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The Effectiveness of the IUVIRLAB on Undergraduate Students' Understanding of Some Physics Concepts

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Abstract

The present study was conducted to investigate the effectiveness of Istanbul University Virtual Laboratory (IUVIRLAB) electromagnetic field and magnetism experiments on undergraduate students' understanding of electromagnetic field and magnetism concepts and to determine the students' misconceptions about electromagnetic fields and magnetism. IUVIRLAB has unique characteristics in terms of being a 3-dimensional, interactive virtual laboratory that enables students to learn in cooperative groups, and is the first of its kind due to its qualities of enabling multi-admin and multi-user operation, having special software compatible to run on iPad, iPhone, android and smart phone platforms, and having been designed on the basis of active learning approaches. To determine 120 (n=60 experimental and n=60 control groups) students' misconceptions about electromagnetic fields and magnetism and the effectiveness of IUVIRLAB, Magnetic Field Concept Test consisting 20 items was used as a pre-test and post-test. According to the results, twenty-four misconceptions about electromagnetic field and magnetism were identified. The results from the paired sample t-test indicated that the students who were instructed using IUVIRLAB instruction had significantly higher scores in terms of achievement than those taught by the traditional approach and it was also found that IUVIRLAB group was more successful in preventing of the determined misconceptions.

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Keywords: Education; e-learning; New communication technologies; Physics concepts.

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1. Introduction

In the last century, it was quite important to access information and to learn information quickly for the development of individuals and society. In the 21st century it has become impossible to follow improvements in information technologies. This convenience in accessing information has brought together e-learning and contributed significantly to the development of global communication networks together with distance education applications. Due to developments in education technology and learning theories and the start of computer usage, the types and diversity of learning have increased.

Virtual laboratory programs which are one of the most important applications in the field of education where computers are used were defined as programs that were adapted for the requirements of teachers and students, combining modeling, simulation and information technologies in order to create highly interactive environments. Prieto-Blázquez, Herrera-Joancomartí and Guerrero-Roldán (2009), who set forth a new definition by examining and synthesizing several studies which had previously been conducted, defined virtual laboratories as interactive virtual learning environments that are adapted according to students' and teachers' needs and that embody all pedagogical, technological and human-specific resources in order to perform applied experiments. These programs also include a software system, simulator and smart teaching systems (Scherp 2002). Virtual laboratories are simulations of real laboratories. Their most prominent feature is a highly interactive user interface. In a virtual laboratory program the user can move objects, use laboratory equipment and carry out experiments using the mouse and keyboard. In short, virtual laboratories can be described as simulation-based multi-media (Scherp 2002). Jeschke, Richer and Zom (2001) reported the characteristic features of a virtual laboratory as being virtual, complex, flexible, structuralist, taking an experimental approach to intangible objects, possessing a trial-error approach, having 24/7 accessibility and reliability. Examining these characteristic features shows that these programs can be used to create the ideal environments that will help learning and teaching.

2. Literature Review And Hypotheses

Physics is a discipline established on a conceptual basis and is grounded in experiments. In spite of this, the common perception of the physics course as a numerical course where one is overwhelmed with formulas makes it more difficult and leads students to deal with numerical problems instead of concepts. This, in turn, prevents students from accurately structuring the concepts and therefore causes misconceptions. However, when a physics course is not taught in a visualizable way blended with visual cases, and is not integrated with laboratory studies and experiments; it cannot be addressed as a science in real terms. The laboratory is an active environment where data is used. Laboratory studies have effects on reasoning, critical thinking, comprehension of science, processing and manipulative skills, and enable students to use information, identify new problems, explain observations and make decisions. Due to this, the laboratory is an important part and the focal point of physics education. In this context, the importance of teaching through experimental methods in physics education has been emphasized in many conducted studies. On the other hand, it has been revealed once again by the studies carried out that material and time insufficiencies are frequently experienced in teaching physics through experimental methods, and therefore teachers usually do not prefer to follow these methods so the rate of application is quite low (EARGED 1995). Consideration of these problems indicates the necessity to search for suitable alternatives, and ways of utilizing technology for this purpose are frequently sought. Studies conducted on the topic of education indicate that computers play an important role in this sense. In this respect, computers are one of the important tools that can be used in experiments. Today, computers have secured their place in physics laboratories in many countries. The richness and access to modeling tools that computer-based laboratories provide have a significant importance in physics education and teaching. Being defined by a high level of simulation programs, virtual laboratories today provide teachers and students with the means of laboratories without any constraints of time and space, and enable them to do experiments wherever and whenever they want. Virtual laboratory programs, the number of which is rapidly increasing all around the world, are needed as supplementary tools of traditional laboratories (Jeschke, Richer and Zom 2003). With these programs students are able to carry out the experiments they want, whenever they want and in an ideal environment which greatly enhances their creativity. Students that use virtual laboratory programs have the opportunity to reason and comprehend the details and causes of the phenomena they frequently experience in their daily lives (Brown, McHugh, Standen, Evett, Shopland, & Battersby 2011).

