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Effects of the Physical Laboratory versus the Virtual Laboratory in Teaching Simple Electric Circuits on Conceptual Achievement and Attitudes towards the Subject

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Abstract

Current study examined the effects of virtual and physical laboratory practices on students' conceptual achievement in the subject of electricity and their attitudes towards simple electric circuits. Two groups (virtual and physical) selected through simple random sampling was taught with web-aided material called "Electricity in Our Lives". Quasi experimental research design was used in the study and "Simple Electric Circuits Achievement Test" composed of three dimensions (CCAB, FCC and RCE) and "Attitude Scale for Simple Electric Circuits" composed of five dimensions were given to the groups are pre and posttests. It was identified that conceptual achievement significantly differed in the CCAB and RCE dimensions of the virtual laboratory implementations on the basis of total scores compared to the physical group whereas no meaningful differences were detected in the FCC dimension. It was also found that virtual laboratory implementations did not generate differences in student attitudes towards simple electric circuits.

Key Words: virtual laboratory, elementary science, achievement, electricity subject

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Introduction

Visual materials are needed in science education for students to better comprehend the subjects since science classes have theoretical natures and include abstract concepts. Computer-aided instruction plays an important role in presenting science subjects to students in a more concretized manner and presents active learning opportunities to teachers and students through computer technologies (Akçay et. al., 2006).

Meta-analysis studies that present a wide perspective regarding the effectiveness of computer-aided instruction suggest that these practices are most effective at primary education levels (4-8 grades) (Tekbıyık & Akdeniz, 2010; Liao, 2007). Similarly, various meta-analysis studies discovered that computer-aided instruction is more effective in teaching physics subjects compared to other science disciplines (Tekbıyık & Akdeniz, 2010; Bayraktar, 2001-2002; Christmann & Badgett, 1999). All these studies show the inevitable popularity of computer-aided practices and recently, many studies have begun focusing on whether virtual implementations can replace real, physical implementations (Finkelstein et al., 2005; Klahr, Triona, & Williams, 2007; Zacharia, Olympiou, &Papaevipidou, 2008; Olympiou&Zacharia, 2012).

Theoretical Framework

For students, experiments and laboratory work are crucial in correctly making sense of the natural world. Virtual laboratories have started to become alternatives for physical laboratories with the rising popularity of technology use in education. Studies on the effectiveness of physical environment (PE) and virtual environment (VE) implementations suggest that each environment provides distinctive benefits (Carmichael et al., 2010; Finkelstein et al., 2005; Gire et al., 2010; Zacharia, 2007). It is stated that PE implementations in which students can undertake laboratory activities by active touches provide them with opportunities to plan and implement an experiment process. In this process, students go through phases to obtain data and finalize their research by selecting appropriate materials (Gire et al., 2010). PE implementations allow individuals to realize errors in laboratory work as well (Toth, Klahr & Chen, 2000).When one considers that errors direct students toward accurate information, it is apparent that errors in one simulation will have a limited teaching effect. It is also reported that physical laboratories will develop psycho-motor skills and create awareness about laboratory safety procedures (Balamuralithara & Woods, 2009).

On the other hand, VE allows students implementations without the necessity for safety precautions. Experiments in the virtual laboratory can be repeated rapidly and economically (Huppert & Lazarowitz, 2002). It can be thought that virtual environments are not necessary when experiments are carried out physically; however, advantages provided by virtual laboratories in concretizing events that cannot be observed with the naked eye (such as the load flow in a conductor) and making them clearer and understandable should not be overlooked (Windschitl, 2000). One of the crucial purposes of instruction is to ensure conceptual understanding in students. Various studies have presented the effectiveness of PE and VE implementations separately (Zacharia & Anderson, 2003; Zacharia & Constantinou, 2008; Zacharia & Olympiou, 2011) and in blended forms (Olympiou & Zacharia, 2012).

Related Literature

The Primary and secondary school science instruction program in Turkey has been developed in a spiral manner, i.e. subjects are repeated annually and their scopes are expanded in the next year. (Ministry of National Education, 2005; Ministry of National Education; 2013).The subject of electricity is presented in the third grade of primary school. This practice may negatively affect the next year in cases where there are problems in the necessary skills.

