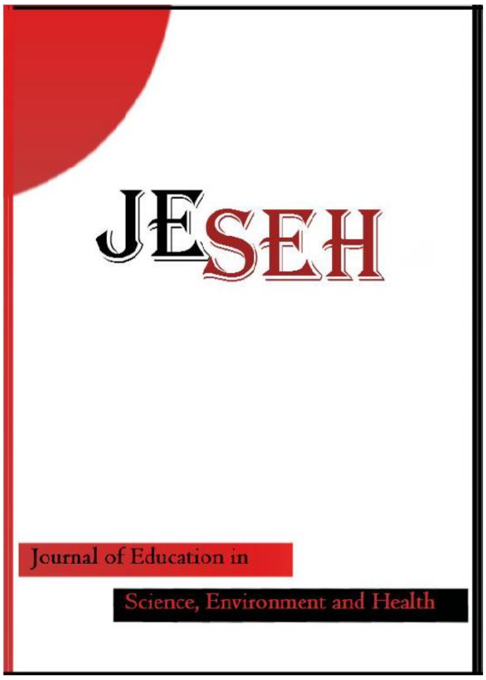

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Abstract

This study investigated the effect of using (VL) on grade 10 students' conceptual understanding of the direct current electric circuit and their attitudes towards physics. The research used a quantitative experimental approach. The sample of the study was formed of 50 students of the tenth grade, aged 14 to 16 years old, of an official secondary school in Mount Lebanon. Participants were randomly assigned into two groups of 25 students each. The experimental group was taught using VL, where experimental activities were conducted through Circuit Construction Kit developed by the PhET simulations. However, the control group was taught through interactive demonstrations using real laboratory equipment. Both groups were pre and post-tested by means of two instruments: "Determining and Interpreting Resistive Electric current Concepts test" (DIRECT) and "Physics Attitude Scale" (PAS). The data analysis of the DIRECT test scores showed that, after 10 weeks, the conceptual understanding of the direct current electric circuit had markedly improved in both groups. However, the mean score of the experimental group was significantly higher than that of the control group. On the other hand, there was no significant difference in students' attitudes towards physics between the two groups.

Introduction

Physics is the science of experimental evidence, criticism, and rational discussion where knowledge and understanding of its concepts depends on the perception of the physical phenomena. Among many researchers in Physics education, Halloun and Hestenes (1985) and McDermott (2001) have shown the ineffectiveness of traditional instructional methods, and shed the light on the lack of understanding science content and processes when students were subjected to conventional teaching of lecture and demonstrations. Resorting to laboratory experiments is one of the main efficient means to make the comprehension of difficult theories simpler and clearer (McDermott, 2001). Meaningful learning, can be achieved when laboratory activities become an integral part of the science curriculum (NSTA, 2007). According to Onyesolu (2009) learning science has been restrained by the deficiency or inadequacy of laboratory equipment in schools. From this standpoint, there is a need for a new unconventional alternative laboratory environment where students can conduct the different required experiments at any time and in safe conditions. One of the solutions that may help in overcoming these obstacles can be the use of virtual laboratories. According to Halloun (1996) resorting to progressively sophisticated software endorses a constructivist approach to learning. Pedagogical principles of inquiry-based learning, exploration, and genuine activities in science support the use of technology in an attempt to provide basic instruction mainly due to the increasing importance of enhancing students' motivation and engagement in science instruction. Virtual laboratories offer students the opportunity to achieve the learning objectives, while overcoming the aforementioned constraints. Virtual laboratories have therefore arisen in schools and universities as being powerful efficient tools that may offer wide-range alternatives as learning environments that attract students' interests and may be a great incentive to them (Onyesolu, 2009).

