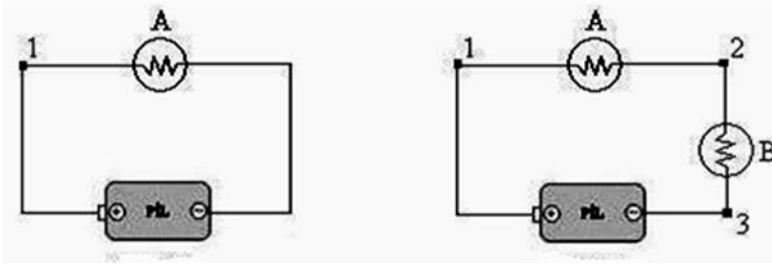
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Şekil I' de gösterilen bir elektrik devresine, Şekil II' de gösterildiği gibi özdeş B lambası ekleniyor. 11. ve 12. soruları bu bilgiye göre cevaplandırınız.



Şekil I

Şekil II

Soru 11: Şekil I ve Şekil II' deki 1 noktalarından geçen akımlarının büyüklüklerini karşılaştırınız?

- A) Şekil I' de daha fazladır.
 B) Şekil II' de daha fazladır.
 C) Her iki şekilde de eşittir.

Cevabınızın nedenini açıklayınız.

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Soru 12: Şekil II' de 1, 2 ve 3 noktalarındaki akımların büyüklükleri ile A ve B lambalarının parlaklığını karşılaştırınız?

Akım

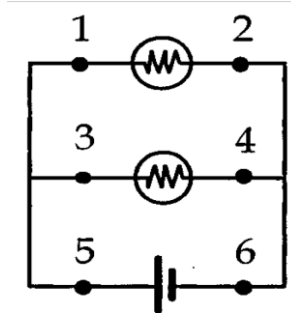
Parlaklık

- A) $i_1 = i_2 = i_3$ A ve B ampulleri aynı parlaklıktadır.
 B) $i_3 > i_2 > i_1$ B ampulü daha parlaktır.
 C) $i_1 > i_2 > i_3$ A ampulü daha parlaktır.
 D) $i_1 > i_2 > i_3$ A ve B ampulleri aynı parlaklıktadır.
 E) $i_1 = i_2 > i_3$ B ampulü daha parlaktır.

Cevabınızın nedenini açıklayınız.

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Soru 13:



1, 2, 3, 4, 5 ve 6 noktalarından geçen akımları büyükten küçüğe doğru sıralayınız. (Lambalar özdeşdir.)

- A) $5 > 1 > 2 > 3 > 4 > 6$
 B) $5 > 3 > 1 > 4 > 2 > 6$
 C) $5 = 6 > 3 = 4 > 1 = 2$
 D) $5 = 6 > 1 = 2 = 3 = 4$
 E) $1 = 2 = 3 = 4 = 5 = 6$

Cevabınızın nedenini açıklayınız.

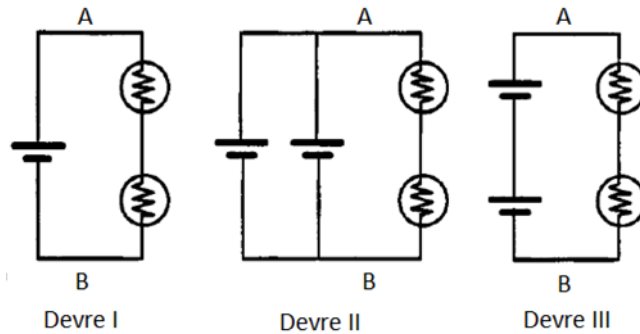
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Soru 14:



Yukarıda verilen devrelerde özdeş lambalar ve özdeş üreteçler kullanılmıştır. Aşağıdaki seçeneklerden hangisi A-B noktaları arasındaki potansiyel farkı doğru olarak göstermektedir?

- A) $V_1 < V_2 < V_3$
 B) $V_1 = V_2 < V_3$
 C) $V_1 = V_2 > V_3$
 D) $V_1 > V_2 > V_3$
 E) $V_1 < V_2 = V_3$

Cevabınızın nedenini açıklayınız.