Studies show that students consider the subject of electric circuits as difficult and have trouble comprehending it (Duit & von Rhöneck, 1998; Driver et al. 1994; Engelhardt & Beichner, 2004; Ergin & Atasoy, 2013; Shipstoneet al., 1988;).Various misconceptions or alternative conceptions are common in the subjects of electric current, resistor, potential and direct current in a wide range from primary grades to the university level (Çepni, & Keleş, 2006; Demirezen, 2010; Ergin & Atasoy, 2013; Jabot, & Henry, 2007; Kucukozer, 2004; Lee &Law, 2001; Osborne, 1983; Sencar & Eryılmaz 2004; Tsai, Chen, Chou, & Lain, 2007). Keser and Başak (2013) investigated the level of student acquisition in the “Electricity in Our Lives” unit of the science instruction program. The study, which analyzed qualitative and quantitative data regarding the acquisitions of 200 6th graders in the instruction program, showed that the obtained knowledge and skills were not at the desired level and that students displayed misconceptions in subjects such as composing circuits and controlling the brightness of the bulb. Reasons for misconceptions included the abstractness of the subject (Kucukozer, 2004), changes in the academic knowledge by the time it is used in the classroom environment (Tekbıyık & Sağlam Arslan, 2008), and negative student attitudes towards the lesson or the subject (Akgün, 2009).

It is also stated that focusing on the conceptual dimension of the “simple electric circuits” subject and associating it with practices in daily life will increase student interest and help students better comprehend the importance of the subject (Taşlıdere & Eryılmaz, 2012). It is suggested that simple analogies will not be sufficient to provide conceptual development and therefore complex models that allow different practices should be used (Clement & Steinberg, 2002). Therefore, various approaches have been investigated and the question of whether PE or VE will be more effective in teaching simple electric circuits has occupied the researchers’ minds.

Zacharia (2007) tried to teach electric circuits by forming two groups. In the process, one of the groups utilized real experimentation (RE) while the other group used real experimentation during the first half of the semester and virtual experimentation (VE) in the second half. Study results showed that the group utilizing virtual experimentation displayed better conceptual development and more rapidly acquired conceptual knowledge compared to the RE group.

In another experimental study, Jaakkola and Nurmi (2008) created three different environments and gave the same assignments to each group about electric circuits. The first group engaged with their tasks in the physical environment (PE) and the second group used the virtual environment (VE), whereas the third group first used the virtual environment followed by the physical environment. Results of the study showed that the most advantageous group was the one that utilized both environments, followed by the virtual group and physical groups, respectively.

Another study that compared physical and virtual implementations is Finkelstein et al’s (2005) study, which investigated university students’ skills in connecting resistors, forming circuits and measuring resistance and current. The group working in the physical environment used real physical circuit materials that were similar to the manipulatives in the simulations used by the group in the virtual environment. The results revealed that the group working with virtual manipulatives were more successful compared to the group using physical manipulatives. Finkelstein et al’s (2005) study showed that well designed simulations are effective in teaching the electric circuits unit.

Various implementations that compared virtual and physical environments in teaching electric circuits can be found in literature. These studies investigated cognitive variables such as conceptual achievement, forming circuits, and measuring current or resistance. However, modern instruction

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programs include affective goals such as developing positive attitudes towards a lesson or a subject in addition to cognitive goals (Ministry of National Education, 2005; Ministry of National Education, 2013). It is understood that attitudes in science are related to many factors, particularly achievement (George, 2006; Koballa, 1988; Osborne, Simon & Collins, 2003; Sorge, 2007; Tekbıyık & İpek, 2007). Today, it is reported that attitudes towards subjects that constitute the lesson should be investigated instead of just studying the attitudes towards the lesson (Şengören, Tanel &Kavcar, 2007; Taşlıdere & Eryılmaz, 2012). Therefore, it is crucial to examine the effect of physical or virtual environment implementations on attitudes as well as on cognitive characteristics.

Purpose of the Study

The current study aimed to compare the effects of virtual and physical laboratory implementations regarding the “Simple Electric Circuits” unit on 5th graders’ conceptual achievement and their attitudes towards the “Simple Electric Circuit” subject.

