THE EFFECT OF COMBINING ANOLOGY-BASED SIMULATION AND LABORATORY ACTIVITIES ON TURKISH ELEMENTARY SCHOOL STUDENTS' UNDERSTANDING OF SIMPLE ELECTRIC CIRCUITS

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ABSTRACT
The purpose of this study was to investigate whether the combination of both analogy-based simulation and laboratory activities as a teaching tool was more effective than utilizing them separately in teaching the concepts of simple electricity. The quasi-experimental design that involved 66 seventh grade students from urban Turkish elementary school was used. The groups were randomly assigned to the control group I in which the real laboratory activities were used, to the control group II in which analogy-based simulation activities were used and to the experimental group in which both analogy-based simulation and laboratory activities were used together. Electricity performance test (EPT) prepared by the researchers was administered to assess the students' understanding of electric circuits before and after the teaching intervention. The results indicated that the combination of both analogy-based simulation and laboratory activities caused statistically greater learning acquisition than the analogy-based simulation and laboratory activities did alone. However, on the contrary to our expectations there was no statistical difference between the control I and control II groups. The results highlighted that environments of laboratory and computers are complementing each other, not to prefer one to another in teaching the concepts of simple electricity.
Keywords: Science and technology education, Concepts of simple electricity, Laboratory environment, Analogy-based simulation environment, Quasi-experimental design.

INTRODUCTION

The physics science topic "electrical circuits" is one of the core elements of the elementary science and technology curriculum in Turkey. Teaching and learning of this topic is based on use of formal representation and hands-on activities fascinating the imagination of young children in elementary schools. However, our experience in teaching of electricity with prospective science teachers have shown that even after a systematic and fairly advanced study of the topic in a college, in which the students become quite efficient in carrying out circuit analysis by using Kirchhoff law, they are still incapable of qualitatively analyzing simple circuit. For example, they do not have sufficient qualitative identification about what the potential difference between two points of resistance and the electric current mean in basic electrical circuit. According to the research containing similar finding afore mentioned, many difficulties and misconceptions in the topic of electric circuit are still found after the study, at all ages and levels (Arons, 1982; Borges & Gilbert, 1999; Cohen, Eylon & Ganiel 1983; Iona, 1979; Fredette & Clement, 1981; Fredette & Lochhead, 1980; Osborne, 1983). Most of the common difficulties are due to an incomplete understanding of the abstract concepts such as electric current and electric potential (Carlton, 1999; Lee & Law, 2001; Liegeois, Chasseigne & Papin, 2003). Electricity even itself is a difficult concept for students to come to terms with. The invisible nature of what is happening makes it an abstract topic (Carlton, 1999). What is required is that the student develops a mental model which can visualize the electrical circuits concepts based on other system which are easily visualized to enhance the learning of these abstract topic. Logically, we learn through either deductive and inductive or analogical reasoning; that is to say, moving from the whole to the part and from the part to the whole or from the part to the part. It can be said that there is no further way to learn. Therefore, visualization by analogy constitutes an important part of the learning process when instructors try help students to understand what is happening inside an electrical circuit and to explain its concepts. Analogy is a powerful cognitive mechanism that is used to learn new abstractions in electrical topics by students (Chiu & Lin, 2002; Genter & Genter, 1983; Gutwill, Frederiksen & Ranney, 1992) and it is often used to in the form of text, pictures, videos and verbal examples in traditional classrooms. But to further enhance students' visual perception of a phenomenon, some of the unobservable relationships that comprise the phenomenon may be depicted via computer simulations (Trey & Khan, 2008). Computer simulations have special value as they offer a high potential for interactive learning in all domains of science education (Trundle & Bell, 2010). A significant amount of previous research has demonstrated the effectiveness of computer simulations in student learning. A good number of these studies have focused on the success of computer simulations in supporting students' understanding, inquiry and reasoning skills (Akpan & Andre, 2000; Chang, Chen & Finkelstein et al., 2005; Geban, Aşkar & Özkan, 1992; Huppert & Lazarowitz, 2002; Lin & Sung, 2008; Magin & Reizes, 1990; Monaghan & Clement, 1999; Yaman, Nerdel & Bayrhuber, 2008). However, many researchers have indicated that the positive effects of simulations on students' learning performance are not self-evident (de Jong & van Joolingen, 1998). Marshall and Young (2006) have shown that the use of computer simulations is less effective than traditional instruction and hands-on laboratory approaches.

