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# EFFECTS OF TECHNOLOGY-ENHANCED METACOGNITIVE LEARNING PLATFORM ON STUDENTS' MONITORING ACCURACY AND UNDERSTANDING OF ELECTRICITY

**Eylem Yıldız Feyzioğlu,**
**Ercan Akpinar,**
**Nilgün Tatar**

**Abstract.** *The aim of this research was to explore the effect of a Technology-enhanced Metacognitive Learning Platform (TeMLP) on student's monitoring accuracy and understanding of electricity. An interactive TeMLP was prepared on the electricity unit covering the topics of static and current electricity for 7th graders; the platform contained computer animations, science experiments, e-diaries, and metacognitive prompts. In this research, pre-test/post-test control group semi-experimental model was used. The Metacognition Scale and Essay Questions on Static and Current Electricity were used as data collection tools in this research. In addition, Essay Questions on the Learning Platform and the self-explanations of students in the learning platform database were also used in the experimental group. The pre-test and post-test comparisons regarding the Metacognition Scale for the group showed that the students in the experimental group had significantly higher post-test scores compared to control group students in terms of the control and monitoring subscales. The results of the essay questions on static and current electricity revealed an important difference between the groups favoring learning platform. The views of the students about the software support these results. The conclusions drawn by the research led to recommendations for researchers about the metacognitive prompts to be employed in technology-enhanced learning platforms.*

**Keywords:** *metacognition prompt, science teaching, technology-enhanced learning.*

**Eylem Yıldız Feyzioğlu**
*Adnan Menderes University, Turkey*
**Ercan Akpinar**
*Dokuz Eylul University, Turkey*
**Nilgün Tatar**
*Alanya Alaaddin Keykubat University, Turkey*

## Introduction

Technology-enhanced Learning (TEL), devised through the opportunities provided by the effective and productive use of today's Internet and computer facilities, provides a learning environment which can help students to learn scientific concepts meaningfully. In the light of the interest students demonstrate toward technological devices, it is inevitable that such tools should be used in the classroom as instruments of learning. This is because a technology-enhanced setting gives students the opportunity to design and implement experiments, explore the relationships between variables and thus learn scientific concepts (Beishuizen, Wilhelm & Schimmel, 2004). It is however important what role students will assume when they are using technological applications. For example, it has been shown that learners' perception of satisfaction with the degree of control in TEL is related to their interest in the learning task and the enjoyment they derive from it (Vandewaetere & Clarebout, 2011). For this reason, researchers offer formats with which students may create their own material as an active learner, become aware of their misconceptions and realize that they can use their newly learned knowledge in different learning situations. For instance, students can actively pursue predict-observe-explain strategy to attain conceptual change in physics topics (Zacharia & Anderson, 2003). Individually-constructed and collaboratively-constructed concept mapping in TEL can be used to support students in their science concept learning and knowledge construction (Chang, Sung & Chen, 2001; Kao, Lin & Sun, 2008; Kwon & Cifuentes, 2009; Liu, 2011). Computer-animated conceptual change texts supported by verbal explanations can be effective in helping students to eliminate alternative concepts in their minds (Özmen, Demircioglu & Demircioglu, 2009; Özmen, 2011). Adaptive dual-situated learning models can aid students in attaining conceptual change and also provide them with the opportunity to develop their scientific reasoning skills (She & Lee, 2008).

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On the other hand, the diversity of students in the same learning environment also leads to a diversity of prior knowledge and learning strategies in TEL (Veermans & Järvelä, 2004). As prior knowledge is a characteristic of all learners (Winters, Greene & Costich, 2008), it may be used as a bridge between the learner's existing knowledge and the new knowledge introduced through the medium of technology-enhanced learning (Azevedo, 2005). A low level of prior knowledge about a subject, however, challenges the student to interpret the new knowledge and make more of an effort to comprehend it (ChanLin, 2001). For this reason, a learner who has limited prior knowledge must activate this cognitive knowledge at regular intervals (Azevedo, 2005). Kapa's research (2001) in a computerized setting reported that if learners with a low level of prior knowledge were to be asked guiding questions at an early step of the learning process, they could be helped to complete the task at hand using their knowledge of rules or procedures and to make less error.

In learning environments, students need to determine their learning goals, map out their learning strategies and assess how effective these strategies are (Azevedo, Cromley & Seibert, 2004). Novice learners however may find it difficult to understand content since they will be more likely to choose the first strategy to come to mind instead of determining a strategy on the basis of what has to be learned (Schoenfeld, 1983). On the other hand, more experienced learners will use strategies that will help them to set forth and construct their own ideas and thus they will be able to learn the new knowledge because they have activated their prior knowledge in this way (Liu, 2011). According to Azevedo, Guthrie and Seibert (2004), expert learners are also able to take the scope and context of their prior knowledge into consideration to strategically determine what learning tools they will use, setting up a plan to serve this purpose. It has therefore been asserted that students will set up their own mode of working, that is, their plan concerning what they want to learn, and decide on how to learn this subject, and in this context, it is important that a learning environment provides them with the means to decide on whether they have understood the material and when they should make their learning plans and how to change their strategies (Kramarski & Michalsky, 2008; Schraw 1998). Murphy (2008) states that the effectiveness of TEL depends upon whether or not the learner can activate metacognitive processes. Thus, to understand how individual learners adapt and regulate their learning in contexts of technology, the issue must be approached from a theoretical perspective of metacognition (Salovaara, 2005).

### *Theoretical Foundation: Technology-enhanced Metacognitive Learning*

The metacognition aids learning in many ways but one of the most important of these is the manner in which it helps learners to use the resources needed for the task effectively, process knowledge at a deeper level, and monitor performance more accurately (Schraw, Wise & Roos, 2000). Metacognition has two components: knowledge about cognition and regulation of cognition (Nietfeld, Cao & Osborne, 2005). Knowledge of cognition comprises the elements of what learners know about their own cognition (Schraw & Moshman, 1995). The regulation of cognition relates to how learners plan their own cognitive processes and how they monitor and assess them (Jacobs & Paris, 1987; Pintrich, 2002). The analysis of planning and learning (Zimmerman, Bonner & Kovach, 1996) requires decisions on what the specific outcome of the learning should be, what kind of performance will serve the purpose (Zimmerman, 2000) and on activating prior knowledge on the subject (Veenman, 2011; Winters et al., 2008). If learners think in depth about the tasks they must complete and set up goals based upon the complexity of these tasks, they can then develop an appropriate plan for learning (Stahl, Pieschl & Bromme, 2006). For example, in a research by Herscovitz, Kaberman, Saar and Dori (2012), a planning tool was used that was suited to understanding chemistry and to thinking levels and thus students were ultimately able to produce more complex and in-depth questions about the topic than the questions they had posed at the outset.

Monitoring is defined as the learner's thinking about the learning process, checking to see whether the process serves the goal, ensuring the accuracy of the process and deciding about the time and mental effort the task will need (Halpern, 1999). When individuals set out to reach a goal, it is likely that they will compare the goal with their performance (Schunk, 2003). In this case, the learner is able to differentiate between what has been learned from the task and what has not, thus finding the opportunity to focus more efficiently on the task and on cognitive resources (Tobias & Everson, 2002). This metacognitive ability helps the learner to avoid making the same mistake twice and to use more reliable sources of evidence as well as time and resources more efficiently (Yeung & Summerfield, 2012). For this reason, monitoring accuracy is an even more important indicator of learning than prior knowledge of the content to be learned (Tobias & Everson, 2002). Meanwhile, van Loon, Bruin, Gog and Merriënboera (2013) report that incorrect prior knowledge has a negative impact on the student's metacognitive judgments because the student may not be able to accurately monitor the quality of the knowledge in the individual's accessible memory. This may be associated with the learner's belief that existing prior knowledge is accurate and complete and may lead to the learner's feeling overconfident and to a premature termination of the task (van Loon, 2014). Ultimately, the learner who cannot decide upon the accuracy of existing prior knowledge may also not be able to decide upon the quality of the performance or the product when the task is finished (Dunning, Johnson, Ehrlinger, & Kruger, 2003). In short, because learners at a higher metacognitive level are able to decide upon the accuracy of their prior knowledge, use their monitoring skills and evaluate their performance when the task is finished, their monitoring accuracy may prove to be more effective.