Method

Design and Sample

The study was implemented with a pretest-posttest quasi-experimental design. One of two groups selected through simple random sampling method in the 2012-2013 academic year in a province of Turkey was assigned as the Virtual group while the other was assigned as the Physical group. The virtual and physical groups included 32 and 33 students respectively. The virtual group was taught with the “Electricity in Our Lives” educational software developed by the researchers. Students in the virtual group used individual computers during implementations. Educational software was downloaded onto personal computers which were equipped with headphones for audio support necessary for the software. The physical group used hands-on materials in their activities. Each group was given an attitude scale about simple electricity and a conceptual achievement test on simple electric circuits as pretest and posttest. Instruction was completed in both groups in five weeks in a total of 30 class hours. Table 1 presents the experimental design of the study.

Table 1. Design of Study

Groups	Pretest	Treatment	Period	Posttest
Virtual (N=32)	CAT SECAS	Virtual Manipulative	5 Weeks	CAT SECAS
Physical (N=33)	CAT SECAS	Physical Manipulative	5 Weeks	CAT SECAS

Data Collection Tools

Simple Electric Circuits Attitude Scale (SECAS)

The Simple Electric Circuits Attitude Scale (SECAS), developed by Taşlıdere and Eryılmaz (2012), was used in the study to identify student attitudes towards the simple electric circuits subject. The scale is a five point Likert scale composed of 24 items and five sub dimensions (interest, importance, behaviors associated with interest, achievement-motivation, and self-competence). Scale items were evaluated as follows: completely Disagree 1, Disagree 2, Undecided 3, Agree 4 and Completely Agree 5.

Cronbach' Alpha reliability coefficient of the original scale was found to be 0.93 and it was found to be 0.92 in the current study.

Conceptual Achievement Test (CAT)

Students were expected to develop the required skills for "controlling and changing variables that affect the brightness of the bulb, forming closed circuits, and recognizing circuit elements" at the end of the instruction period of the study. The test developed for the study was envisioned to include these characteristics. A conceptual achievement test of 25 items was developed by the researches with this aim. Test items were examined by two field expert instructors and two science teachers. Five items were removed from the test according to expert views. Experts were asked to group the items in the test according to subject. By consensus, all experts stated that the test was composed of three sections: "controlling and changing variables that affect the brightness of the bulb" (CCAB) (9 items), forming closed circuits (FCC) (6 items) and recognizing circuit elements (RCE) (5 items). According to the item analysis of the test, the mean item difficulty was found to be 0.58 and the mean item discrimination was calculated as 0.42. The KR-20 coefficient regarding the internal consistency of the test was also calculated, and the value of 0.75 was obtained for the 20-item test.

Characteristics of the Software Used in the Virtual Environment

Educational software on the "Electricity in Our Lives" unit in the Primary Education 5th grade Science and Technology class instruction program, which was developed in a web based environment using PHP language, was implemented. The web site prepared for the study was supported by visual content, figures, and simulations developed by Adobe Photoshop, Adobe Flash, and Freehand to ensure suitability for age and level, arousal of interest and active participation.

When the educational software starts, the welcome page comes up. This section includes an informative text with directions on how to use the educational software and a short video. When the user name is entered, the main page appears. This section includes the textbook, lectures, activities, assessment and chat options. The instructional design and content of the educational software consists of level appropriate interactive practices, particularly lectures and activities sections which allow students to learn by doing.

Activities such as matching models and symbols to support recognition of simple electric circuit elements are presented in the materials. One of the activities asks students to match the models of circuit elements with their symbols. Students need to drag the circuit element models to the boxes under the symbols. The system does not allow dragging the wrong symbol to the right box. Therefore, the software directs students to correctly match the symbols with the models. Another activity asks students to form the circuit diagram provided on the left with the circuit elements provided on the top. Students manage to form the accurate circuit diagram after several attempts (see Figure 1).