The results of two recent studies by Zacharia (2007), Jaakkola and Nurmi (2008) have indicated that the benefit of using simulation along with hands-on laboratory activities is that it promotes students' understanding of electricity. While one of these studies (Zacharia, 2007) had one control group assigned to the real laboratory environment, the other one (Jaakkola & Nurmi, 2008) had two control groups assigned to the real and virtual laboratory environments. Students in the experimental group of both studies were responsible for completing the assignments using simulation and laboratory works about the electric circuit. With the simulation tool of the study by Jaakkola and Nurmi (2008), elementary school students were able to set up various circuits easily by dragging wires, bulbs and resistors into desired points in the circuits with simple mouse moves; the battery voltage can be changed this way as well. They could also conduct different electric measurements with a multimeter simply by dragging its probes onto the required testing points.

For further analysis, in our work, we investigated whether it would be more beneficial to combine analogy-based simulation and laboratory activities (in experimental group) than to use them separately (in two control groups) in learning simple electricity. For analogy-based simulation activities, the analogy of fluid system by Hewitt (1987) was developed to render interactively in a virtual environment. In this context, the main research questions examined in this study were "Would it be better to combine analogy-based simulation and laboratory activities than to use them separately?" and "How do these three environments affect students' learning electricity?". For this purpose, the following sub-problems were determined:

- Is there a significant difference among the pre-test scores of the students in the experimental group (using analogy-based simulation and laboratory activities together), the control group I (using real laboratory activities) and the control group II (using analogy-based simulation activities)?
- Is there a significant difference between the pre-test and post-test scores of the students in control group I?
- Is there a significant difference between the pre-test and post-test scores of the students in control group II?
- Is there a significant difference between the pre-test and post-test scores of the students in experimental group?
- Is there a significant difference among the post-test scores corrected according to the pre-test scores of the experimental group, control group I and control group II?

METHOD

Sampling and Experimental Design

The participants given in Table 1 were 66 seventh grade students at about 13 years old from an urban Turkish elementary school. The participants in three groups were selected from three public schools. For the quasi-experimental design, these groups were assigned randomly, namely, the control group I (using real laboratory activities), the control group II (using analogy-based simulation activities) and the experimental group (using analogy-based simulation and laboratory activities together). The students had not received any formal education on electricity before the study was carried out.

Table 1. The gender of the students in three groups

Groups	N	P
Experimental group	27	
Male	13	48
Female	14	52
Control group I	21	
Male	12	43
Female	9	57
Control group II	18	
Male	10	55
Female	8	45

N: Number of the students who participated in the study
P: Percentage of students who participated in the study

"Pre-test and Post-test Design with Matched Control Group" which was one of the quasi-experimental designs was used in the study. Of the groups in the study, the experimental group was taught using the combination of analogy-based simulation and laboratory method, the control group I was taught using laboratory method and control group II was taught using analogy-based simulation method (Table 2).

Table 2. Experimental design of study

Groups	Pre Test	Method	Post Test
Experimental group	EPT	Combining analogy-based simulation and laboratory activities	EPT
Control group I	EPT	Laboratory activities	EPT
Control group II	EPT	Analogy-based simulation activities	EPT

EPT: Electric Performance Test

In the study, academic achievement test (EPT) which was prepared by the researchers was implemented to the experimental and control groups as the pre-test. The same test was implemented to the experimental and control groups once more at the end of the study.

Procedure

The implementation of the study lasted for three weeks and 12 periods on the basis of 4 hours per week in 2009-2010 educational year. Before the implementation, the students were given pre-tests. To move to the next stage of study, the results of the pre-tests were evaluated. The pre-test scores indicated the homogeneity within three groups. The students in the control group I, control group II and the experimental group were placed to their learning environments and given information about the course and learning environments. Throughout the course, instructions were given in specially designed worksheets for three learning environment. 24 worksheets were prepared according to of Turkish Science and Technology Curriculum (TSTC) by the researchers. The 13 of the worksheets which were organized according to the learning method of inquiry were including analogy-based activities and 11 of them were including laboratory activities. Therefore, the instructions were made to preserve the same teaching method and the curriculum material. The students in each group worked in a small-group during the course to supply effective learning (Chang & Lederman, 1994; Huber, 2003). In order to measure and compare the effectiveness of the different learning environments, subject knowledge post-test was administered to students a day after the course. Although students worked in a small group during the course, they completed all of the test individually.