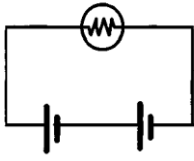
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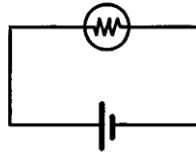
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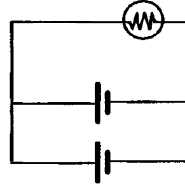
Soru 15:



I



II



III

Yukarıda verilen devrelerde özdeş lambalar ve özdeş üreteçler kullanılmıştır. Buna göre I,II ve III lambalarının parlaklık sıralaması nasıldır?

- A) I>II>III
 B) II>I>III
 C) III>II>I
 D) I=II=III
 E) I> II=III

Cevabınızın nedenini açıklayınız.

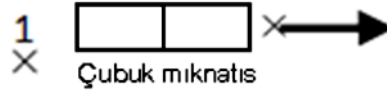
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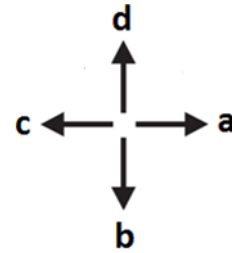
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Soru 16: Aşağıdaki şekilde bir çubuk mıknatıs ve mıknatısın belirtilen noktada oluşturduğu manyetik alan vektörü gösterilmiştir.



Mıknatısın sol tarafında yer alan 1 numaralı noktada manyetik alanın yönü, yanda belirtilen yönlerden hangisi olabilir?

- A) a
B) b
C) c
D) d
E) Manyetik alan sıfırdır.



Cevabınızın nedenini açıklayınız.

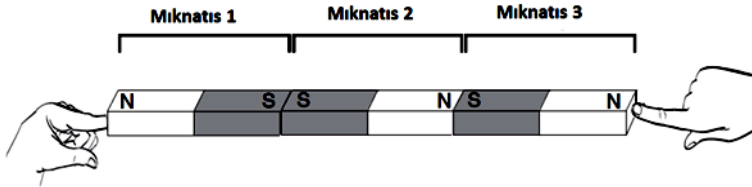
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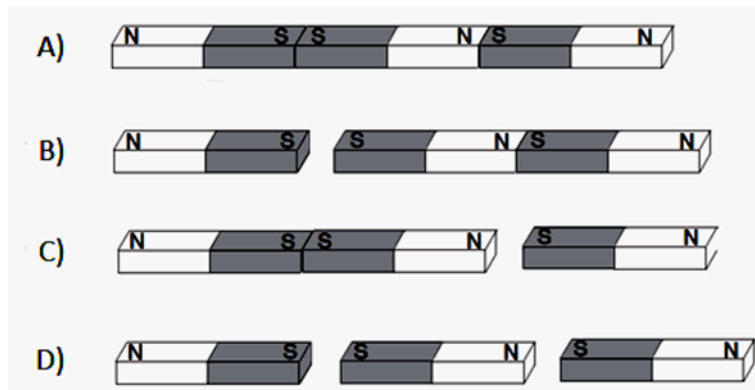
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Soru 17:



Üç mıknatıs yukarıdaki şekilde görüldüğü gibi bir arada tutulmaktadır. Mıknatıslar serbest bırakıldığında son durumları aşağıdakilerden hangisi gibi olabilir?



Cevabınızın nedenini açıklayınız.

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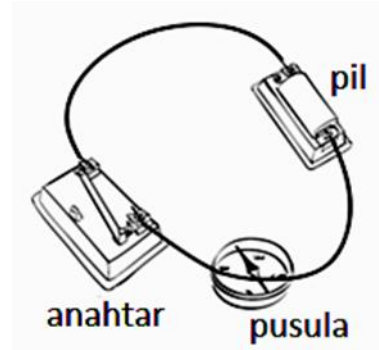
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Soru 18: Bir öğrenci, şekildeki gibi bir devre kurmuştur. Devrenin hemen yanında masanın üzerinde şekilde görüldüğü gibi bir pusula mevcuttur. Öğrenci bakır teli pile bağladığında, pusulanın ibresinde bir miktar sapma gözlemlenmiştir. Bu öğrenci aşağıdakilerden hangisini yaparsa pusulanın ibresindeki sapma miktarı artar?