In Lebanon, the Center for Educational Research and Development (CERD), established and categorized competencies that must be developed in science into four domains: Using acquired knowledge, practicing scientific reasoning, mastering experimental techniques, and mastering communication techniques (CERD, 1995). The experimental techniques depend extremely on laboratory work and experiments that unfortunately are not used in most Lebanese schools, particularly the public ones, due to a number of barriers (Zgheib, 2013). As a physics teacher for secondary classes in Lebanon since 2008, the first researcher has tried to resort to laboratory experiments in her teaching approach. However, she was able to realize only few experiments due to the lack of laboratory equipment on one side and the inexpertness of students on the other. Some of the main problems she has encountered during her experience in the secondary teaching were: The insufficiency or absence of laboratory facilities; the time factor in planning and performing experiments; and the inability to keep tracking of students' performance during the activities. Based on this approach, and in order to solve the problems faced, experiments were conducted by replacing the real lab with a virtual lab. According to Aldrich (2005) virtual labs help students conduct experiments and explore phenomena that cannot be conducted in traditional laboratory surroundings, either because it is not feasible or because of the unavailability of essential laboratory equipment.

Virtual Laboratories

Virtual laboratories provide simulated versions of traditional laboratories referring to a learner-centered approach in which the learner is provided with objects that are virtual representations of real objects used in traditional laboratories. Virtual laboratories may contribute to teaching and learning processes by giving students the opportunity to learn by doing, providing them with intriguing and enjoyable activities urging them to discover, and guaranteeing an active classroom interaction by means of discussions and debates (Lkhagva, Ulambayar, & Enkhtsetseg, 2012). The use of virtual laboratories can offer students the opportunity to investigate situations that cannot be tested in real time by speeding up or slowing down time (Aldrich, 2005). They are also beneficial to study advanced concepts such as relativity and experimentation that would not be studied or realized in traditional laboratory settings (Aldrich, 2005, Reese, 2013, Scheckler, 2003). Virtual laboratories offer a visual context for numerous abstract concepts and provide notable visualization and graphical analysis abilities (Wieman & Perkins, 2005).

Virtual lab instruments are used to save space and time. They can be more easily assembled and more properly used than real laboratory equipment, and therefore are more time efficient than traditional hands-on laboratories (Reese, 2013). They may resolve the problem of crowded groups and help the non-visual or auditory learners to interact with their learning environment (Mestre, 2006). In addition, they are cost effective since up-to-date lab equipment and supplies, in addition to their shortage, can have high operational cost in traditional laboratories (Ma & Nickerson, 2006). Dangerous experiments can be safely conducted through virtual laboratories (Scheckler, 2003). Despite all advantages, some researchers highlighted certain disadvantages such the lack of students' hands-on approach, the lack of lab partner which may facilitate peer-learning (Scheckler, 2003).

Review of Research Comparing Virtual and Traditional Laboratories

The latest modifications and progresses in educational delivery, especially in the field of technology have raised many questions concerning the effectiveness of the virtual laboratory as an instructional tool. One of the studies done in Lebanon in this domain is the one done by Zoubeir (2000). The researcher explored the impact of a constructivist approach through the use of computer projected simulations and interactive engagement approaches. The analysis of the data collected showed an improvement in the conceptual understanding of Newtonian mechanics exclusively in the experimental group that taught with the use of projected simulations. However, the research did not find a statistically significant difference between the two groups neither in students' views about physics, nor in their performances in the exams (Zoubeir, 2000).

Ma and Nickerson (2006) accomplished a literature review, of 20 articles, regarding comparative usefulness and perceptions of simulated, remote, as well as hands-on laboratories. The findings revealed that educators could not consent on the efficiency of each lab type in comparison to one another, claiming that each study had different educational outcomes and instruments/methods to measure the effectiveness. Finkelstein et al. (2006) compared the usage of PhET simulations with the usage of traditional educational resources in all the settings of teaching introductory college physics including laboratory, lecture, recitation and informal settings. They demonstrated the utility of PhET simulations in a wide array of environments in teaching undergraduate physics, and concluded that under favorable conditions those simulations could be as profitable and even more, than the traditional educational tools including textbooks, live demonstrations, and even real equipment. To document the efficiency of the use of a computer simulation, specifically the (CCK) developed by the PhET, Keller, Finkelstein, Perkins, and Pollock (2007) made a comparison between students viewing CCK and those viewing a traditional demonstration during Peer Instruction. Results showed that students viewing CCK presented a larger relative gain in conceptual understanding measures in comparison with traditional demonstrations. In a study conducted by Tüysüz (2010) on 341 chemistry students from the high school level, the influence of virtual lab on the students' achievements and attitudes were investigated. Results showed that students' attitudes towards chemistry have varied according to teaching methods used in the study, and that virtual laboratory practice had a positive influence on students' achievements and their attitudes toward chemistry when compared to traditional instruction method. Tüysüz (2010) argued that using computer in science teaching is appropriate and convenient, particularly when the content is well employed.