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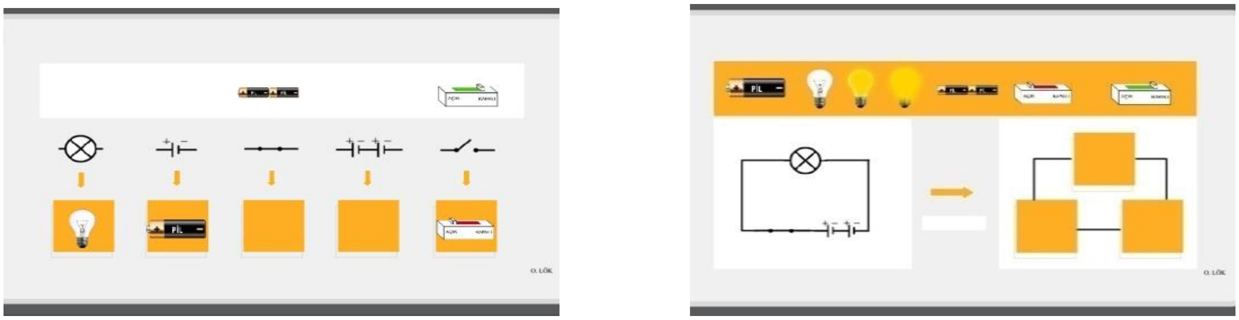

a. b.

Figure 1. a. Model-symbol matching activity b. Forming circuits based on the circuit diagram- print screen

In the next steps of the process, students discover the factors that affect the brightness of the bulb by forming closed circuits based on the directions provided on the screen. In this section, students are given unlimited trials and opportunities to use as many circuit elements in the way they choose. The “Activities” tab of the software provides active learning experiences and the “Lectures” tab presents theoretical materials to read. For instance, the definition of electric energy and samples of how we use electric energy in daily life are located in these tabs. Also, the chat environment in the software provides active interaction between the teacher and students, and among students themselves.

Results

An independent samples t-test was given to students to identify probable differences between the conceptual achievement levels of virtual and physical groups. Results show no significant differences in the CCAB (t(63) = 0.736; $p > 0.05$), FCC (t(63) = 0.900; $p > 0.05$) and RCE (t(63) = 1.082; $p > 0,05$) and total conceptual achievement scores (t(63) = 0.270; $p > 0,05$) of the Virtual and Physical groups prior to the study (see Table 2)..

Table 2. Comparison of Conceptual Achievement Pretest Scores of the Virtual and Physical Groups

			Pretest		Posttest	
Dimension	Group	*N*	*M (SD)*	*t*(63)	*M (SD)*	*t*(63)
CCAB	Virtual	32	25.9 (7.6)	0.736*	40.0 (3.6)	2.603**
	Physical	33	27.4 (8.7)		37.1 (5.2)	
FCC	Virtual	32	21.7 (7.2)	0.900*	28.6 (2.6)	0.063*
	Physical	33	20.0 (8.1)		28.6 (2.9)	
RCE	Virtual	32	21.3 (5.4)	1.082*	24.4 (1.7)	2.376**
	Physical	33	22.4 (3.1)		22.7 (3.6)	
Total	Virtual	32	68.91 (14.4)	0.270*	92.9 (4.5)	3.013**
	Physical	33	69.8 (13.7)		88.5 (7.1)	

Notes. SD= *Standard Deviation* $^{*}p>.05$. $^{**}p<.05$

Table 2 shows significant differences between Virtual and Physical groups’ posttest conceptual achievement scores in favor of the virtual group in CCAB (t(63) = 2.603; $p < 0.05$) and RCE (t(63) = 2.376; $p < 0.05$) dimensions and based on total scores (t(63) = 3.013; $p < 0.05$). However no significant differences were detected in the FCC dimension (t(63) = 0.063; $p > 0.05$). This result suggests that virtual implementation is more effective than physical implementation in regards to students’ conceptual achievement.

The graphic displayed in Figure 2 was generated to better display the changes in the groups' mean conceptual achievement scores before and after the implementation. The graphic shows that the achievement level is similar in all sub dimensions of the conceptual test. Examination of the posttests suggests increases of conceptual levels in all dimensions. In other words, both virtual and physical implementations increased students' conceptual achievement. However, the virtual group had better results in developing CCAB and RCE skills compared to the other group.