Curriculum Materials

The course for the experimental and control groups was carried out depending upon the 7th year Science and Technology teaching program which was developed by Turkish Republic Ministry of National Education. In the program, the learning field is "Physical Phenomena", the name of the unit is "Electricity in Our Life" and the suggested period is 12 hours. The program aims at enabling students by constructing basic circuits by means of battery, bulb, key, ampere meter, voltmeter and connection wires to

- ✓ make the features of four basic concepts of electricity unit which are "Electricity Circuit Intensity (I)", "Potential difference or tension between the points of the battery (V)", "Resistance (R)", "Potential difference or tension between the points of resistance (V)" meaningful at the microscopic and macroscopic level,
- ✓ express these features using numbers and units after measuring,
- ✓ discover the relationship (ohm law) among these qualities,
- ✓ and learn what kind of changes occur when the bulbs (resistance) are connected in series and how these connection types change in our daily life according to the purpose.

This unit includes learning activities which encourage the students to solve a problem in an electricity circuit in accordance with the required conditions besides their making experiments. Moreover, it is aimed at students' acquiring scientific process skills and having certain attitudes and values in addition to their acquiring knowledge about the electricity circuit throughout the unit (MEB, 2005).

Learning Environment

Laboratory Environment for Control Group I: Students assigned to the *Laboratory Environment* tried to learn the basic concepts of circuit and the relationship among them in a traditional classroom with laboratory equipment kits that included real batteries, bulbs, wires, switches, ampere meter and voltmeter (see Figure 1).

Figure 1. Sample of laboratory environment for control group I in a classroom of Turkish elementary school.

Analogy-based simulation Environment for Control Group II: Students assigned to the *Analogy-simulation Environment* tried to learn the basic concepts of circuit and the relationship among them in a computerized classroom with an online electricity analogy-based simulation, the 'Electricity Analogy-based Simulation Tool (EAST)' (see Figure 2 and 3). The activities in EAST were developed by originating the analogy of fluid system of Hewitt (1987) in virtual environment.

Students could manage to accomplish the following processes in a simple electricity circuit which is composed of battery, bulb, connection cable, key, ampere meter and voltmeter while using EAST:

- They can observe the water and electricity circuit respectively turning the valve in the water circuit and the key in the electricity circuit on.
- They can accelerate and slowdown these circuits using the mouse.
- They can measure the intensity of the electricity circuit. Students try to discover the "electricity circuit intensity" during these quantitative and qualitative observations.
- They can observe the changes in the circuits increasing the number of batteries in the electricity circuit and increasing the power of pump in the water circuit. This observation is to help them to discover the "the potential difference between the edges of the battery" concept.
- They can quantitatively observe the change water causes when the power of the pump in the water circuit changes and the change of brightness of the bulb (resistance) when the number of batteries changes. Thus, students can discover what the intense means by measuring the change in the bulb using voltmeter.
- They try to discover the role and the meaning of "resistance" in an electricity circuit changing the resistance of the bulb in the electricity circuit and the pipe in the water circuit.
- The students that make the basic concepts meaningful construct more complex circuits connecting more bulbs or the battery parallel or in series. They try to discover according to which law these circuits work.

Figure 2. Sample of analogy-based simulation environment for control group II in a computerized classroom of Turkish elementary school.