Similarly, Bozkurt and Ilik, carried out a research on 152 physics students at the University level aiming to assess the influence of the use of interactive computer simulations in teaching on students' achievements and beliefs about physics. For this aim, lessons were taught according to traditional instruction methods for the control group and resorting to computer simulations prepared by PhET for the experimental group. Students were subjected to a pre and post success test, as well as a 5-point Likert scale test (CLASS) used to identify their beliefs on physics and learning physics. The results showed enhancements in the students' beliefs before and after the treatment. In addition, it was noticed that groups who studied by means of computer simulations had better achievements than those who learned through traditional methods (Bozkurt & Ilik, 2010).

Shegog et al. (2012) conducted a randomized clinical control design study on a sample of 44 students from two high schools to evaluate the skills and knowledge about the molecular labs processes as well as students' attitudes towards science and computers by using HEADS UP Virtual Molecular Biology Lab as an instructional tool. The Virtual Lab was found to lead to a significant development in students' knowledge with time; however, the researcher did not notice any significant differences in science attitude scores. Similar results were found by Tsihouridis et al. (2014) who conducted a study in which students were able to use both real and virtual lab according to their educational needs. The results showed that the use of the virtual lab, as a mobile School-Lab, during teaching considerably enhanced the students' conceptual understanding of certain physics concepts. Recently, Brinson (2015) presented a review 56 articles published in and after 2005 that emphasized on comparing learning achievements by using traditional and non-traditional lab participants as experimental groups. Results proposed that most of the reviewed studies (n=50, 89%) have shown that student learning outcomes were equal or higher in "Non-traditional Lab" in comparison with "Traditional Lab" concerning all learning outcome types (knowledge and understanding, practical skills, inquiry skills, perception, analytical skills, as well as social and scientific communication).

In contrast, Quinn, King, Roberts, Carey, and Mousley (2009) found that students in some conditions could reach a better understanding of topics after hands-on laboratories, when compared to virtual labs. They concluded that it was due to the fast distraction of students while working with simulations, whereas in hands-on laboratories, students were able to maintain focus throughout their involvement. Similarly, specialized establishments for science education, like the National Science Teachers Association, emphasized the roles of hands-on activities in improving students' interest and acquisition of science skills (NSTA, 2007).

Tsihouridis, Vavougios, and Ioannidis (2013) compared the effectiveness of virtual lab and real school-labs in teaching electric circuits at Upper High-School. The analysis of the collected data showed that there was no significant difference between the two groups in their conceptual understanding of the basic concepts of electric circuits. However, some individual non-significant differences in favor of the real-lab group were observed in the 3 out of 12 teaching objectives. These results led to the conclusion that the two teaching approaches used would decisively help students to develop an investigative attitude relating to everything scientific, their cooperative skills, and their ability to express important queries with clarity and precision.

The unison of the two types of lab was tested by Zacharia (2007) who examined the worth of joining real and virtual lab experiments concerning the modification in students' conceptual understanding of electric circuits' concepts; the researcher discovered that this arrangement improved students' conceptual understanding more than the use of real lab experiments solely. Supporting the same standpoint, the American Chemical Society (ACS) stated in 2011 that computer simulations mimicking laboratory processes are likely to be valuable supplements to student hands-on activities, but could not substitute them (ACS, 2011). Tsihouridis et al. (2015) investigated the effect of the use of real and virtual lab in changing order in the teaching of the electric circuit concepts for third year high school learners. The results revealed that the order of the real and the virtual lab in the teaching process affected the understanding of the scientific concepts related to electric circuits. Tsihouridis, Vavougios, and Ioannidis (2016) found that the cyclical process of virtual and real lab, without seeming to be a straight repetition, maintained learners' interest by enhancing their critical thinking and improving the learning process.