In a virtual laboratory environment physics experiments that cannot be conducted or that are difficult and time-consuming to be conducted in real laboratories are simulated within minutes and presented in a way that is suitable for education purposes (Noor and Wasfi 2001). It has been reported in several studies that students can be taught the concepts they can learn in real laboratories in a much cheaper way and shorter time in virtual laboratories and accordingly, their problem-solving performance will be greatly enhanced. Virtual laboratories saved time and visually attracted students' interest by means of the simulation experiments they carried out with the aid of the Internet. In addition to this, use of virtual laboratory programs also affects students' problem-solving skills positively (Hodge, Hinton and Lightner 2000).

In the previous studies; Warner, Catterall, and Lıpson (1997) developed applets on the use of Java simulations for teaching physics, and Morooneyc (1998) carried out a Java simulation for computable electromagnetics. Wærn, Dahlqvist and Ramberg (2000) prepared four different types of computer-based teaching materials with the purpose of examining the effects of the texts, pictures and computer animations on university physics students' comprehension levels, and reported that computer-aided designs are effective in the comprehension of concrete concepts. Cox . Belloni, Christian, and Dancy (2003) prepared a CD titled "Physlet", while Jimoyiannis and Komis (2000) used computer simulations as a method to target students' conceptual knowledge. Michael (2001) conducted computer simulations particularly to develop students' creativity. Christian and Belloni (2001) introduced the "Physlet" software package that consisted of physics simulations prepared with Java for use in physics education. Yen and Li (2003) presented web-based teaching for pneumatic vehicles. Finkelstein (2005) created a virtual laboratory application that includes Java simulations on direct current circuits. Tavares (2005) used the concept map method and the interactive animation method included in teaching methods together and Zacharia (2005) aimed to ensure proper teaching of the concepts of mechanics, waves, optics and heat through the use of interactive simulations. In addition to these published studies, there are many web-based physics laboratories prepared with Java and Flash simulations: (http://phet.colorado.edu /en/simulations/ category/physics, http://www.phy. ntnu.edu.tw/java/, http://www.myphysicslab.com/, http://www.colpus.me.uk/vplabd/).

It is not enough to just apply teaching-learning methods or strategies in courses with traditional approaches. Currently, there are several implementations teaching-learning scenarios that facilitate innovation processes in education. In innovatiove approach, Istanbul University Virtual Laboratory (IUVIRLAB) that based on active learning methods and techniques for university students was developed as a model of the 3-dimensional, interactive, multi-user and multi-admin (Ince et al. 2014). The structure of the system as following;

- The Master-Admin: Enters the user name and password information of the multi-admin to the database.
- Each multi-admin enters student information, usernames and passwords to the database.
- When the system is activated by the multi-admin, all users can login to the related experiments.
- At the end of the first experiment's period, the multi-admin deactivates the system and any user that logs in after this sees the message "Laboratory is closed".
- When admin decides to initiate the next experiment period, he or she clicks on the "create the groups for the next experiment" button and the system automatically assigns the groups and experiments of all users (names of experiments change without changing experiment tables; for instance experiment 1 - table 1 becomes experiment 2 - table 1 in the next experiment).
- In order to initiate any experiment, the minimum number of users defined for each experiment needs to be logged in. A minimum of 3 users is required for each experiment, while the maximum number of users is 4.