TEL may serve to develop the learner's metacognition by offering different methods of developing a strategy to formulate a plan for monitoring and regulating a task (Quintana, Zhang & Krajcik, 2005). It has been shown that TEL designed for the purpose of instructing and supporting students in using their metacognition has a positive impact on students' cognitive outcomes. For example, using self-explanation as an metacognitive strategy (Aleven & Koedinger, 2002), e-learning supported with improved self-metacognitive questioning (Kramarski & Gutman, 2006), regulative tool support (Manlove, Lazonder & De Jong, 2007), metacognitive support devices in both computer and paper-based prompts (Bannert, Hildebrand & Mengelkamp, 2009) and dynamically scaffolding social regulation (Molenaar, Roda, van Boxtel & Sleegers, 2012) not only aid the student to progress but also develop the student's planning, monitoring and evaluation skills, thereby enhancing learning (Schraw, 2007). Research has also reported that TEL is effective in supporting and fostering metacognitive, motivational and affective regulatory processes (Greene, Moos & Azevedo, 2011; Lee, 1997; Raes, Schellens, de Wever & Vanderhoven, 2012; Ross, 1999; Vovides, 2005). For instance, Kramarski and Michalsky (2010) studied Computer-based Learning (CBL) with metacognitive instruction (CBL+META) as opposed to CBL without this instruction. They reported that being exposed to metacognitive instruction by means of self-questioning may improve pre-service teachers' ability to reflect on the learning process.

### *Cognitive, Metacognitive and Technology-Enhanced Learning Aspects of Learning Electricity*

Students' understanding of concepts such as force, light, heat and electricity is a frequently studied subject and it is known that student understanding is considerably different from conventional scientific views (Engelhardt & Beichner, 2004; Slotta & Chi, 2006). Students' misunderstandings are important learning issues that prevent them from learning the concepts introduced to them during instruction and lead them to misinterpreting phenomena that they encounter in daily life (Akgün & Deryakulu, 2007). For this reason, many studies have been conducted on exploring how students understand concepts related to static and current electricity, particularly to discover which topics they have difficulty learning. Guruswamy, Somars & Hussey (1997) report that students make mistakes in describing charge transfers between two conductors placed in contact with each other. Park, Kim, Kim and Lee (2001) have reported that many students find it difficult to explain the job of an electroscope and cannot identify materials as conductors or non-conductors. Students also have many conceptual misunderstandings about concepts of charge, electrons and neutral objects. These misunderstandings have been reported by Bilal and Erol (2009) and Siegel & Lee (2001) as, *a body with a larger charge exerts a bigger force, a charged body contains either electrons or protons, an electron is a purely negative charge with no mass, neutral objects have no charge, a charged body has only one type of charge, static electricity is caused by friction.*

Other researchers too have noted that students have misunderstandings regarding current electricity. McDermott & Shaffer (1992) have grouped the topics on current electricity that students have difficulty with in three categories: their inability to transfer the concepts they know about electricity into the topic of electrical circuits, their inability to draw and interpret an electrical circuit, their inability to explain the behavior of an electrical circuit. Eylon & Ganiel (1990) have asserted that students cannot form an association between an electrical circuit at the macro level with electrical charges on the micro level (cited in Gutwill, Frederiksen & White, 1999). Students are also challenged in understanding the properties of energy, current, voltage and resistance. Students think that voltage and resistance are only present when there is a current (Engelhardt & Beichner, 2004). Liégeois, Chasseigne, Papin and Mullet (2003) report that when students are asked to use their knowledge about resistance and current to find voltage, many of them use their knowledge about currents but not what they know about resistance, or else they ignore the matter of resistance altogether. It is said that students have a hard time structuring their knowledge because of the abstractness of concepts about electricity and due to the fact that they are unable to construct models of microscopic processes (Jaakkola, Nurmi & Veermans, 2010; Thacker, Ganiel & Boys, 1999). Beyond this,

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when students try to learn these abstract concepts with traditional teaching methods based on equations and mathematical formulas, they will continue to be unable to construct developed mental models (Thacker et al., 1999). For this reason, demonstrations, models, real-time graphs and videos may serve to allow students to build mental models related to electrical concepts and thereby understand the material (Escalada & Zollman, 1997). Because of its potential impact on student's conceptual understanding, many researchers have looked into the effect TEL has on students' understanding of electricity (Akpınar & Ergin, 2007; Başer & Durmuş, 2010: Jaakkola & Nurmi, 2008; Jaakkola et al., 2010; Zacharia, 2003). In Sengupta and Wilensky's (2009) research, a group of students who were taught with NetLogo Investigations in Electromagnetism (NIELS) showed evidence of macro-micro complementarity in charges (negative-positive), voltage, battery and electricity, whereas only a few of the students in the non-NIELS group could demonstrate macro-micro complementarity. Kong, Yeung and Wub (2009) developed open-source software called LabVNC that used a remote-controlled source to experiment with electrical circuits. This software was tested on students and their pretest/posttest results showed that the equipment had helped the students understand the electrical concepts. Thus, it was understood that the LabVNC-based system had the potential to provide an appropriate environment for students to comprehend a target topic by learning through observation.

Ultimately, successful learning relies predominantly on metacognitive activities that are performed and monitored during the learning process. A great deal of research on metacognition exists in the literature but studies on TEL in the primary school setting and students' monitoring accuracy are few. Those that do exist are largely about high school or university students (Zion, Michalsky & Mevarech, 2005). It may therefore be suggested that learners' cognitive and metacognitive control in technology-enhanced learning may be improved through guidance and support (Lee, Lim & Grabowski, 2010). This is particularly true and important when abstract subjects like electricity are the topics to be taught. As has been discussed in the previous section about electricity, from primary school to the university, it is known that students at every level have difficulty with learning topics of electricity. Technology enhanced learning environments can be effective in eliminating the students' misconceptions or help them learn difficult topics more easily. Furthermore, students engaging metacognitive skills can monitor their misconceptions more easily than novice students. As a result, successful learning is mainly based on metacognitive activities which have to be performed and constantly monitored during learning. For meaningful learning thanks to electronic learning environment, students should use and develop their metacognitive skills (Bannert, Hildebrand & Mengelkamp, 2009).

### *Problem of the Research*

The main problem of this research is "what is the effects of a Technology-enhanced Metacognitive Learning Platform (TeMLP) on student's monitoring accuracy and understanding of the electricity?"

It consists of three sub-problems. They are stated below:

- How does the TeMLP affect students' monitoring accuracy?
- What are the students' reasons for their monitoring status?
- How does the TeMLP affect students' understanding of electricity?

## Methodology of Research

This research is a part of a wide project (Preparing educational software integrated with metacognitive prompts in primary school and investigating its efficacy) applied in four classes in two primary schools in different cities in Turkey. A pre-test/post-test and control group research design was used in the project to conduct research on the effects of the TeMLP. The students in experimental group used a learning platform that integrated metacognitive prompts within the scope of the "Electricity in Our Lives" unit of the Science and Technology course. The students in the control group took the same courses according to the teaching methods recommended by the science curriculum program. The same teacher taught the topics in both experiment and control groups. The effect of TeMLP on students was examined both quantitatively and qualitatively. In the quantitative analysis, students' monitoring accuracy, and understanding of electricity were measured by means of pretest and posttests. For the qualitative analysis, the self-explanations of students in the learning platform database were used in the experimental group. Once the experimental and control groups were defined, the participants were informed about the research process and its scope. Both groups were administered the Metacognition Scale and Essay Questions on Static and Current Electricity as pre-test at the beginning of the research. Throughout the instructional process, the experimental group practiced the platform, whereas the control group practiced a normal teaching approach. At the end of the instruction, both groups were administered the Metacognition Scale and Essay Questions on Static and Current Electricity as post-test. About three months later, the same Metacognition Scale was administered again with the purpose of assessing the retention level of the students in the experimental and control group. The research was completed in four years and conducted in the same school throughout the research. In the first year, instruments and learning materials were prepared. In the second year, a pilot study was conducted to determine the effects of the TeMLP, and to evaluate usefulness of it, to identify potential errors and weaknesses in the TeMLP. In the third year, the final version of the TeMLP was conducted to both experimental and control groups. Finally, the effects of the platform were assessed.