- A) Pusulayı telden uzaklaştırmak
 B) Pili ters bağlamak
 C) Devreye seri bağlı bir pil daha eklemek
 D) Pusula ile akım taşıyan tel arasına cam koymak
 E) Hiçbiri



Cevabınızın nedenini açıklayınız.

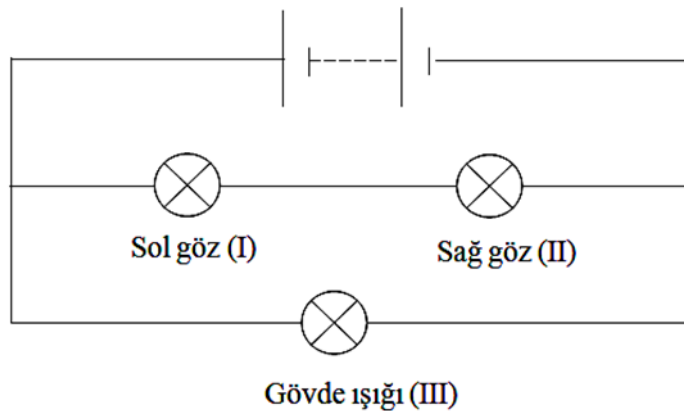
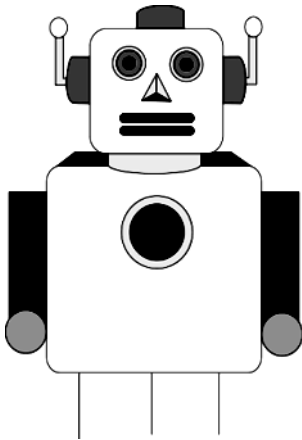
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Soru 19:



Yukarıdaki devre gösterimi bir oyuncak robotun elektrik devresine aittir. Devrede sol gözde(I), sağ gözde(II) ve gövdede(III) olmak üzere üç adet özdeş lamba mevcuttur.

Buna göre lambaların parlaklık sıralaması nasıldır?

- A) $I > II > III$
 B) $I = II > III$
 C) $I = II = III$
 D) $III > I = II$
 E) $III > II > I$

Cevabınızın nedenini açıklayınız.

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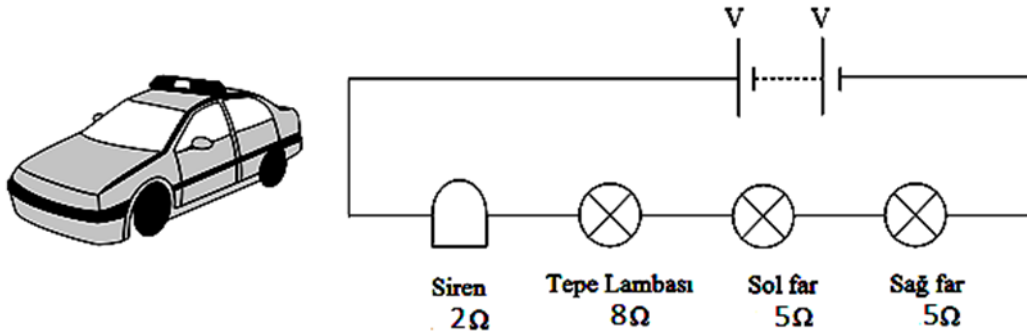
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Soru 20:

Aşağıda gösterilen oyuncak polis arabasının bir sireni, bir tepe lambası ve iki tane de farı mevcuttur. Bu dört devre elemanı, devreye seri olarak bağlanmıştır.



Buna göre, bu devre elemanlarından geçen akımların büyüklük sıralaması nasıldır?

