International Journal of Business, Human and Social Sciences
ISSN: 2517-9411
Vol:3, No:6, 2009

The Effect of Combining Real Experimentation With Virtual Experimentation on Students' Success

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***Abstract*—**The purpose of this study was to investigate the effect of combining Real Experimentation (RE) With Virtual Experimentation (VE) on students' conceptual understanding of photo electric effect. To achieve this, a pre–post comparison study design was used that involved 46 undergraduate students. Two groups were set up for this study. Participants in the control group used RE to learn photo electric effect, whereas, participants in the experimental group used RE in the first part of the curriculum and VE in another part. Achievement test was given to the groups before and after the application as pre-test and post test. The independent samples t- test, one way Anova and Tukey HSD test were used for testing the data obtained from the study.

According to the results of analyzes, the experimental group was found more successful than the control group.

***Keywords*—**Computer Based Teaching, Java, Physics Education, Virtual Laboratory.

I. Introduction

RESEARCH on learning shows that students learn better when they construct their own understanding of scientific ideas within the framework of their existing knowledge [1]. To accomplish this process, students must be motivated to actively engage with the content and must be able to learn from that engagement. Interactive computer simulations can meet both of these needs. Simulations can therefore be designed to introduce students to increasing levels of complexity and messiness, which may be an effective and engaging way to prepare students for real scientific research. Carefully developed and tested educational simulations can be engaging and effective.

Research in science education has shown that difficulties in understanding scientific concepts are widespread across all ages and levels [2]. Students' ideas and interpretations, based on everyday experiences and language, often interfere with learning of the scientific models introduced during science classes, and affect the ability of the students to assimilate the scientifically correct ideas [3]. This finding suggests a need to refocus our efforts on ways of promoting conceptual understanding through meaningful learning experience which embraces students' worldviews in a way that promotes assimilation of the scientifically accurate conceptions [4]. Researchers suggested that conceptual understanding is only accomplished through learning that promotes conceptual change [5-8].

Both the use of laboratory inquiry-based experimentation called Real Experimentation (RE) and the use of virtual experimentation provided through interactive computer-based simulations called Virtual Experimentation (VE) could be used as conceptual change learning environments [9, 10].

Real Experimentation has long played a vital role in science education [9]. Science educators have suggested that there are rich benefits that accrue from using RE; mainly its potential to be an important medium for introducing students to central conceptual and procedural knowledge and skills in science [11]. The challenge for RE or any other form of experimentation, is to help learners taking control of their own learning in a search for understanding. In this process, it is vital to provide opportunities that encourage learners to ask questions, suggest hypotheses and design investigations – "minds-on as well as hands-on" [12, 13].

The simulations encourage student engagement. As is now thoroughly documented in the physics education research community and elsewhere [1,14-16], environments that interactively engage students are supportive of student learning. At start-up for instance, the simulations exactly invite users to engage with the components of the simulated environment. Furthermore, often students build (virtual) objects in the simulation, which further serves to motivate, ground, and support student learning [17].

Many of the simulations create a self-consistent world, allowing students to learn about key features of a system by engaging them in systematic play, "messing about," and open-ended investigation [18]. Simulations can be used in a variety of ways in the lecture environment. Most often they are used to take the place of, or augment chalk-talk or demonstration activities.

Understanding the photoelectric effect is a crucial step in understanding the particle nature of light, one of the foundations of quantum mechanics. The photoelectric effect is a powerful tool to help students build an understanding of the photon model of light, and to probe their understanding of the

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photon model. However, research shows that students have serious difficulties understanding even the most basic aspects of the photoelectric effect, such as the experimental set-up, experimental results, and implications about the nature of light [19-22].

The simulation allows students to control inputs such as light intensity, wavelength, and voltage, and to receive immediate feedback on the results of changes to the experimental set-up. With proper guidance, students can use the simulation to construct a mental model of the experiment.

Despite all the research efforts in science education to reveal the impact of RE or VE, the scientific literature lacks studies that investigate the impact that the combination of the two methods has on students' conceptual understanding of science [10]. Therefore, this study was designed in an attempt to contribute towards this direction by investigating whether the effect of RE on undergraduate students' conceptual understanding of photo electric effect changed when RE was complemented with VE. The current study presents the evaluation of an effort to combine the potentials of both methods of experimentation.