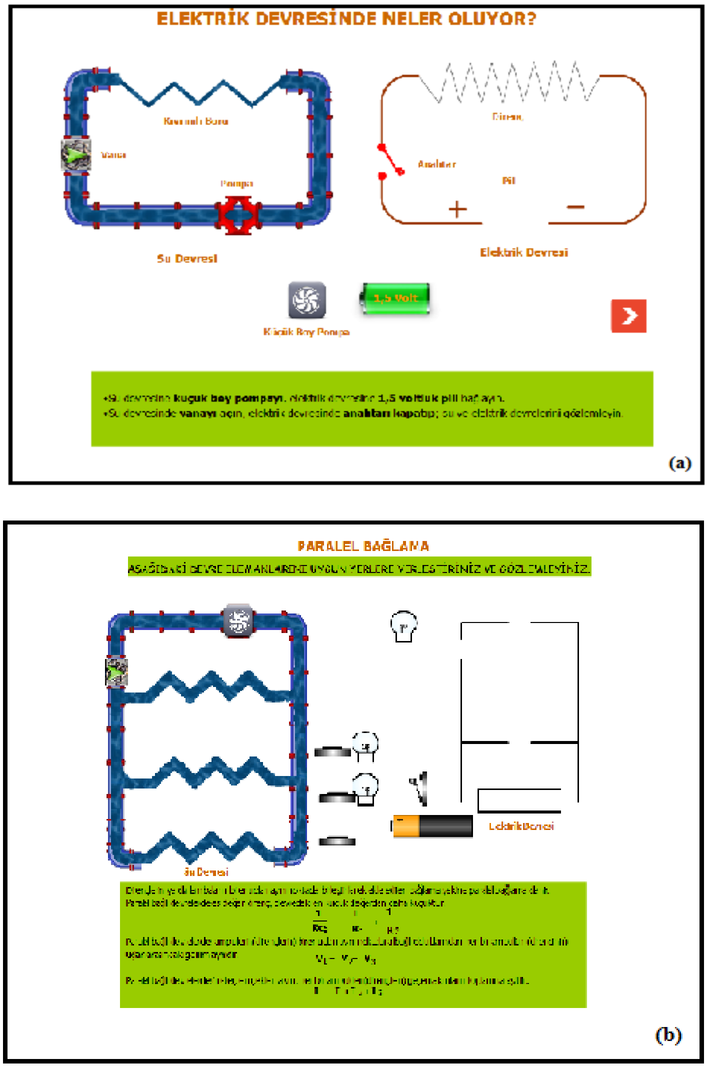

Figure 3. A sample of Electricity Analogy-based Simulation Tool (EAST): The analogy-based simulation for the basic electricity concept in the simple electric circuit (a), in the parallel circuit (b).

Combination Environment for Experimental Group: Students in computerized classroom used both the EAST and laboratory equipment kits to learn the basic concepts of circuit and the relationship among them. Students were first asked to complete the assignment using the analogy-based simulation; and then they were asked to repeat the assignment with the laboratory equipment kits.

Data Collection

Electricity Performance Test (EPT) consisted of 24 multiple choice questions was prepared according to the objectives of Science and Technology Curriculum for the 7th grade students in Turkey by researchers. The test was applied to 225 students in 7th grade to provide the validity and reliability of this test and it was found that the reliability of the EBT based on Cronbach alpha was 0.83. Each correct answer was scored as one point; false or empty answers were scored as zero point; and the total score was calculated and this score was used in evaluation.

Data Analysis

The data were evaluated in SPSS 11.5 package program. It was accepted that there was .05 degree of significance. The mean and standard deviation scores, which students got from pre-tests and post-tests in experimental and control groups, were presented descriptively.

One-way ANOVA was used to determine whether there was significant difference among the pre-tests of the groups; and one-factor ANCOVA was used to determine whether there was significant difference among the post-tests of the groups. In order to determine the differentiation way of the post-tests, Bonferroni, one of the multiple comparison test, was used.

T-test (Paired Samples t-test) was used to determine if there was a meaningful difference between the applied method and academic achievements of the groups.

FINDINGS

The Findings Related to the Pre-test Scores of Experimental, Control Group I and Group II Students

The mean and standard deviation values related to the "EPT" pre-test scores of the experimental and control group students were presented in Table 3.

Table 3. The mean and standard deviation values related to the academic pre-test scores of the students in the experimental and control groups.

Group	N	Mean	Std. deviation
Experimental Group	27	6.52	2.17
Control Group I	21	7.24	2.8
Control Group II	18	6.06	2.81

When Table 3 was examined, it could be seen that the students in both experimental and control groups exhibited a homogeneous structure in terms of their pre-test scores.

Table 4. One-way ANOVA (Analysis of Variance) results of the students in the experimental and control groups based on the EPT pre-test scores

The Source of the Variance	Sum of Squares	df	Mean Squares	F	p	η^2
Between Groups	14.03	2	7.01			
Within Groups	415.49	63	6.59	1.06	.35	.03
Total	429.53	65				

When the Table 4 was examined, it could be seen that there was significant difference ($F_{2,63}$=1.06, p>.05, η^2=.03) between the "EPT" pre-test scores of the students in experimental and control groups. Based on this, it could be claimed that the pre-test scores of the students in experimental and control groups were equal.

The Findings Related to the Pre-test and Post-test scores of the Control Group I Students

The scores of the t-test which was conducted for the significance between the pre-test and post-test scores of the control group I students who had learned the Primary School 7th grade "Electricity in Our Life" unit through laboratory method were presented in Table 5.

Table 5. The t-test Scores of the Students who were taught through Laboratory Method Based on EPT.