*Participants*

The participants in this research were 53 (25 in experimental group, 28 in control group) students from a seventh grade (11-12 age) classroom at a public school in Turkey. Two of the 7$^{th}$ classes were assigned randomly as experimental and control groups at the beginning of the research, because the Turkish Ministry of National Education does not allow changes in the classes after the school term has begun. Both groups were generally taught by the same primary school teachers until 5$^{th}$ grade. In 5$^{th}$ grade, they were allotted to their classes according to their achievement levels in various subjects such as science, mathematics, Turkish language etc. Up to 7$^{th}$ grade, students have had similar teaching about electricity topic in school. Therefore, the students in both groups had similar backgrounds about electricity.

*Design of Research*

First of all, the aim of the research was introduced by the science teacher. The software was introduced by the science teacher and she used the software a few times and attained the necessary knowledge and skills to work with it. In addition, the teacher used the software in the pilot run of the research. The researcher of this research informed the teacher about teaching methods and other procedures which were used in experimental and control group. So, the effects of the teacher on the results of the research have been controlled.

Since there were not enough of computers in the laboratory, the students worked either individually or in couples in the computer laboratory. Each group was assigned to use the computer lab twice a week for 2 hours to use the learning platform during the Science and Technology course. The learning platform was set up for 16 course hours, enabling the instruction to be completed within 4 weeks. The control group used instruction recommended in the class by the curriculum of the Ministry of National Education and the instruction used by the teacher in all semesters.

*The Technology-enhanced Metacognitive Learning Platform*

The Technology-enhanced Metacognitive Learning Platform (TeMLP) was developed for seventh grade students within the scope of the project. The TeMPL dealt with concepts in static electricity-natural and charged objects, charging by friction, induction, conduction, charge interactions, the electroscope, thunder and lightning, grounding and lightning conductors. Also, the TeMPL dealt with concepts in current electricity-electric current, resistance, Ohm's Law, series and parallel circuits, and shortcut concepts. The researchers created interactive activities, interactive experiments and analogies. A predict-observe-explain strategy was used in the activities to create cognitive conflict. Students were expected to use their science process skills while conducting the experiments.

The TeMLP included three main metacognitive prompts: planning, monitoring, and evaluating. At the planning stage, students were engaged in activities to activate their prior knowledge and to determine their learning goals. This stage encouraged students to remember what they learned previously and to define what their goals were as they started on the new topic, asking them what it was that they wished to learn. In all the processes, the information offered by the students was recorded in text boxes in the database or with radio buttons. At the monitoring stage, the student was urged to monitor the learning process while the learning was occurring to make sure that the goal was being reached and the activity was being understood. Thus, the student had the opportunity to focus on reaching his/her goals or changing the cognitive strategies that were being used.

The learning platform made recommendations to the student. In the evaluating stage, students were asked

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to assess whether the multiple-choice questions taught them the concepts they needed to learn. The platform allowed the students to predict what they would score on the test prior to the answering of the questions. The students then completed the test and compared their predictions with their actual scores. The TeMLP has the learning environment in such a way that students' misconceptions about the subject of electricity could be identified and repaired. The flow chart of the learning platform can be observed in Figure 1.

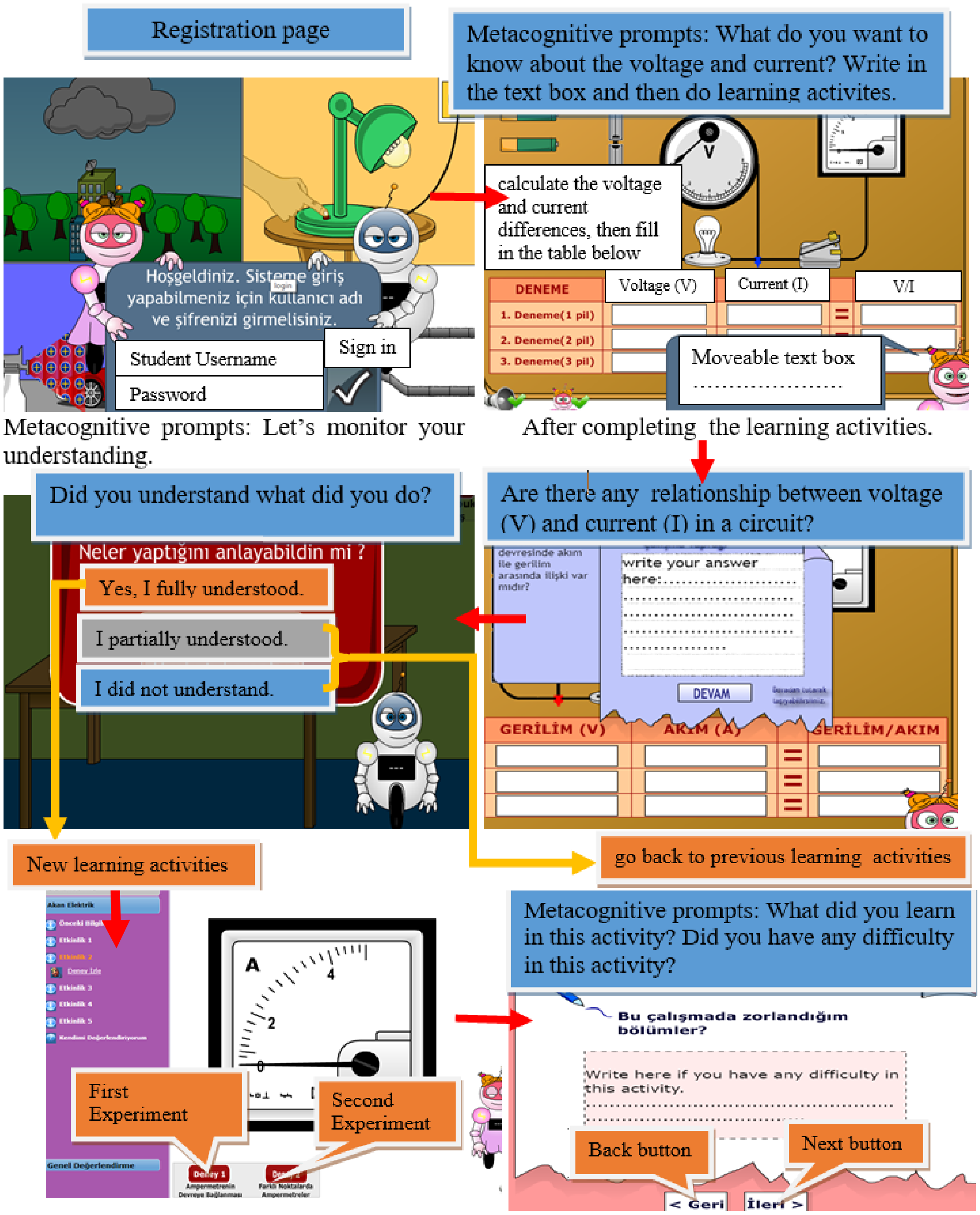


**Figure 1: The flow chart of the learning platform.**

*Instruments*

1. Metacognition Scale (MS)

MS was developed by Yıldız, Akpınar, Tatar and Ergin (2009) and contains 30 items to which participants respond on a 4-point Likert scale ranging from "Always" to "Never." The two main components of MS are knowledge of cognition and knowledge of regulation. There are many dimensions under these two components. Component knowledge of cognition comprises declarative knowledge, procedural knowledge and conditional knowledge. The knowledge of regulation component, however, includes the factors of planning, self-control, cognitive strategies, self-evaluation and self-monitoring. The internal consistency of the MS is .96.