II. Method

A. Purpose

The purpose of this study was to investigate the effect of combining Real Experimentation (RE) with Virtual Experimentation (VE) on students' conceptual understanding of photo electric effect.

B. Sampling

The participants of the study were 46 undergraduate students (27 male, 19 female), ranging in age from 19 to 23 and taking "Modern Physics Laboratory" class at Department of Physics Education of Ahmet Keleşoğlu Education Faculty at Selcuk University during the first term of 2008-2009 academic year. The more detailed information about sampling is shown in the Table I below.

TABLE I
The Data about Sampling

			Gender		
			Female	Male	Total
Groups	Control group	N	9	14	23
		%	39,1	60,9	100,0
	Experimental group	N	10	13	23
		%	43,5	56,5	100,0
	Total	N	19	27	46
		%	41,3	58,7	100,0

C. Data Collection and Analysis

For the study, a virtual laboratory atmosphere was created regarding "Experiment of Photoelectric Effect". To do that, it had been benefited from the Java Simulations. The Photoelectric Effect simulation, shown in Fig. 1, downloaded from the PhET website. This simulation is available for free download, along with many other simulations in introductory physics and quantum mechanics, from the PhET website [23].

This simulation allows students to control inputs such as light intensity, wavelength, and voltage, and it allows them to receive immediate feedback on the results of changes to the experimental set-up. With proper guidance, students can use the simulation to construct a mental model of the experiment. This simulation also allows students to interactively construct the graphs commonly found in textbooks, such as current vs. voltage, current vs. intensity, and electron energy vs. frequency. By seeing these graphs created in real time as they change the controls on the experiment, students are able to see the relationship between the graphs and the experiment more clearly than they see when viewing static images.

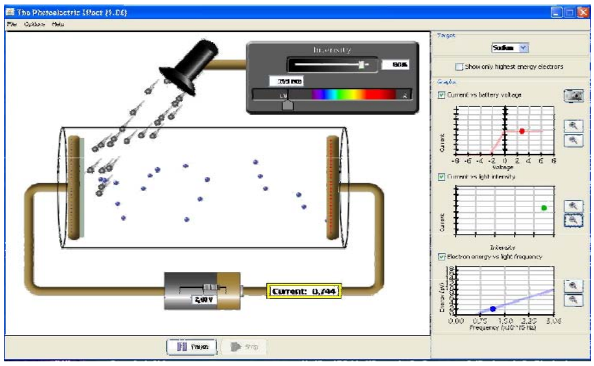

Fig. 1 The photoelectric effect simulation

This application was made with the 46 undergraduate students, who get "The Modern Physics Laboratory" class. This laboratory contains eight experiments. One of these experiments was "Photoelectric Effect Experiment". Firstly all the participants were randomly and evenly separated into two groups, namely, the control group (use of RE) and the experimental group (use of RE and VE). As could be seen from Table I, The control group was formed of 23 students, 9 of whom were female and 14 of whom were male. The experimental group was formed of 23 students too, 10 of whom were female and 13 of whom were male. After then, these groups separated into eight groups, so there were eight groups in control group and eight groups in experimental group. Every week, one group of the control and one group of the experimental group made the "Photoelectric Effect Experiment". Meanwhile the other groups of the control and experimental groups made the other experiments of "The Modern Physics Laboratory" lesson every week.

A pre–post comparison study design that involved an experimental and a control group was used. Before the application, a physic achievement test on photoelectric effect, contained eight open-ended items, that asked conceptual questions, were prepared. The physic achievement test which had been prepared, applied to the control and experiment groups as a pre-test before the application.

Both groups used the same instructional method and curriculum on photoelectric effect. However, participants in the control group used RE that involved the use of real apparatus and materials about “Photoelectric effect” (for example photocell, rheostat, power supply, ammeter, and voltmeter) in a conventional physics laboratory (see Fig. 2), while participants in the experimental group used RE and VE that involved the use of virtual apparatus and material on a computer too (see Fig. 1).