Measurement	N	$\bar{X}$	S	df	t	p	η^2
Pre-test	21	7.24	2.8	20	6.69	.00	.69
Post-test	21	12.95	3.51				

It was found that there had been a significant increase in the academic achievements of the students after having the unit through laboratory method $t(20)=6.69$, $p<.05$, $\eta^2=.69$. While the mean of the achievement test scores was 7.24 before the implementation, it increased to 12.95 after having the course through laboratory method. According to this finding, it could be claimed that laboratory method had an important role in increasing the academic achievements of the students.

The Findings Related to the Pre-test and Post-test scores of the Control Group II Students
The scores of the t-test which was conducted for the significance between the pre-test and post-test scores of the control group II students who had learned the Primary School 7th grade "Electricity in Our Life" unit through analogy-based simulation method were presented in Table 6.

Table 6. The t-test Scores of the Students who were taught through Analogy-Based Simulation Method Based on EPT.

Measurement	N	$\bar{X}$	S	df	t	p	η^2
Pre-test	18	6.06	2.81	17	8.97	.00	.82
Post-test	18	11.94	4.91				

It was found that there had been a significant increase in the academic achievements of the students after having the unit through analogy-based simulation method $t(17)=8.97$, $p<.05$, $\eta^2=.82$. While the mean of the achievement test scores was 6.06 before the implementation, it increased to 11.94 after having the course through analogy-based simulation method. According to this finding, it could be claimed that analogy-based simulation method had an important role in increasing the academic achievements of the students.

The Findings Related to the Pre-test and Post-test Scores of the Experimental Group Students
The scores of the t-test which was conducted for the significance between the pre-test and post-test scores of the experimental group students who had learned the Primary School 7th grade "Electricity in Our Life" unit through the combination of laboratory method and analogy-based simulation method were presented in Table 7.

Table 7. The t-test Scores of the Students who were taught through the Combination of Laboratory Method and Analogy-Based Simulation Method Based on EPT.

Measurement	N	$\bar{X}$	S	df	t	p	η^2
Pre-test	27	6.52	2.17	26	20.34	.00	.94
Post-test	27	15.3	2.92				

As shown in Table 7, it was found that there had been a significant increase in the academic achievements of the students after having the unit through the combination of laboratory method and analogy-based simulation method $t(26)=20.34$, $p<.05$, $\eta^2=.94$. While the mean of the achievement test scores was 6.52 before the implementation, it increased to 15.3 after having the course through the combination of laboratory method and analogy-based simulation method. According to this finding, it could be claimed that the combination of laboratory method and analogy-based simulation method had an important role in increasing the academic achievements of the students.

The Corrected Post-test Scores of the Experimental, Control I and Control II Group Students According to Pre-test Scores Based on EPT
EPT corrected post-test scores of the groups according to the pre-test scores were presented in Table 8. According to this, EPT post-test scores of the experimental group was calculated as 15.3; of the control group I was as 12.95; and of control group II was 11.94. Depending on these scores, it could be considered that the control group II had the lowest mean score of the post-tests. However, when the pre-test scores of the groups were controlled, it was observed that there had been some changes in the EPT post-test scores of the control group I and control group II. The corrected EPT post-test mean scores were 15.38 for the experimental group; 12.41 for the control group I; and 12.43 for the control group II.

Table 8. The Descriptive Statistics of the EPT Scores According to Groups

Group	N	Mean	Corrected Mean
Experimental Group	27	15.3	15.38
Control Group I	21	12.95	12.41
Control Group II	18	11.94	12.43

If the groups were ranked from top to down according to their academic achievements according their EPT mean scores, it could be stated that the group with the highest mean score was experimental group and control group I and control group II followed this group respectively. The results of ANCOVA which was conducted to see whether there were a significant difference observed among the corrected EPT mean scores of the groups were presented in Table 9.

Table 9. The ANCOVA Results of the Post-test Scores that were Corrected Based on EPT Pre-test Scores According to the Groups

The Source of the Variance	Sums of Squares	df	Mean Squares	F	p
Pre-test	317.39	1	317.39	35	.00
Groups	139.72	2	69.86	7.7	.00
Error	562.13	62	9.06		
Total	132.88	66			

According to the ANCOVA results, it was found that there was a significant difference $F(2,62)=35$, $p<.05$ among the EPT corrected post-test scores of the groups in which different teaching methods were applied. In other words, the different teaching methods that were applied in groups were related to the post-test scores of the groups.