2. Essay Questions on Static and Current Electricity

With the essay questions, the students were required to answer the question and this response was expected to show the level of understanding the student had about the concept queried (Becker & Johnston, 1999). In responding in the form of an essay, the student must generate an answer, and therefore has the potential to show originality and a deeper understanding of the subject (Becker & Johnston, 1999). The questions were used to determine how students constructed concepts of electricity in their minds and degree for understanding they displayed. For this reason, the question was worded, explain what made you give this answer and why? Also, care was shown to ensure that the questions reflected situations that the students encountered in their everyday lives. Related literature was reviewed (e.g. Peşman, 2005) and the questions were adopted, and researchers developed new questions for the aim of the research. Five questions that included the topics of static electricity, lightning and thunderbolts, charges (positive, negative and neutral), charging by Friction, charging by Induction, charging by conduction and electrical current were analyzed for this research. Students were asked to write sentences or draw figures to explain their answers to the questions. The opinions of experts and teachers were enlisted to determine if the questions were comprehensible, readable and appropriate for what was being taught in the seventh-grade science class. To determine the reliability of the encoders, the same questions were administered to 30 seventh-grade students.

3. Essay Questions on the Learning Platform

When the session was over, the students in the research group were asked to write an essay about the learning platform. The questions were about the ways they found the learning platform helpful in their planning, monitoring and self-control in the learning process. The students were additionally asked to elaborate on their reasons and explanations (Mason & Shriner, 2008). The students worked on their essays for 25 minutes. The essay questions were more useful for the research because the researchers were able to learn the students' opinions about the metacognitive prompts offered in the learning platform. While analyzing essay questions on the learning platform, the researchers reviewed the students' opinions and grouped together the general ideas and themes expressed in their explanations (Cavallo, McNeely & Marek, 2003).

*Data Analysis*

MS scale was used as a pre-measurement, post-measurement and retention measurement tool in the research. An independent t-test was used to determine the differences between the MS mean scores of students on the pre-test, post-test and retention test in the experimental and control group. However, only the scale's monitoring and control factor scores were analyzed, and other factors are out of this analysis because the students use only their monitoring and control skills when they decide their monitoring accuracy).

While analyzing the students' self-explanations about essay questions on static and current electricity, three researchers reviewed the students' answers and categories assigned according to the accuracy of the responses. In drawing up these categories, inspiration was gathered from the adaptation of Çimen (1995)'s version of Westbrook and Marek's (1991) Concept Evaluation Scheme. To analyze the students' answers, five different levels of categories were set up. These categories were: Completely right, partially right, A little right, less right and No answer. These categories were scored as 4, 3, 2, 1 and 0 respectively. The details on how each category in the research was defined

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and how the analysis applied to the students' responses is shown in Table 1. The students' responses were encoded separately by each of the three researchers. The reliability of the coding categories was calculated according to the agreement / (agreement + disagreement) formula of Miles & Huberman (1994). The level of agreement between the researchers for the independent assessment was .87.

**Table 1. Criteria for scoring.**

| Degree of understanding | Criteria for scoring |
|---|---|
| 0-No answer | Concept missing or Completely irrelevant (almost no right answers or no answer) |
| 1-Less right | Completely the opposite or a misunderstanding (a little right, many conflicting wrongs) |
| 2-A little right | The concept was partially learned, wrongs are more than rights (there are rights but there are also wrongs) |
| 3- Partially right | The concept was partially learned, wrongs are less than rights (rights are more, but they're not enough) |
| 4-Completely right | All parts of the concept are there, and the answer can be accepted as scientific (right and with nothing missing) |

The students' self-explanations on the learning platform were analyzed using qualitative content analysis (Chi, 1997). The explanations were collected under Monitoring Accuracy headings. In the analysis of students' monitoring accuracy status, we applied Tobias and Everson (2009)'s knowledge monitoring framework. This framework includes students' scores for each item/task presented to the students; subsequent scores were represented in a student response matrix. The 2 x 2 matrix of four scores for each item/task is produced to indicate the number of items/tasks estimated as known and then scored as correct on the test (+, +), estimated as unknown yet scored as correct (-, +), estimated as known and scored as incorrect (+, -), and estimated as unknown and scored as incorrect (-, -). Using this as their starting point, the researchers developed a new matrix. Before starting on each task, the student was asked to make an estimate. After the activities in the software were completed, depending upon the results of the experiment, the student was required to decide whether his/her estimate had been true or false and write this decision down in the text box. The researchers decided whether the student's decision about the estimate was correct and then revised the student response matrix. The columns of the matrix were marked (+, T) if the student's estimate was true and (-, F) if it was false; (+, T) if the decision was true and (-, F) if it was false. Accordingly, the student's estimate was examined to see whether there were mistakes in the estimate and to decide whether it was right or wrong. If the student had made no mistake and had indicated this, the response was on the (+, +, TT) level of accuracy. If the student's estimate was true but he/she had decided it was false, the response was at the (+, -, TF) level. If the student had made a mistake in the estimate and was aware of this, then the response was (-, +, FT) but if the student made the wrong decision without realizing the mistake, the response was (-, -, FF). Table 2 pertains to the students' monitoring status.

**Table 2. Students' monitoring status.**

| | | Accuracy of Monitoring | |
|---|---|---|---|
| | | True (+) | False (-) |
| Accuracy of Estimate | True (+) | + + (TT) | + - (TF) |
| | False (-) | - + (FT) | - - (FF) |

*Note. (TT): Prediction is true, monitoring is true, (TF): prediction is true, monitoring is false, (FT): prediction is false, monitoring is true, (FF): prediction is false, monitoring is false.*

For example, before charging by friction, the students were asked to predict the charge status of two objects. Later, when the student rubbed a balloon and a piece of woolen cloth against each other, he/she was able to observe the exchange of charges between the objects. At this stage, the student was asked to compare his/her prediction before the experiment and what was observed afterwards. If the student marked the charge of the balloon as

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neutral before the experiment and then responded afterwards that the balloon's charge had more of a negative charge, in this case, the response was (TT). If the student's prediction was true, but the status of the charge in the balloon was marked false, the response was (TF). If the student made the wrong prediction about the charge of the balloon before the experiment but then gave the right answer about the charge after the experiment, then the response was (FT). If the student both predicted the charge of the balloon incorrectly before and also made a mistake in the charge of the balloon after the experiment despite the observation, this was considered to be in the (FF) category. Figure 2 shows the monitoring accuracy prompt that was presented to the student for this experiment.