- After a minimum of 3 users are connected to the experiment in question, the system assigns a task for each user. There are at least 3 tasks for each experiment. In cases where 4 users connect to an experiment of 3 tasks, the fourth user can be the "observer". In cases where 4 users connect to an experiment of 3 tasks, the fourth user can be the "observer". They solely observe the experiment. If there are 4 tasks defined but only 3 users connected, then the first user will perform 2 tasks.
- The task command on the screen of each user is different. During the experiment, the system notifies each user concerning the tasks they need to perform.
- In case one or more users go offline during the experiment, the message "waiting for other users" is displayed and the experiment resumes when all users are online again.
- Multi-admin can assign homework to users concerning the experiments realized and perform measurement-evaluation. For this purpose, an upload-download section is included in the system. From here, the multi-admin can upload new homework and download the finished assignments. The system stores all experiment tables in the database.
- After the group completes an experiment, it cannot do anything related to that particular experiment before the admin allows for the next period. In this case, users see the "experiment completed" message and can only see the experiment result table when logged in.

3. Methodology

3.1. Research Goal

The purpose of this study to investigate the effectiveness of IUVIRLAB - electromagnetic field and magnetism experiments on undergraduate students' understanding of the concepts of electromagnetic fields and magnetism and to determine the students' misconceptions about electromagnetic fields and magnetism. In the context of this study, the following research sub objectives were investigated.

1-Investigation of the relationships between experimental and control groups' pre-test and post-test Concept Test scores.

2-Determination of experimental and control groups' misconceptions about electromagnetic fields and magnetism and the effectiveness of IUVIRLAB in preventing students' determined misconceptions about electromagnetic fields and magnetism.

3.2. Sample and Data Collection

The sample of the study consists of the 120 students attending from Istanbul University Hasan Ali Yucel Education Faculty Science Education Department. The students was taken general physics and general physics laboratory courses and learnt Magnetic Field and Magnetism subjects. Traditional approach (control) group includes 60 students and IUVIRLAB (experimental) group includes 60 students.

In this study, two-tier diagnostic test "Magnetic Field Concept Test (MFCT)" which was developed by (Ince 2012) was used.

Magnetic Field Concept Test (MFCT): A Magnetic Field Concept Test (MFCT) was developed by the researchers (Ince, 2012) The MFCT consisted of 20 items and the reliability coefficient of the test (KR-20) was found to be 0.77. The test items contain; magnets, magnetic fields, magnetic poles, charged particles in a magnetic field, magnetic fields of a wire, Biot-Savart and Coulomb laws, magnetic fields of the earth, magnetism properties of the matter, magnetic field effects of electric currents and magnetic field applications in daily life.

Structure of IUVIRLAB System: IUVIRLAB developed as a model of the 3-dimensional, interactive, multi-user and multi-admin that embodies active learning methods and techniques for university students. It is estimated that this virtual laboratory -in comparison to traditional laboratory implementation- will further increase students' success levels, enable them to correctly structure concepts and enhance their critical thinking and problem solving skills as well as their capability to associate physics with their daily lives. It is believed that the present study, together with any similar studies to be conducted, will contribute to the rectification of the deficiencies of experimental applications in physics education in Turkey and the world (Ince et al. 2014).

In this study to investigate the effectiveness of IUVIRLAB on undergraduate students' understanding of the concepts and to determine the students' misconceptions about electromagnetic fields and magnetism experimental and control group pre-test and post-test experimental model was used.

The experimental group: The IUVIRLAB virtual physics laboratory application includes 4 experiments concerning magnetic fields and magnetism. These experiments are; examination of the magnetic field of a solenoid, magnetic field within a solenoid, magnetic induction, and electromagnetic resonance. Before the IUVIRLAB virtual physics laboratory application, students were performed traditional laboratory experiments and were informed about the structure of the virtual laboratory, how to use it, how to enter the website, how to see their group friends and the test booklet and MFCT were applied. Students were added to the system from the Admin panel of the IUVIRLAB virtual physics laboratory, passwords and the collaborative groups of each student were determined. During application students entered the "www.iuVIRalfiziklab.com" web address which was determined for teachers; they communicated on-line via Skype and Twitter both with their group friends and system administrator. For the application to be as realistic as possible, experiments were carried out for 4 weeks, and after MFCT were applied to the students as pre- and post test.

The control group: In this treatment, the instruction in the control group was depend on regular traditional method physics laboratory course. Traditionally, a lecturer presented and explained the experiments setup which are all the same with experimental groups' experiments (examination of the magnetic field of a solenoid, magnetic field within a solenoid, magnetic induction, and electromagnetic resonance) and the students performed experiments using by their laboratory notes. For the application to be as realistic as possible, experiments were carried out for 4 weeks, and after MFCT were applied to the students as pre- and post test.