The review of literature lacks important studies on Arabic students in general and on Lebanese ones in particular, except those done by Zgheib (2013) and Zoubeir (2000). Lebanese students rarely used the virtual lab and the new technology in their learning process due to many barriers (Zgheib, 2013). This study was conducted on Lebanese secondary school students to investigate the effect of virtual physics labs on Lebanese learners.

Purpose of the Study

Based on the above**,** this study aimed to investigate the effect of using virtual laboratory on grade 10 students' conceptual understanding of the direct current electric circuit and their attitudes towards physics in terms of students' confidence, beliefs, and teacher perception.

Research Questions

By choosing the teaching method as an independent variable, and by choosing the students' conceptual understanding and their attitudes towards physics as dependent variables, the following questions were raised:

1) Does the use of virtual laboratory affect the conceptual understanding of the direct current electric circuit of grade 10 students?
   1.1) Is there any significant difference in students' conceptual understanding as measured by the pre and post-test scores before and after the implementation of virtual laboratory?
   1.2) Is there any significant difference in students' conceptual understanding of direct current electric circuit as measured by the pre and post-test scores before and after the implementation of the interactive demonstrations using real laboratory equipment?
   1.3) Is there any significant difference in students' conceptual understanding, as measured by the post-test scores, between the group performing experiments using virtual laboratory and the other group taught by interactive demonstrations using real laboratory equipment?
2) Does the use of virtual laboratory produce positive attitudes towards Physics?
   2.1) Does the use of virtual laboratory enhance the students' confidence to learn and to perform well on physics tasks?
   2.2) Does the use of virtual laboratory affect the students' beliefs about the usefulness of physics and its relation to their future education?
   2.3) Does the use of virtual laboratory enhance students' perception of their teachers' attitudes towards them, as learners?

Method

Design

This study used a quantitative experimental pre-test versus post-test control-group design (table 1) in which students were randomly assigned into experimental and control group. The two groups were pre-tested on the dependent variables before the implementation of the study and then post-tested after the treatment has been administered.

Table 1. The experimental design of the study

Control group	O_1	O_2	T_1	O_3	O_4
Experimental group	O_1	O_2	T_2	O_3	O_4

Variables

In this study, the independent variable was the teaching method (virtual lab versus interactive demonstrations using real lab equipment). The dependent variables were the students' conceptual understanding of the direct current electric circuit and their attitudes towards physics.

Sample

The sample of this study consisted of 50 students of grade 10 from the English department of a public secondary school in Mount-Lebanon, during the academic year 2015-2016. Among the participants of this study, 26 were females and 24 were males. The sample was randomly assigned, using random number generator from SPSS statistical software, into experimental group "A" and control group "B", of 25 students each (Table 2).

Table 2. Characteristics of the participants

Group	Total	Experimental group A	Control group B
Number of students	50	25	25
Age average	15 years 4 months	15 years 6 months	15 years 3 months
Average of the previous year grades in physics	12.5	12.25	12.75
Standard deviation of the previous year grades in Physics	4.725	4.95	4.5

Data Collection Instruments

The instruments used in this research included an electricity conceptual understanding test "Determining and Interpreting Resistive Electric circuits Concepts Test" (DIRECT) and the Physics Attitude Scale (PAS).