- A) Tepe lambası akımı $>$ Sol far akımı = Sağ far akımı $>$ Siren akımı
 B) Siren akımı $>$ Sol far akımı = Sağ far akımı $>$ Tepe lambası akımı
 C) Siren akımı = Sol far akımı = Sağ far akımı = Tepe lambası akımı
 D) Sol far akımı = Sağ far akımı $>$ Siren akımı $>$ Tepe lambası akımı
 E) Tepe lambası akımı $>$ Sol far akımı = Sağ far akımı = Siren akımı

Cevabınızın nedenini açıklayınız.

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SINAV BİTMİŞTİR.

APPENDIX H: PHYSICS MOTIVATION QUESTIONNAIRE (PMQ)

FİZİK MOTİVASYON ANKETİ

Fizik dersleri hakkında ne düşündüğünüzü ve neler hissettiğinizi daha iyi anlamak için aşağıdaki ifadeleri “Fizik dersinde olduğunuzu düşünerek” değerlendiriniz. Sizden istenilen bu ifadeleri okuduktan sonra kendinizi değerlendirmeniz ve sizin için en uygun seçeneğin karşısına çarpı (X) işareti koymanızdır. Her sorunun karşısında bulunan; (1) Hiç bir zaman (2) Nadiren (3) Bazen (4) Genellikle ve (5) Her zaman anlamına gelmektedir. Lütfen her ifadeye mutlaka TEK yanıt veriniz ve kesinlikle BOŞ bırakmayınız. En uygun yanıtları vereceğinizi ümit eder, katkılarınız için teşekkür ederim.

1	Fizik konularını öğrenmekten hoşlanırım.	1	2	3	4	5
2	Öğrendiğim Fizik konuları hedeflerimle ilişkilidir.	1	2	3	4	5
3	Fizik sınavlarında diğer öğrencilerden daha başarılı olmak isterim.	1	2	3	4	5
4	Fizik sınavlarının nasıl geçeceğini düşünmek beni endişelendirir.	1	2	3	4	5
5	Fizik sınavı zamanı geldiğinde kaygılanırım.	1	2	3	4	5
6	Fizikten yüksek bir not almak benim için önemlidir.	1	2	3	4	5
7	Fizik konularını öğrenmek için yeterince çaba sarf ederim.	1	2	3	4	5
8	Fiziği iyi öğrenmemi sağlayacak yollar kullanırım.	1	2	3	4	5
9	Öğrendiğim Fizik konularının bana nasıl bir yararının olacağını	1	2	3	4	5
10	Fizik sınavlarında başarısız olmaktan endişe duyarım.	1	2	3	4	5
11	Fizik notumun genel not ortalamamı nasıl etkileyeceğini düşünürüm.	1	2	3	4	5
12	Bence, Fiziği tam anlamıyla öğrenmek yüksek not almaktan daha önemlidir.	1	2	3	4	5
13	Fizik sınavlarından nefret ediyorum.	1	2	3	4	5
14	Öğrendiğim Fizik bilgilerini nasıl kullanacağımı düşünüyorum.	1	2	3	4	5
15	Fizik projelerinde ve laboratuvar uygulamalarında başarılı olacağım konusunda kendime güvenirim.	1	2	3	4	5
16	Fiziği öğrenmek bana ilginç geliyor.	1	2	3	4	5
17	Fizikte öğrendiklerim yaşantımla ilgilidir.	1	2	3	4	5
18	Fizik dersindeki bilgi ve beceriler konusunda kendimi daha da geliştirebileceğime inanıyorum.	1	2	3	4	5
19	Öğrendiğim Fizik bilgileri günlük hayatta benim için değerlidir.	1	2	3	4	5
20	Fizik sınavları ve laboratuvar uygulamalarına iyi hazırlanırım.	1	2	3	4	5
21	Fizik sınavlarında başarılı olacağım konusunda kendime güvenirim.	1	2	3	4	5
22	Fizik konularını anlamak bana başarı hissi verir.	1	2	3	4	5