TABLE II
THE SUCCESS LEVEL OF THE PRE-TEST OF THE RESEARCH GROUPS

	Groups	N	Mean	Std. Deviation
Pre-test	Control Group	23	19,78	7,459
	Experimental Group	23	19,57	8,382

Fig. 2 Real experimentation materials regard photoelectric effect

The physic achievement test was applied again to the experimental and control groups as a post-test. The SPSS 11.00 (Statistical Package for Social Sciences) statistical program was used to evaluate all the data collected from pre-and post-tests. The independent samples t-test, one way anova and tukey hsd test were used for testing the data obtained from the study at 05 level of significance.

III. FINDINGS

In this study the findings obtained are given in the tables and figures below. In Table II the success level of the pre-test of the research groups are shown.

As seen in Table II control groups’ mean is 19,78 and experimental groups’ mean is 19,57 points at pre-test. For comparing the pre-test means of the research groups, the independent samples t-test analysis was applied and the results of this analysis are given in Table III.

As it is seen in Table III there was not any significant difference between research groups before the application (t = ,093; df = 44; sig (2-tailed) = ,926 > ,05). So it can be stated that success of the groups were equal at beginning of the application.

TABLE III
THE COMPARATIVE RESULTS OF PRE-TEST OF THE RESEARCH GROUPS

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Pre-test	Equal variances assumed	,180	,673	,093	44	,926	,22	2,340
	Equal variances not assumed			,093	43,414	,926	,22	2,340

TABLE IV
THE SUCCESS LEVEL OF THE POST-TEST OF THE RESEARCH GROUPS

	Groups	N	Mean	Std. Deviation
Post-test	Control group	23	42,83	11,854
	Experimental group	23	64,35	13,425

As seen in Table IV control groups’ mean is 42,83 and experimental groups’ mean is 64,35 points at post-test. For comparing the post-test mean of the research groups, the independent samples t-test analysis was applied and the results of this analysis are given in Table V.

TABLE V
THE COMPARATIVE RESULTS OF POST-TEST OF THE RESEARCH GROUPS

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Post-test	Equal variances assumed	,083	,775	-5,763	44	,000	-21,52	3,734
	Equal variances not assumed			-5,763	43,335	,000	-21,52	3,734

As it is seen in Table V there was a significant difference between research groups after the application (t = -5,763; df = 44; sig (2-tailed) = ,000 < ,05). This finding suggests that the combination of RE and VE had a stronger effect on undergraduate students’ conceptual understanding of photoelectric effect than RE alone.

Furthermore, in point of gender the success level of the groups were analyzed and the results are given in Table VI, Table VII, Table VIII, Table IX and Table X.

TABLE VI
THE SUCCESS LEVEL OF GENDER GROUPS AT PRE-TEST

Groups	Gender		Pre-test
Control group	Female	Mean	20,56
		N	9
		Std. Deviation	3,909
	Male	Mean	19,29
		N	14
		Std. Deviation	9,169
Experimental Group	Female	Mean	20,00
		N	10
		Std. Deviation	8,165
	Male	Mean	19,23
		N	13
		Std. Deviation	8,861
Total		Mean	19,67
		N	46
		Std. Deviation	7,846

As seen in Table VI, mean of success level of females in control groups is 20,56 and mean of success level of males in control groups is 19,29 points, while mean of success level of females in experimental group is 20,00 and mean of success level of males in experimental groups is 19,23 points at pre-test. For comparing the pre-test mean of the research groups in point of gender the one way anova analysis was applied and the results of this analysis are given in Table VII below.

TABLE VII
THE COMPARATIVE RESULTS OF THE GENDER GROUPS AT PRE-TEST

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	12,722	3	4,241	,065	,978
Within Groups	2757,387	42	65,652		
Total	2770,109	45			

As it is seen in Table VII, there wasn't any significant difference in point of gender between research groups before the application (F = ,065; df = 3; sig.= ,978 > ,05).

TABLE VIII
THE SUCCESS LEVEL OF GENDER GROUPS AT POST-TEST

Groups	Gender		Post-test
Control group	Female	Mean	46,67
		N	9
		Std. Deviation	11,180
	Male	Mean	40,36
		N	14
		Std. Deviation	12,004
Experimental Group	Female	Mean	67,00
		N	10
		Std. Deviation	18,439
	Male	Mean	62,31
		N	13
		Std. Deviation	8,066
Total		Mean	53,59
		N	46
		Std. Deviation	16,589

As seen in Table VIII, mean of success level of females in control groups is 46,67, and mean of success level of males in control groups is 40,36 points, while mean of success level of females in experimental group is 67,00 and mean of success level of males in experimental groups is 62,31 points at post-test. For comparing the post-test mean of the research groups in point of gender the one way anova analysis was applied and the results of this analysis are given in Table IX below.