Determining and Interpreting Resistive Electric Circuits Concepts Test (DIRECT version 1.0)

DIRECT is a diagnostic test developed by Paula Vetter Engelhardt (Engelhardt & Beichner, 2004). This test was used as pre-test and post-test in order to assess students' conceptual understanding and to compare the efficiency of virtual lab and interactive demonstrations using real lab equipment. The test is based on 11 objectives as appears in table 3. For the purpose of this research, and because two of the objectives were beyond the scope of grade 10's physics curriculum, only nine objectives were taken into consideration. The eliminated objectives were covered by four questions, which implied the omission of these questions from the test. However, this omission did not affect the validity of the test as these questions only covered the eliminated objectives and did not integrate with other objectives of the instrument. Moreover, one of the concepts that objective nine deals with is the electric field that is beyond the scope of grade 10 physics' curriculum. Therefore, the question related to electric field concept was eliminated. Hence, only 24 questions were used from this test. To test the reliability of the test after eliminating the five questions, the researcher used Kuder- Richardson formula 20. The established reliability was 0.702. To test the content validity and to ensure that the test actually measures what is intended to measure, the researcher presented the test and the corresponding objectives to two physics teachers having long experiences in the secondary teaching. They asserted that the test was valid and adequate to grade 10 physics' curriculum.

The Physics Attitude Scale (PAS)

To measure students' attitude, an attitude scale was adapted from the modified Fennema-Sherman attitude scale (Doepken, Lawsky & Padwa, n.d.). PAS was used in this study to evaluate students' attitude towards physics. Participants had to answer these statements on a 5-point Likert scale. The original test included four subscales: a confidence scale, a usefulness scale, a scale measuring physics as a male domain, and a teacher perception scale (Doepken et al., n.d.). For the purposes of this study, gender-related questions were eliminated, so the used PAS included 36 questions and three subscales of 12 questions each. The items in each of the scales were divided equally between statements that measure positive and negative attitude. The confidence scale (Co) measured self-confidence to learn and to achieve well on physics tasks. The usefulness scale (U) measured beliefs about the usefulness of physics and its relationship to students' future education. Finally, the teacher perception scale (T) measured students' perception of their teachers' attitudes towards them as learners. Items of the three scales were randomly arranged in the test (Doepken et al., n.d.). The maximum possible score on each subscale was 60 (Doepken et al., n.d.). Thus, the maximum total score that could be achieved on the PAS was 180. The reliability and validity of the physics attitude scale were established by the developer and many other investigators. The researcher recalculated the reliability (Alpha coefficient) of the 36 items of PAS that was found to be 0.981.

Table 3. The objectives of the direct test used

Objectives:
Physical Aspects of DC electric circuits (objectives 1-5):
1) Identify and explain a short circuit (more current follows the path of lesser resistance). 2) Understand the functional two-endedness of circuit elements (elements have two possible points with which to make a connection). 3) Identify a complete circuit and understand the necessity of a complete circuit for current to flow in the steady state (some charges are in motion but their velocities at any location are not changing and there is no accumulation of excess charge anywhere in the circuit).
Objectives 1-3 combined
4) Apply the concept of resistance (the hindrance to the flow of charges in a circuit) including that resistance is a property of the object (geometry of object and type of material with which the object is composed) and that in series the resistance increases as more elements are added and in parallel the resistance decreases as more elements are added. 5) Interpret pictures and diagrams of a variety of circuits including series, parallel, and combinations of the two.
Circuit layout (objectives 1-3, 5)
Current (objectives 6-7)
6) Understand and apply conservation of current (conservation of charge in the steady state) to a variety of circuits. 7) Explain the microscopic aspects of current flow in a circuit through the use of electrostatic terms such as electric field, potential differences, and the interaction of forces on charged particles.
Potential difference (Voltage) (objectives 8-9)
8) Apply the knowledge that the amount of current is influenced by the potential difference maintained by the battery and resistance in the circuit. 9) Apply the concept of potential difference to a variety of circuits including the knowledge that the potential difference in a series circuit sums while in a parallel circuit it remains the same.
Current and voltage (objectives 6 and 9)
Energy (Eliminated objectives)
▪ Apply the concept of power (work done per unit time) to a variety of circuits.
▪ Apply a conceptual understanding of conservation of energy including Kirchhoff's loop rule (V=0 around a closed loop) and the battery as a source of energy.