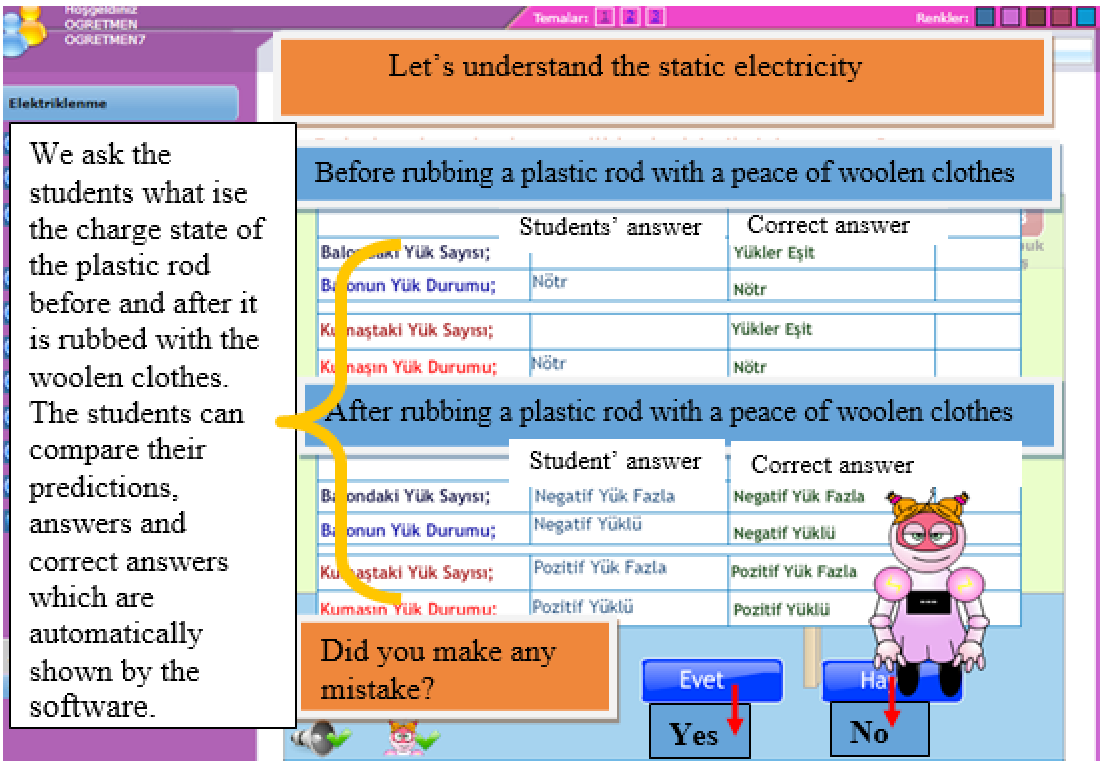


**Figure 2: Sample screen from the TeMLP prompt for monitoring accuracy.**

Two raters analyzed a random sample of five students' monitoring accuracy based on the criteria outlined in the framework. The raters achieved a reliability of .95 for the students' status and an examination was made of the final sample, which included seventeen problem predictions and decisions compiled in the learning platform.

## Results of Research

*Changes in Students' Monitoring Accuracy during the Technology-enhanced Metacognitive Learning*

It can be seen that the students' monitoring accuracy status in the topics of both static and current electricity was at different levels in each activity (Figure 4). In non-consecutive activities, for example from SE#1 to SE#2.1, from SE#4 to SE#6.1 and from CE#7 to CE#8.1, it was found that there were not changes of status. In other words, when the students compared their predictions with the experiment results after non-consecutive activities, because they were not aware that they had made a mistake, their status was (FF). On the other hand, in consecutive activities, while their monitoring status was (FF) in the first activity (for example, SE#2.1-2.1; 3-4; CE#8.1-8.2-8.3; 9.1-9.2), their status changed to (FT) or (TT) in the next activity. In other words, the student took into consideration his/her prediction about the problem and was able to decide after the experiment that the prediction had been wrong or right. For this reason, as the activities continued, they were able to accept their mistakes, if any, and arrived at a point where they could explain these mistakes.

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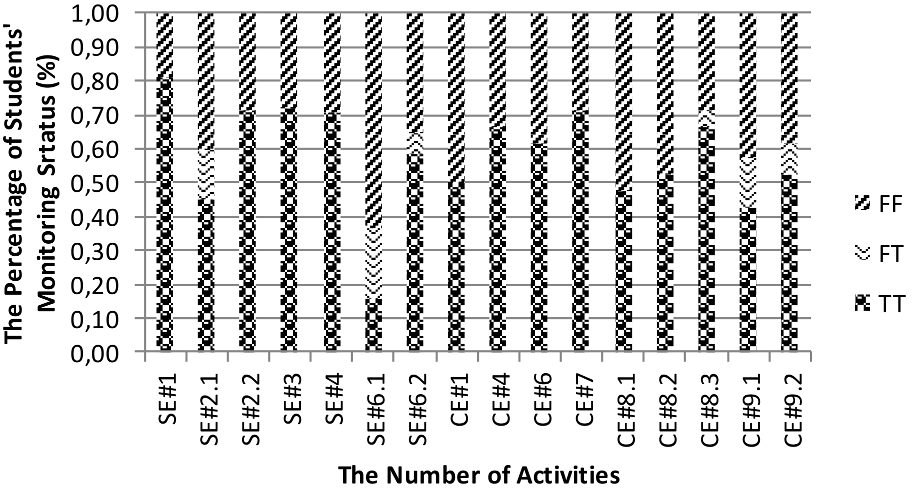


**Figure 3: Students' monitoring accuracy status in the topics of both static and current electricity.**

Accordingly, Table 3 shows that the students in the experimental group showed a significant increase in their control scores in the posttest and retention test compared to the control group' posttest and retention test scores (t (51) = 3.161, p = .003, t (51) = 2.421, p = .019 respectively) but there was no significant difference between the experimental and control group's control scores in the pretest (t (51) = .175, p = .683). In the retention test, this finding showed that the instruction which was used in the experimental group affected the students' control skills in positive way. In addition, according to the pretest results of the monitoring scale, there was no statistically significant difference between the experimental and control groups. However, when the posttest and retention test results of the groups were compared, there was a significant difference between the arithmetical averages of the groups in favor of the experimental group (t (51) = 2.533, p = .014, t (51) = 2.964, p = .005 respectively). In other words, the arithmetical average of the experimental group is statistically higher than that of the control group.

**Table 3. The independent t-test results of the monitoring and control scores of the experimental and control groups on MS.**

| Factors | Groups | Pre-Post-Retention Tests | N | Mean | SD |
|---|---|---|---|---|---|
| Self-Control | Experimental | Pre-Test | 25 | 8.36 | 2.03 |
| | Control | | 28 | 8.46 | 2.26 |
| | Experimental | Post-Test | 25 | 10.40 | 1.55 |
| | Control | | 28 | 8.60 | 2.42 |
| | Experimental | Retention-test | 25 | 9.80 | 1.44 |
| | Control | | 28 | 8.46 | 2.39 |
| Self-Monitoring | Experimental | Pre-Test | 25 | 5.60 | 1.93 |
| | Control | | 28 | 5.17 | 1.76 |
| | Experimental | Post-Test | 25 | 6.52 | 1.50 |
| | Control | | 28 | 5.50 | 1.42 |
| | Experimental | Retention-test | 25 | 6.12 | 1.30 |
| | Control | | 28 | 4.75 | 1.95 |

*Students' Reasons for Their Monitoring Status*

According to the self-explanations of the students with an FT status, there were two reasons for the mistakes they made in their predictions about the first activity. (a) Two of the students stated that their predictions were wrong because this was the first time they had come across this particular subject (I had no previous knowledge of the subject). In other words, if a student has no prior knowledge about a problem, the student's predictions may turn out to be wrong. (b) The students were mistaken in their prior knowledge. In other words, students' misunderstandings may hinder them from monitoring their knowledge accurately. The students' mistakes in their knowledge about static and current electricity are presented below (Table 4).