Table 10. Summary data from post – hoc test of learning environment

Learning environment (I)	Learning environment (J)	Mean Difference (I-J)	Std. Error	Significance	95% Confidence interval for difference	
					Lower Bound	Upper Bound
Control group II	Control group I	.02	.98	1	-2.39	2.44
	Experimental group	-2.94*	.91	.00	-5.2	-.68
Control group I	Control group II	-.26	.98	1	-2.44	2.39
	Experimental group	-2.97*	.88	.00	-5.14	-.8
Experimental group	Control group II	2.94*	.91	.00	.68	5.2
	Control group I	2.97*	.88	.00	.8	5.14

**p< .05, Control Group I-Experimental Group, Control Group II-Experimental Group*

Control Group I : The group in which the experiment method was applied
Control Group II : The group in which the analogy-based simulation method was applied
Experimental Group : The group in which the analogy-based simulation and experiment method was applied

According to the results of Bonferroni test (Table 10) which was conducted among the corrected EPT post-test scores of the groups, significant difference was found between the mean scores of the control group I in which the experiment method was applied and the experimental group in which analogy-based simulation method and laboratory method were applied together; and between the mean scores of control group II in which the analogy-based simulation method was applied and the experimental group in which analogy-based simulation method and laboratory method were applied together. This difference was in favor of the experimental group. No significant difference was found between the EPT post-test mean scores of the control group II in which the analogy-based simulation was applied and control group I in which the experiment method was applied. It could be stated that the combination of the analogy-based simulation and laboratory methods was more effective than the other methods.

CONCLUSION AND DISCUSSION

The purpose of this study was to test whether the combination method composed of analogy-based simulation and laboratory method was more effective than using these methods separately while teaching the basic concepts of electricity circuits or not. The results indicated important developments after evaluating pre-tests and post-test in all three learning environments. It was observed that the students who were taught in combined learning environment were more successful when the post-test scores for the three learning environments were compared. In order to carry out the study, 13 analogy-based simulations and 11 experiments which were appropriate to the electricity circuit topics in Turkish Science and Technology course program were designed and developed. There was no significant difference between the pre-test scores of the experimental and control groups in which the topics were told using different teaching materials. When the post-test mean scores in the combined learning environment were compared with the ones in laboratory and analogy-based simulation environments, it was found to be significantly higher. This finding is parallel with many studies (Jaakkola & Nurmi, 2008; Ronen & Eliahu, 2000; Zacharia, 2007) in literature. Jaakkola and Nurmi found that the combined simulation and laboratory activities were more effective in understanding the electricity circuits and increasing the success than when the simulation and laboratory activities were used separately; besides, they could not found statistically significant difference between the simulation and laboratory groups. This study we completed was started inspiring from Jaakkola and Nurmi's study and it was hypothesized that simulation group would be more successful than the laboratory group as the simulation tool was developed one step more with the analogy support. However, the results were not as we expected. To the contrary to our expectations, there was no statistically significant difference between the scores of the students who were taught in analogy-based simulation and laboratory environments. Although this finding was not in accordance with the results of the study carried out by Finkelstein et al., (2005), the results of some studies (Jaakkola & Nurmi, 2008; Ronen & Eliahu, 2000; Zacharia, 2007) indicated that computer and laboratory environments complemented with each other and either of them could not be preferred to the other in teaching electricity topics.

An individual has three types of learning: the first one is *induction* which is defined as the learning from part to whole. The second one is *deduction* which is defined as the learning from whole to part. The third one is analogy which is defined as the learning from part to part. The role of analogy and simulations supported with the analogy in making the microscopic phenomena related to the electricity concrete and providing conceptual development is quite important (Heywood, 2002). However, although analogy-based simulations provide with the students clear and informative learning environment, it is also important for students to have real experiences with electricity related laboratory materials in laboratories. Many studies have indicated that the activities carried out in real laboratory environments are effective in increasing students' conceptual developments and correcting their current misconceptions besides developing students' skills and attitudes (Glasson, 1989; Hofstein & Lunetta, 1982).

As a result, the findings of this study expressed that the teaching in which the analogy-based simulations were used with laboratory activities together provided with the students in better understanding the electricity topics (Jaakkola & Nurmi, 2008; Ronen & Eliahu, 2000; Zacharia, 2007). In addition to this, it was also observed during the teaching implementations that the students using analogy-based simulations were more motivated for the course, their attention was not distracted and even the student with low level of success were quite eager to participate into the course. When the fact how the motivation is important is taken into account, which one is more effective in increasing students' motivation-the simulation method or the laboratory method-should be suggested as for the further research.

NOTE: This study includes a part of the first author's master thesis.

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