3.3. Analyses and Results

Quantitative analysis methods were used to analyze of data using by SPSS 16.0. The scoring scheme indicated by Haidar and Abraham (1991) was adapted in this study. The original version of this scheme was explained by Piaget. Piaget classified children's understanding into three categories: no understanding, partial understanding, and sound understanding, and previous researchers have added more categories. According to this scheme, answers of the multiple-choice items were classified as correct (3 points), incorrect (0 points) and blank answer (0 points). Responses to the open-ended items were categorized as correct (3 points), partially correct (2 points), incorrect (1 point) and no response (0 points). Each of the answers was evaluated by the researchers and the scores were compared and discussed until an agreement was reached.

The paired sample t-test was used to compare students' pre- and post-test scores. The test analysis showed that there was no statistically significant difference between the mean scores of the experimental and the control groups according to ($t = -44,30$, $p > .05$) the pre-test. The mean scores of the experimental group and control were 24.31 (SD=10.12) and 22.23 (SD=8.66), respectively. According to the results from the pre-test, students from each group had misconceptions about electromagnetic field and magnetism subjects. Student's paired sample t-test was also used to compare post-test scores of the groups after IUVIRLAB application. Each of the students' answers to the concept test was evaluated by researchers. Post-test mean scores, after either the IUVIRLAB or traditional instruction on subject matters, were found to be 90.73 (SD=7.31) in the experimental and 65.08 (SD=13.83) in the control groups ($t = -21.64$, $p<.05$) (Table 1). The results from the paired sample t-test indicated that the students who were instructed using IUVIRLAB had significantly higher scores in terms of achievement than those taught by the traditional approach. According to the results, it was also found that IUVIRLAB learning group was more successful in preventing of the determined misconceptions.

Comparison of experimental and control groups according to paired sample t-test results magnetism subjects (Table 2). These misconceptions were not seen as much and some of these misconceptions were not detected in the post-test where the IUVIRLAB virtual physics laboratory was applied.

Table 1. Comparison of experimental and control groups according to paired sample t-test results

	Experimental Group (N=60)		Control Group (N=60)		Paired samples t-test		
Groups	Mean	SD	Mean	SD	t	SD	p
Pre-Test	24,31	10,12	22,23	8,66	-44,30	59	.229
Post-Test	90,73	7,31	65,08	13,83	-21,64		.000*

Undergraduate students' answers to the MFCT underlined that they could not understand the concepts of magnets, magnetic fields, magnetic poles, charged particles in a magnetic field, magnetic fields of a wire, Biot-Savart and Coulomb laws, magnetic fields of the earth, magnetism properties of matter, magnetic field effects of electric currents or magnetic field applications in daily life correctly (Table 2).

Table 2. Percentages of students' misconceptions determined at the pre-test and post-tests in experimental and control groups.

Students' Misconceptions	Control Group (N=60)		Experimental Group (N=60)	
	Pre-Test (%)	Post-Test (%)	Pre-Test (%)	Post-Test (%)
1. Magnetic poles can be separated from each other, when the magnetic poles of the magnet are separated into two parts, like electrical loads.	58.0	42.0	53.0	12.0
2. If the distance between two magnetic poles is large, the interaction gets higher.	51.0	44.0	62.0	18.4
3. There is only a repulsive effect between two magnetic poles.	55.2	39.2	47.0	16.7
4. The force between two magnetic poles shows the same characteristics as the force between two electrical charges.	76.4	48	44.3	7.3
5. If a non-magnetic piece of iron is placed close to a strong magnet without touching, it does not show magnetic property.	37.0	26.6	38.6	5.3
6. If a non-magnetic piece of iron rubs on a magnet, it does not show magnetic property.	51.0	44	42.6	14.6
7. The strength of the magnetic force is not proportional to the particle's speed and load.	73.0	34.3	56.7	15.2
8. Electric field is perpendicular to the electric force, while magnetic force is parallel to the magnetic field.	71.4	38.0	71.0	16.8
9. If a proton and an electron interact with each other, it is required to show the magnetic properties of matter.	38.0	18.4	45.8	8.2
10. Magnetism does not occur with spins of a neutron, proton and other particles. It just depends on the electron's spin.	52.7	24.0	58.1	24.8
11. Steel is a metal-metal alloy and it does not include magnetic properties.	57.1	42.8	36.4	13.4
12. Mobile phones emit radiation, indeed this radiation is a magnetic field.	41.3	20.0	45.6	21.7
13. X-ray devices and mobile phones just have radiation. There is no magnetic field.	72.1	62.8	37.6	6.8
14. The magnetic field does not change according to	68.4	54.5	65.4	13.9