**Table 4. Types of misunderstandings revealed by students in their open-ended responses.**

| Misunderstandings | Sample | Student |
|---|---|---|
| In the final charging of objects electrified by friction | I had said 'neutral' after the ebonite rod had been electrified. | S1, S7, S8, S12, S15, S16, S17 |
| In objects that became electrified by contact | I thought that positive charges were in motion and would be transmitted as positive charges. But they were negative charges. | (S3, S19) |
| About the type of charges in the ball of the electroscope and its leaves | I gave the wrong answer, I said that the head of the electroscope would be negatively charged but the leaves of the electroscope opened. | (S10, S21) |
| About the final charged state of grounded objects | I said that the negatives would increase in the iron rod, but they repelled each other. | (S6, S7, S10) |
| The confusion of the direction of movement of electrons and the direction of electrical current | My mistake was that I reversed the process and gave a wrong answer. | (S1, S20) |
| About which light bulb will light up when there is a short circuit | We were mistaken about the light bulbs turning on and off in a short circuit. | (S1, S4, S6, S7, S8, S10, S11, S12, S16, S21) |
| The brightness of parallel connected light bulbs is different | I thought the same current would pass through the circuit and that's why I made the mistake. | (S8, S12, S14, S17, S19) |
| Light bulbs that light up according to whether the switch is on or off in series and parallel circuits | | (S3, S4, S7, S8, S10, S11, S12, S14, S15, S21). |

Thus, the students' misunderstanding can have an impact on their monitoring accuracy status. If the student has a misunderstanding, he/she may make a prediction without being aware of the mistake. However, with the continuation of the activities in the platform, the student soon realizes that he/she has a misunderstanding and may be able to explain this misunderstanding. The point that must be underlined here is that the student becomes able to accurately monitor the mistakes in his/her pre-knowledge. This is because the student that realizes his/her mistakes is helped by the activities in the platform to change his misunderstandings and make an effort to learn the correct scientific information. Or, the student that does not realize his/her mistake is able to enhance his/her pre-knowledge by participating in the new activities.

*Changes in Students' Understanding of Electricity during the Technology-enhanced Metacognitive Learning*

The finding of the essay questions on static and current electricity indicated at the end of the research that the posttest scores of the experimental group had increased in terms of students' understanding of electricity as

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compared to the scores of the control group. This finding shows that the TeMLP improved the students' understanding about electricity. This finding is also obviously depicted that there is a greater loss in retention by the normal teaching method than the Technology-enhanced Metacognitive Learning Platform (TeMLP). The detail findings of the questions were given below.

It seems that approximately 75% of students in the experimental and control groups did not answer rubbing a plastic rod with woolen cloth question (see Appendix question 1, Table 5) or completely gave irrelevant answers. In addition, six students in the experimental group and four students in control group had misunderstandings. Some misconceptions or false pre-knowledge in the students on this question; "Positively charged aluminum sphere", "both (aluminum sphere and ebonite rod) charged positive", "both are neutral. After instruction, 60% of students in the experimental group and 28% of students in control gave the correct answer to this question in the partially right or completely right level. However, some students in both group had some misconceptions after the instruction. These misconceptions were observed in 8% of the experiment group students, whereas they were observed in 14 % of the control group students.

**Table 5. Comparison of students' degree of understanding of the first question in the control and experimental groups.**

| | | | Degree of understanding | | | | | *n* |
|---|---|---|---|---|---|---|---|---|
| | | | 0 | 1 | 2 | 3 | 4 | |
| Pre-Test | Experimental | Frequency | 19 | 6 | 0 | 0 | 0 | 25 |
| | | % | 76 | 24 | 0 | 0 | 0 | 100 |
| | Control | Frequency | 21 | 4 | 0 | 3 | 0 | 28 |
| | | % | 75 | 14 | 0 | 11 | 0 | 100 |
| Post-Test | Experimental | Frequency | 4 | 2 | 4 | 4 | 11 | 25 |
| | | % | 16 | 8 | 16 | 16 | 44 | 100 |
| | Control | Frequency | 6 | 4 | 10 | 4 | 4 | 28 |
| | | % | 21 | 14 | 36 | 14 | 14 | 100 |

In Table 6, pre-test findings of second rubbing a plastic rod with woolen cloth question open-ended questions showed that two groups were nearly equivalent on this question (see Appendix question 2). Accordingly, it was concluded that students in both groups had similar knowledge about this question before the instruction. When the post-test finding of this question was examined, 92% of the students in experimental group, 61% of the students in the control group answered this question in the partially right or completely right level. At the end of the instruction, two students in the experimental group and five students in the control group have misconception about this subject. However, 46% of students in the control group and 16% of students in experimental group have given no response to this question or have misconceptions. Consequently, the students in the experimental group gave more correct responses to this question than the students in the control group.

**Table 6. Comparison of students' degree of understanding of the second question in the control and experimental groups.**

| | | | Degree of understanding | | | | | *n* |
|---|---|---|---|---|---|---|---|---|
| | | | 0 | 1 | 2 | 3 | 4 | |
| Pre-Test | Experimental | Frequency | 15 | 10 | 0 | 0 | 0 | 25 |
| | | % | 60 | 40 | 0 | 0 | 0 | 100 |
| | Control | Frequency | 17 | 9 | 2 | 0 | 0 | 28 |
| | | % | 61 | 32 | 7 | 0 | 0 | 100 |

| | | | Degree of understanding | | | | | *n* |
|---|---|---|---|---|---|---|---|---|
| | | | 0 | 1 | 2 | 3 | 4 | |
| Post-Test | Experimental | Frequency | 0 | 2 | 0 | 4 | 19 | 25 |
| | | % | 0 | 8 | 0 | 16 | 76 | 100 |
| | Control | Frequency | 0 | 5 | 6 | 4 | 13 | 28 |
| | | % | 0 | 18 | 21 | 14 | 47 | 100 |

The findings of pre-test revealed that 16% of the students in the experimental group and 25% of the students in the control group did not know that the brightness of identical light bulbs connected in series are the same and they also had the idea that the nearer the battery, the brighter the light bulbs and also some students in both groups believed that the amount of the electric current in the point 3 was more than the one in the point 1 in Table 7 (see Appendix, question 3). Because they think that the point 3 was nearer the battery than the point 1. The findings of post-test revealed that 72 % of the students in the experimental group and 53% of students in the control group knew that brightness of identical light bulbs connected in series are the same and explained their reason for this question in scientifically acceptable way. But 8% of the students in the experimental group and 21% of the students in the control group still had misconceptions about the brightness of bulbs and the amount of electric current in the different points in a series circuit. Some students in both groups had also the idea that brightness of the light bulb was inverse proportional to a distance between the bulb and the battery.

When the findings of pre-test analyses were examined in the Table 8, it seems that most students in both groups didn't give response to the amount of electric current in a circuit questions or gave response in less right level (see Appendix, question 4). Moreover, 12 of the 25 students (48 %) in the experimental group and 9 of the 28 students (32 %) in the control group had misconceptions about the amount of the electric current in the points 1, 2, 3 and 4. In general, these misconceptions are "points 2 have more electric current than the other points, "electric current in all points is the same", and points 1 and 3 have the same amount of electric current. Only two students in the control group gave response to this question in partially right (3) or completely right level (4). After instruction, the findings of the post-test revealed that 16 of the 25 students (64 %) in the experimental group and 12 of the 28 students (43 %) in the control group gave their responses to this question in completely right level (4) and provided correct and scientific support what they think.

**Table 7. Comparison of students' degree of understanding of the third question in the control and experimental groups.**

| | | | Degree of understanding | | | | | *n* |
|---|---|---|---|---|---|---|---|---|
| | | | 0 | 1 | 2 | 3 | 4 | |
| Pre-Test | Experimental | Frequency | 21 | 4 | 0 | 0 | 0 | 25 |
| | | % | 84 | 16 | 0 | 0 | 0 | 100 |
| | Control | Frequency | 18 | 7 | 1 | 0 | 2 | 28 |
| | | % | 64 | 25 | 3 | 0 | 7 | 100 |
| Post-Test | Experimental | Frequency | 2 | 2 | 3 | 0 | 18 | 25 |
| | | % | 8 | 8 | 12 | 0 | 72 | 100 |
| | Control | Frequency | 1 | 6 | 6 | 0 | 15 | 28 |
| | | % | 4 | 21 | 22 | 0 | 53 | 100 |

In addition, five students in experimental group and seven students in the control group had still misconceptions which were mentioned above.