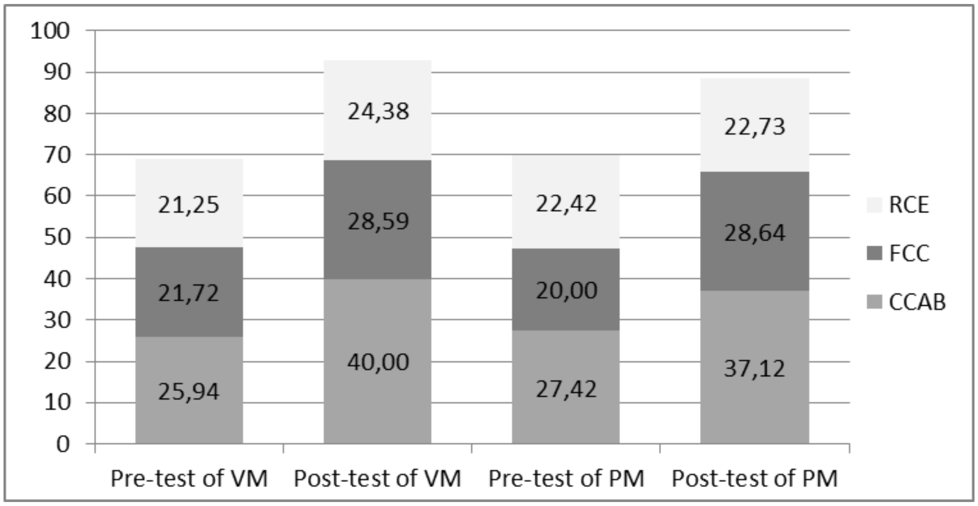

Figure 2. Comparison of group means for pretest and posttest conceptual achievement

Students' attitude scores for Simple Electric Circuits were examined based on dimensions and the findings are provided in Table 3. Results present no significant differences in Virtual and Physical groups' pretest and posttest scores.

Table 3. Comparison of SECAS Pretest Scores of the Virtual and Physical Groups

Dimension	Group	*N*	Pretest		Posttest	
			M (SD)	*t*(63)	*M (SD)*	*t*(63)
Interest	Virtual	32	4.4 (0.6)	1.315*	4.4 (0.8)	0.097*
	Physical	33	4.6 (0.5)		4.4(0.8)	
Importance	Virtual	32	4.3 (0.7)	0.990*	4.3 (0.6)	0.762*
	Physical	33	4.5 (0.5)		4.4 (0.9)	
Behaviors Associated with Interest	Virtual	32	4.2 (1.0)	1.183*	4.4 (0.7)	1.347*
	Physical	33	4.5 (0.6)		4.1 (1.1)	
Achievement-Motivation	Virtual	32	4.6 (0.5)	0.269*	4.5 (0.6)	0.093*
	Physical	33	4.6 (0.4)		4.5 (0.9)	
Self-Competence	Virtual	32	4.0 (0.9)	1.810*	3.9 (0.9)	0.544*
	Physical	33	4.4 (0.7)		3.9 (0.9)	

Note. $^{*}p>.05$

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Discussion

The current study aimed to contribute to the literature by examining whether VE or PE was more effective in teaching "simple electric circuits" subject to 5th grade students studying the "Electricity in Our Lives" unit. In the process, a web-based virtual environment was created to allow active student participation. Similar activities were undertaken in the physical environment with real materials. After the implementation, it was identified that RCE and CCAB skills developed more in the virtual group whereas similar levels of development were observed in both groups in terms of FCC skills. The implemented software included a model-symbol matching activity to develop the recognition of circuit elements (RCE) skill. Students can undertake unlimited trials to match the images of circuit elements with their symbols. Circuit elements such as batteries, bulbs, conducting wires, and switches are presented with rich visual contents. Students in the physical environment attempted to learn about the circuit elements by touching and seeing them in real time. The difference found in the skills development may be related to the fact that the virtual environment provides rapid feedback and allows repetition of the activity (Huppert & Lazarowitz, 2002; Ronen & Eliahu, 2000). Repitition is one of the most important self-regulatory activities that allows individuals to direct their own learning (Pintrich et al.,1991, Pintrich, 1993).