	shape of the conductor.				
15.	Harmful magnetic fields generate radiation.	62.0	34.2	54.8	18.5
16.	Magnetic field, is divided into two as "useful" and "harmful" according to its strength.	45.7	19.2	57.2	12.4
17.	All metals are affected by the magnetic field.	56.3	32.0	57.2	14.7
18.	A magnetic field is caused by electromagnetic waves.	51.0	28.4	46.8	18.5
19.	The magnetic field lines in different directions pull each other, while the magnetic field lines in the same way directions push each other.	68.5	42.1	57.0	4.7
20.	Two wires conducting in the same direction current pull each other.	73.2	65.0	56.3	16.4
21.	Two wires conducting in opposite direction current attract each other	62.0	45.2	27.9	4.0
22.	Magnitude of the magnetic force does not depend on the velocity of the charged particle	73.2	67.5	62.3	16.8
23.	The magnetic force acts as a positive charge in the same direction as the magnetic force acting as a negative charge	34.6	24.0	26.7	6.2
24.	Right-hand rules	45.8	20.0	46.9	11.5

For instance, students had the opinion that “mobile phones emit radiation, indeed this radiation is a magnetic field” at high rates. When undergraduates’ answers to the second-tier part were analyzed, the reasons for these misconceptions were identified. From the paired sample test results it was seen that students had huge misconceptions about electromagnetic field and magnetism concepts but these misconceptions’ rates decreased after IUVIRLAB virtual physics laboratory instruction. For instance, students had the opinion that “mobile phones emit radiation, indeed this radiation is a magnetic field” at high rates. When undergraduates’ answers to the second-tier part were analyzed, the reasons for these misconceptions were identified. From the paired sample test results it was seen that students had huge misconceptions about electromagnetic field and magnetism concepts but these misconceptions’ rates decreased after IUVIRLAB virtual physics laboratory instruction.

4. Conclusion

The aim of this study was to investigate the effectiveness of IUVIRLAB - magnetic field and magnetism experiments instruction on undergraduate students’ understanding of electromagnetic field and magnetism concepts. For this purpose, student’s misconceptions about electromagnetic fields and magnetism were determined using the MFCT test. The MFCT test was applied to 120 students as a pre- and post-test and the survey which was developed in order to determine the views of students about IUVIRLAB virtual physics laboratory application was applied as a post-test.

According to the results from the pre-test, students from each group had huge misconceptions about electromagnetic field and magnetism subjects. The post-test results indicated that the students who were instructed using the IUVIRLAB virtual physics laboratory had significantly higher scores than the pre-test scores and IUVIRLAB virtual physics laboratory instruction was successful in preventing the determined misconceptions.

In terms of using the internet for conducting searches, statistically significant differences were determined in the Communication Skills Inventory, and its Emotional subdimension. The points scored from the whole scale and the emotional and behavioral subscales by the participants who stated that they do use the internet for conducting searches were found out to be significantly higher than the points scored by other participants.

In the later phases of this pilot study, the applications of this system on physics, chemistry and biology experiments generated within the scope of the study are foreseen. Further application of the IUVIRLAB will be used in order to analyze students’ ability to construct concepts correctly and making relationships between physics and daily life and their critical thinking, problem-solving skills. In practice, it is estimated that this virtual laboratory will increase students' success levels, enable them to correctly structure concepts and enhance their critical thinking and problem-solving skills, as well as their capability to associate physics with their daily lives. These results are usage of virtual laboratory supported by usage of virtual laboratory studies; allowing virtual experiments to be undertaken, could help students to achieve the skills within two of these priority areas. Virtual experiments could potentially allow students to improve their skills in deductive reasoning, hypothesis formation and testing as effectively as through real experiments. Skills in recording, reporting and interpreting data could also be effectively developed through these virtual tasks and also observed that observed that the interest of students increased they learned scientific concepts and events better (Trindade, Fiolhais and Almeida 2002; Galgarno, Bishop and Bedgood 2003; Shim, Park, Kim, Kim, Park, and Ryu 2003). It is believed that the present study, together with any similar studies to be conducted, will contribute to rectifying the deficiencies of experimental applications in online education around the world.

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