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**Table 8. Comparison of students' degree of understanding of the fourth question in the control and experimental groups.**

| | | | Degree of understanding | | | | | *n* |
|---|---|---|---|---|---|---|---|---|
| | | | 0 | 1 | 2 | 3 | 4 | |
| Pre-Test | Experimental | Frequency | 13 | 12 | 0 | 0 | 0 | 25 |
| | | % | 52 | 48 | 0 | 0 | 0 | 100 |
| | Control | Frequency | 17 | 9 | 0 | 1 | 1 | 28 |
| | | % | 61 | 32 | 0 | 4 | 4 | 100 |
| Post-Test | Experimental | Frequency | 3 | 5 | 0 | 1 | 16 | 25 |
| | | % | 12 | 20 | 0 | 4 | 64 | 100 |
| | Control | Frequency | 4 | 7 | 3 | 2 | 12 | 28 |
| | | % | 14 | 25 | 11 | 7 | 43 | 100 |

The findings of pre-test revealed that almost most students in both groups didn't respond to this question (see Appendix, question 5) or give answer in level 1 (Table 9). Moreover, 8 of the 25 students (32 %) in the experimental group and 9 of the 28 students (32 %) in the control group had misconceptions about the brightness of the bulb A in the circuit 1 with bulb B in the circuit 2. Some misconception is "the bulb A in the circuit 1 is brighter than the bulb B in the circuit 2 because the circuit 1 has one bulb and other has two and it didn't share its energy with other bulb", "the bulb B in the circuit 2 is brighter than the bulb A in the circuit 1", "they are the same brightness because the circuits 1 and 2 have the same battery and bulb. In addition, one student in experimental group and three students in the control group gave response to this question in completely right level (4). These students could have taken a private course or attended a private science lesson support center. Because the students did not take any course about this subject before the unit in the school.

When the findings of post-test were examined in the Table 9, it seems that only one student in the control group didn't give response to this question. Moreover, 2 of the 25 students (8 %) in the experimental group and 9 of the 28 students (31 %) in the control group had still misconceptions mentioned above about the brightness of the bulb in the circuits after the instruction. 22 of the 25 students (88 %) in the experimental group and 16 of the 28 students (57 %) in the control group gave responses to this question in completely right level (4). The percentage of the students in both groups who gave responses to this question in partially right (3) were almost equal. Consequently, the percentage of completely right level (4) given to this question in the experimental group was higher than the control group.

**Table 9. Comparison of students' degree of understanding of the fifth question in the control and experimental groups.**

| | | | Degree of understanding | | | | | *n* |
|---|---|---|---|---|---|---|---|---|
| | | | 0 | 1 | 2 | 3 | 4 | |
| Pre-Test | Experimental | Frequency | 15 | 8 | 1 | 0 | 1 | 25 |
| | | % | 60 | 32 | 4 | 0 | 4 | 100 |
| | Control | Frequency | 13 | 9 | 1 | 2 | 3 | 28 |
| | | % | 46 | 32 | 4 | 7 | 11 | 100 |
| Post-Test | Experimental | Frequency | 0 | 2 | 0 | 1 | 22 | 25 |
| | | % | 0 | 8 | 0 | 4 | 88 | 100 |
| | Control | Frequency | 1 | 9 | 1 | 1 | 16 | 28 |
| | | % | 4 | 31 | 4 | 4 | 57 | 100 |

In conclusion, students who used this skill correctly saw the incompatibilities, if any, between their previous knowledge and the new knowledge gained and thus adjusted their previous knowledge or enhanced it to improve their monitoring accuracy status. The answers the students gave regarding the software support this finding. All of the students stated that the metacognitive prompts in the software helped them to monitor what they had learned. Students' statements explaining this are presented below:

> I was able to correct my mistakes through the knowledge I gained from what it said to us. (S#3)
> When it asked us to relate everything we knew about the subject, it recorded what I wrote. Then after the subject was explained, it compared that knowledge to what I had said. This way, I was able to learn what I already knew about the subject and what I didn't know. (S#12)
> I used to think I knew some of the topics very well. But it turns out I didn't. I've learned it now. (S#16)
> I learned to really understand what I read and monitor myself to see whether it's wrong. (S#17)

**Discussion**

This research determined the effects of the metacognitive prompts on students' monitoring accuracy and understanding about electricity using the educational software TeMLP developed for the Electricity in Our Lives unit. According to the results, students' monitoring accuracy and understanding of electricity improved with TeMLP. These results are consistent with previous researches. It was found that using interactive computer animation accompanied with real-time science experiments, it was more effective in achieving students' understanding of static electricity compared to the sole use of real-time science experiments (Akpınar & Ergin, 2007; Akpınar, 2014). The Web-based Inquiry Science Environment program (Shen & Linn, 2011) and learning by dynamic computer simulation with the Dual Situated Learning Model were successful in students' conceptual understanding of static electricity concepts (Senthilkumar, Vimala & Al-Ruqeishi, 2014). Furthermore, the responses the students in the research group gave to the questions about the magnitude and intensity of an electrical current at different points on an electrical circuit (parallel and series) were more successful and retentive. Previous researches indicate that students can predict, test and explore their predictions by exploring scientific model outcomes by using the computational model NetLogo Investigations in current electricity concepts (Sengupta & Wilensky, 2009). Technology enhanced learning also challenged students' intuitive conceptions and helped them to understand the theoretical principles of electricity (Jaakkola & Nurmi, 2008). This result indicates that students in the research group were able to carry out the same experiment with the TeMLP with more ease than the students in the control group, and that thanks to the repetitions they were able to implement and their interaction with the metacognitive prompts, they succeeded in providing one-on-one feedback on their learning (Zacharia, 2007).

It can be seen that prior knowledge has an impact on students' monitoring accuracy since prior knowledge offers a cognitive foundation, on the basis of which the individual may evaluate his/her own performance (Nietfeld & Schraw, 2002). If there is misunderstanding in the student's prior knowledge, the individual may make the wrong prediction about the problem at hand. At this point, the critical point is whether the student, after completing the activity, can recognize that there was a mistake in his/her prior knowledge. If the student can make a decision about whether the prior knowledge was wrong or right, then the individual will be able to become aware of the particular mistake that was made. This is because it is not only the gaining of new knowledge but the metacognitive monitoring that makes it possible to enhance prior knowledge (Koriat, 2012). Another matter that must be pointed out is that the students clearly did not accept that they had made mistakes in using their prior knowledge in the first activity. The platform encouraged the students to activate all prior knowledge but in this, the student may have activated the wrong information. The incorrectness of the prior knowledge may have caused the student to make the wrong decision and to construct an incorrect piece of knowledge in place of the target concept. The responses to the platform showed that the students either were not aware of the mistakes in their prior knowledge or that the decisions they made about their learning were incorrect. On the other hand, as the students used the platform, they came to realize that certain parts of their prior knowledge were wrong and thus achieved a point where they were able to decide about what they knew or did not know about the concept (Zhou, 2013). The corrective feedback the software provided the students about monitoring accuracy therefore helped them in curbing their overconfidence and setting a balance (Efklides, 2014).

In addition, students at different levels of prior knowledge need more support and guidance if they are to be

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expected to use the features of technology-enhanced learning environments (Mitchell, Chen & Macredie, 2005). Learners with lower levels of prior knowledge about a subject will not activate this knowledge and therefore have difficulty in understanding the associations between concepts and more important, they will not be able to recognize how much they know or do not know about the topic to be learned (Gurlitt & Renkl, 2008). Since this research has considered the importance of students' prior knowledge, the activities chosen were designed to accommodate students with limited prior knowledge about the content. The platform presents students with examples from daily life in the process of determining goals and includes animations that make the topic interesting. Thus, TeMLP helps students to determine their goals regarding abstract concepts such as electricity before actually starting to research the material. Offering students this prerequisite before starting a new activity is effective in helping students become aware of their prior knowledge and form associations between that knowledge and the new knowledge to be learned. In addition, the activities provided to help students determine the level of their prior knowledge and to have offered the students feedback on their knowledge with the progress of the process. Thus, guiding the students to the gaps in their knowledge so that they can complete the exercise and also complete the missing knowledge in their minds.