The virtual group was also more effective in developing the skills for "controlling and changing variables that affect the brightness of the bulb" (CCAB). It is possible to change the number of bulbs and their wiring styles, series battery numbers, or the resistance of the conductors that forms the circuit in order to change the brightness of the bulb in the electric circuit. Students in the physical group had to form the circuit again each time for a new trial. However, students in the virtual group had the chance to carry the circuit elements anywhere on their screens just by moving their computer cursor. 5th grade is the level in which students' have acquired psycho-motor developments and the manual dexterity necessary to make rapid changes in electric circuits. In that respect, the opportunity to change the variables and monitor the changes instantly in the virtual group may have caused the superiority observed in this group. This finding also supports the information in the literature that computer-aided instruction is most effective at primary education levels (Tekbıyık & Akdeniz, 2010; Liao, 2007). Implementations regarding the FCC skills caused similar developments in both groups. A physical environment allows instant feedback to students during the formation of circuits. Existence of the current can be instantly determined in the closed circuit by using bulbs. The physical environment is more advantageous than the virtual environment based on this characteristic. On the other hand, the fact that the virtual environment can form the circuit rapidly and provides instant feedback (Huppert & Lazarowitz, 2002; Ronen & Eliahu, 2000) may have caused similar conceptual development levels in both groups. It is possible to find cases in which physical and virtual environments cause similar conceptual developments (Farrokhnia & Esmaeilpour, 2010; Zacharia & Olympiou, 2011).

It was observed in the study that implementations in both the physical and virtual groups were effective in providing conceptual development (Figure5). It was also suggested that traditional methods did not provide conceptual growth at the desired level in the "Electricity in Our Lives" unit and were not effective in removing misconceptions (Keser & Başak, 2013). Therefore, it may be implied that implementations used in the current study are superior to traditional methods even though no groups in the current study were taught by traditional methods.

Compared to the use of only one environment, the literature also mentions cases of more effective learning environments in which virtual and physical implementations are blended (Farrokhnia & Esmaeilpour, 2010; Lee, Guo & Ho, 2008; Olympiou & Zacharia, 2012; Zacharia, 2007; Zacharia & Olympiou, 2011). These studies pointed to the fact that blending virtual and physical environments is more effective for conceptual development since it combines the beneficial and superior aspects of both.

The current study found that virtual and physical implementations did not have an effect on student attitudes towards simple electric circuits. Changing individual attitudes towards one subject in a short period of time is a difficult affective process (Tavşancıl, 2005). It may be suggested that the 5-week implementation period of the study may have been insufficient to develop related attitudes.

Conclusions and Implications

Compared to physical environment activities, virtual environment software developed for the study to teach Simple Electric Circuits was found to provide higher levels of conceptual development in students in *recognizing circuit elements* and in *identifying variables that affect the brightness of the bulb*. Both environments provided similar levels of development for the skill of *forming circuits*. These results were caused by the different opportunities provided by each environment. In this regard, using virtual and physical environment activities in a blended manner will provide the use of natural realities of the physical environment along with the rapid feedback options and repetition opportunities of the virtual environment. Also, investigation of the effects of these implementations on removing possible student misconceptions regarding simple electric circuits is crucial for future studies, although this angle was not included in the current study.

The study showed that both physical and virtual environments did not have an effect on student attitudes towards the subject. This may be related to the fact that attitudes towards a subject are hard to change in short periods of time. It is also known that ensuring reliability in measuring attitudes is more difficult compared to ensuring reliability for the measurement of cognitive skills (Mehrens & Lehmann, 1987). Especially in identifying the attitudes of primary grade students, the triple sided structure of attitude which is composed of feelings, thoughts and actions should be measured by a process based on observation and interviews, instead of pen and paper tests, in order to have more valid results. In fact, it is indicated that different results may be obtained when an individual's attitude towards specific communities, objects, institutions, or events is determined through different techniques, and the most valid method to determine an individual's behavior (what he does, tells, writes etc.) is the direct observation of the behaviors of the person in question

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