TABLE IX
THE COMPARATIVE RESULTS OF THE GENDER GROUPS AT POST-TEST

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5669,169	3	1889,723	11,821	,000
Within Groups	6713,984	42	159,857		
Total	12383,152	45			

As it is seen in Table IX, there was a significant difference in point of gender between research groups after the application (F = 11,821; df = 3; sig.= ,000 < ,05). So to understand the reason of this difference tukey hsd analysis was done. The results of the tukey hsd analysis are given in Table X below.

TABLE X
THE SUCCESS LEVEL OF THE GENDER GROUPS ACCORDING TO POST TEST ANALYZED THROUGH TUKEY HSD

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.
Control Groups' Female	Control groups' Male	6,31	5,402	,650
Control Groups' Female	Experimental Groups' Male	-15,64*	5,483	,033
Experimental Groups' Female	Control Groups' Female	20,33*	5,809	,006
Experimental Groups' Female	Control groups' Male	26,64*	5,235	,000
Experimental Groups' Male	Control groups' Male	21,95*	4,870	,000
Experimental Groups' Male	Experimental Groups' Female	-4,69	5,318	,814

As it is seen in Table X, there wasn't a significant difference between females and males of control groups (sig. = ,650 > ,05) and between females and males of experimental groups too (sig. = ,814 > ,05) after the application. But females and males of experimental groups had been more successful than the females and males of control groups (sig. < ,05).

IV. CONCLUSION AND DISCUSSION

As it is seen in Table III there wasn't any significant difference between research groups before the application (t = ,093; df = 44; sig (2-tailed) = ,926 > ,05). So it can be stated that success of the groups were equal at beginning of the application.

As it is seen in Table V there was a significant difference between research groups after the application (t = -5,763; df = 44; sig (2-tailed) = ,000 < ,05). So it can be stated that after the application, the experimental group had been more successful than the control group. As seen from the results, however the achievements of the groups were the equal with each other at the beginning of the application, after the statistical analyses it was seen that there has been important difference in achievement in favour of the experimental group. These results showed that combining Real Experimentation (RE) With Virtual Experimentation (VE) has positive effects upon teaching the hard physics subjects as photo electric effect.

As it is seen in Table VII, there wasn't any significant difference in point of gender between research groups before the application (F = ,065; df = 3; sig.= ,978 > ,05). It can be stated that related with gender, success of the groups were equal at beginning of the application.

In Table VIII it is seen that success level of the females of control group was higher than the males of control group and also success level of the females of experimental group was higher than the males of experimental group. As it is seen in Table IX, there was a significant difference between research groups related with gender after the application (F = 11,821; df = 3; sig.= ,000 < ,05). But as it is seen in Table X, there wasn't a significant difference between females and males of control groups (sig. = ,650 > ,05) and between females and males of experimental groups too (sig. = ,814 > ,05). The significance of Table IX results from teaching methodology, because the females and males of experimental group had been more successful than the females and males of control group. So these results showed that combining Real Experimentation (RE) with Virtual Experimentation (VE) has positive effects on students' success.

It has been proven that combining Real Experimentation (RE) with Virtual Experimentation (VE) have a significant effect on students' evolving skills, attitudes and conceptual understanding [10, 24-30]. The results of this research are compatible with the results of these researches too.

According to the mentioned results above at the end of this study the following implications can be given for the development of physics teaching-learning process;

- The computer-based simulations should be used in all physics lessons.
- The physics teachers should encourage using simulations in their lessons.
- The physics laboratories should be practiced by combining Real Experimentation (RE) with Virtual Experimentation (VE).

ACKNOWLEDGEMENT

This study had been supported by the Scientific Research Projects (BAP) Coordinating Office by the project number of 09701096. The authors are grateful for the support provided by the Scientific Research Projects (BAP) Coordinating Office of the Selcuk University, Turkey.

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