**Conclusions**

In comparison to the normal instruction given in the control group, the TeMLP used in the experimental group increased students' monitoring accuracy and understanding of electricity. This result is also obviously depicted that there is a greater loss in retention by the normal teaching method than the TeMLP after the three months of the instruction. Regarding the reasons behind the loss in retention in the control group, it can be explicated that the normal science classroom which used normal or traditional teaching methods and approaches does not focus on the learners' prior knowledge, other skills and especially metacognitive skills. One of the striking points of this research is that the activities used in the software are more effective in learning abstract concepts compared to their being taught by traditional instruction. This is because the prompts offered in the TeMLP help students become aware of their previous knowledge of abstract concepts. In the case of abstract concepts such as electricity, students tend to continue to retain the incorrect information they have about neutral, positively or negatively charged objects when the materials are taught using the traditional techniques of lecturing or questions and answers. It is for this reason that a TeMLP that is prepared in a manner that will actively uncover the knowledge that has already been learned becomes more effective in ensuring learning and retention of knowledge.

**Recommendations**

The results of this research may provide educators and educational software designers with some recommendations. The most striking result gleaned from the research was related to prior knowledge students had about the topics. Students' prior knowledge may directly impact status of their monitoring accuracy. It is for this reason that educators must be sensitive to the issue of determining the state of students' prior knowledge. Students with complete and correct prior knowledge have increased curiosity about a topic, their willingness to learn is enhanced and intrinsic goals come to the fore. In this case, when they compare their predictions with the results they attain, they are able to arrive at meaningful conclusions. Their academic achievement is thus also enhanced. Since inaccurate knowledge is a barrier to learning, corrective measures should be given priority. It is when misunderstandings and deficiencies are corrected that learning becomes meaningful. It is then that a student may make more of an effort to learn and the learning process is facilitated. Teachers must employ alternative methods and techniques to monitor students' prior knowledge and encourage them to confront the problems and circumstances they have difficulty with in their daily lives. Different materials, examples, analogies, models can be used to help the teacher in this task.

Recommendations for researchers who will be designing educational software include the guidance that students should be provided with not only programs that focus on their cognitive skills but also on developing metacognitive skills. Planning, monitoring and evaluating the learning process are of great importance. This will provide learners with the opportunity to monitor the effectiveness of the learning process.

**Limitations of the Research**

This research has several limitations. The changes observed in the students in the research may have been caused not only by the effects of the educational software, but also by factors that include individual (computer self-sufficiency, confidence in learning, maturity) or environmental (lessons in the computer laboratory, the role of the teacher, peer interaction) influences. To eliminate these limitations, the researchers evaluated the scores of the students on the metacognitive scale, their academic test scores and their statements on the learning platform. The diversity employed here was focused on being able to interpret the data in more detail. Another limitation of the research was that it was confined to the unit on electricity. It is not known how students provide their monitoring accuracy changes with respect to other topics. Researches to be conducted in the future may contribute to the field by providing more detailed research on the results of educational software using metacognitive prompts in other subjects.

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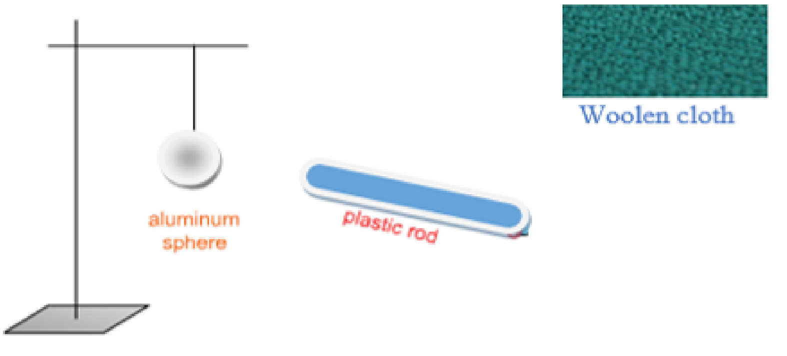
**Appendix**

Question # 1
A plastic rod is charged by rubbing with a woolen cloth is touched to the uncharged (neutral) aluminum sphere, as shown in the figure and then pulled back. In the case, what are the charge states of the plastic rod and the aluminum sphere?



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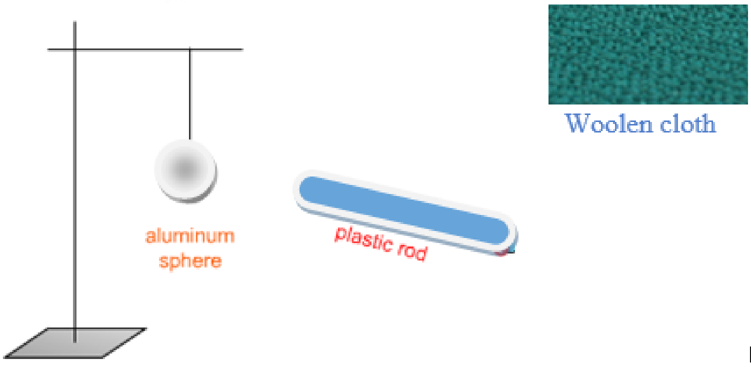
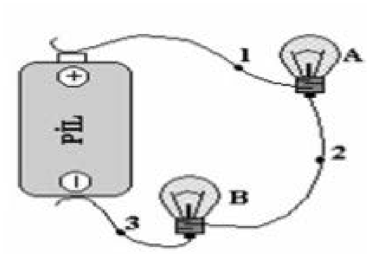
Question 2 #

What do you think would happen if the plastic rod were rubbed with the wool cloth *again* and then brought close to the aluminum sphere to try to touch it?



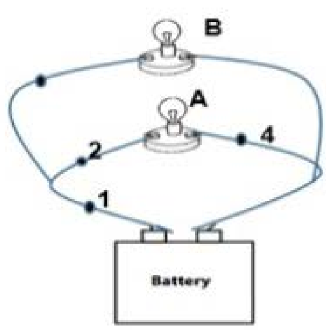

Question # 3

In this circuit containing identical bulbs and ideal battery, compare the amount of the electric current in the point (place) **1, 2** and **3** and the brightness of the bulbs, and explain your reasoning.




Question # 4

In this circuit containing identical bulbs and ideal battery, compare the amount of the electric current in the point 1, 2, 3 and 4 and explain your reasoning.



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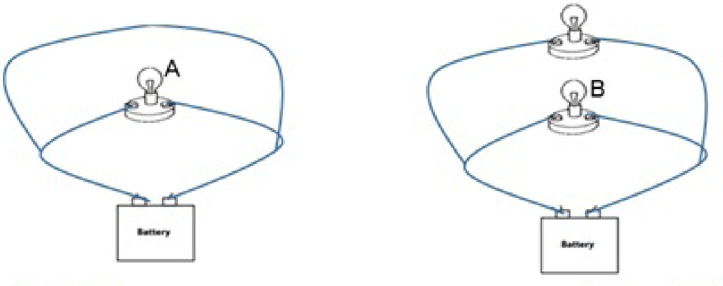
Question # 5

Instruction: All light bulbs are identical and the batteries are perfect (they can supply enough energy for all devices).




**Circuit 1** **Circuit 2**

From the above circuits, please compare the brightness of the bulb **A** in the circuit 1 with bulb **B** in the circuit 2 and write your reasoning.

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| ***Ercan Akpınar*** | PhD, Professor, Faculty of Education, Dokuz Eylul University, 35160, Buca-İzmir, Turkey.<br>E-mail: ercanakpinar@gmail.com<br>Website: http://www.akpinarercan.com |
| ***Eylem Yıldız Feyzioğlu*** | PhD, Associate Professor, Faculty of Education, Adnan Menderes University, Aydın, Turkey.<br>E-mail: eylem1797@gmail.com |
| ***Nilgün Tatar*** | PhD, Associate Professor, Department of Elementary Education, Faculty of Education, Alanya Alaaddin Keykubat University, Antalya, Turkey.<br>E-mail: nilguntatar@gmail.com |