Procedures

To achieve the goal of this research, the sample was randomly assigned into two equal groups of 25 students each. Group "A" was chosen to be the experimental group while Group "B" was chosen to be the control group. The first researcher taught both groups the same content over 10 weeks for three periods per week, of 55 minutes each. The two classes were videotaped, and a randomly selected sample of the videotapes was observed to insure authenticity of the treatment, and to make sure the teacher was implementing the activities as described in the lesson plans. At the beginning of the academic year 2015-2016, each student of each of the two groups completed as pre-tests the DIRECT and the PAS, during 40 minutes and 20 minutes respectively, to investigate their conceptual understanding and attitudes towards physics before the research started. A computer training session was conducted for all students of the experimental group during one period of 55 minutes in which the teacher introduced the PhET simulation software, which will be discussed in the next paragraph, and directed students to some sample laboratory activities.

Both control and experimental groups were taught using structured inquiry activities where both problem matters and procedures were presented. Each two students of the experimental group performed in a virtual laboratory environment, using PhET simulations, a series of experimental activities that were compatible with the curriculum objectives and the DIRECT test objectives. Based on the objectives of the taught chapters, six experiments were conducted in chapter two, four experiments in chapter three, and four experiments in chapter four. For the control group "B", the teacher conducted interactive demonstrations of the same experiments in traditional laboratory settings using real equipment. To carry out the required experiment in the control group, the researcher provided some of the unavailable equipment needed to conduct the experiments. The lack of laboratory equipment from one side and the students' skills from the other side and many other reasons aforementioned in the rationale of this study obliged the teacher to carry out the experiments by herself. Finally, at the beginning of April, the researcher realized the post-tests. Students of both groups were retested, for 40 minutes, using the same DIRECT test. Also, both groups recompleted, during 20 minutes, the same PAS questionnaire.

PhET Simulation

Physics Education Technology (PhET), are one example of the virtual laboratories' software and was established by the University of Colorado that covered the curriculum of introductory physics. All simulations are gratis, and can be accessed online or by downloading for off-line use (Finkelstein et al., 2006). PhET simulations create a highly-interactive atmosphere when it comes to user control, active feedback, and use of multiple representations (Podolefsky, Perkins, & Adams, 2010). The simulations are scientifically accurate, and offer highly illustrative, dynamic representations of principles of physics. At the same time, these simulations play a role in building links between students' daily understanding of the real world and the underlying principles of physics, by making clear the physical models (Finkelstein et al., 2006). They also offer balanced challenges and embedded puzzles that are achievable according to the level of student, thus promoting students' inquiry (Podolefsky et al., 2010). One of the PhET simulations is the Circuit Construction Kit (CCK). Perkins et al (2006) asserted that the use of the CCK may enable students to carry out experimentations in a similar way to real laboratories. Electric components have default parameters that can be regulated by the user to see the simultaneous changes produced. The CCK simulation's model is based on Kirchhoff's laws to accurately describe current and voltage in direct current circuits (Perkins et al., 2006). One of CCK's most noticeable features is its explicit and clear visual illustration of current flow, which is symbolized by small blue spheres that model the behaviour of electrons. This visual model for current may allow the user to visualize and understand how current flows in a circuit just like experts think about the current flow (Perkins et al., 2006). Upon the features discussed above, the researcher used the PhET simulation to perform experiments in virtual laboratory. Special, CCK was used in this study to perform virtual experiments.

Results and Discussion

Results Related to Research Question One

To answer the first research question, an independent T-test was conducted on the pre-test scores of DIRECT. The results of table 4 showed that there was no significant difference between the mean scores of the two groups ($p = 0.750$), revealing that the two groups do not differentiate at the beginning of the study. To test whether the contribution of virtual lab and interactive demonstrations using real lab equipment produces a conceptual understanding of the direct current electric circuit of grade 10 students, a comparison between the pre and the post-test score was done each group. Figure 1 displays the mean scores for each group (A and B) on the pre-test and the post-test, as well as the improvement score. In addition, the researcher conducted a paired T-test to compare the pre and the post-test scores of both groups. Table 5 shows that there was a significant difference in the scores of pre and post-test for the control group ($p = 0.000$) and for the experimental group ($p = 0.000$).

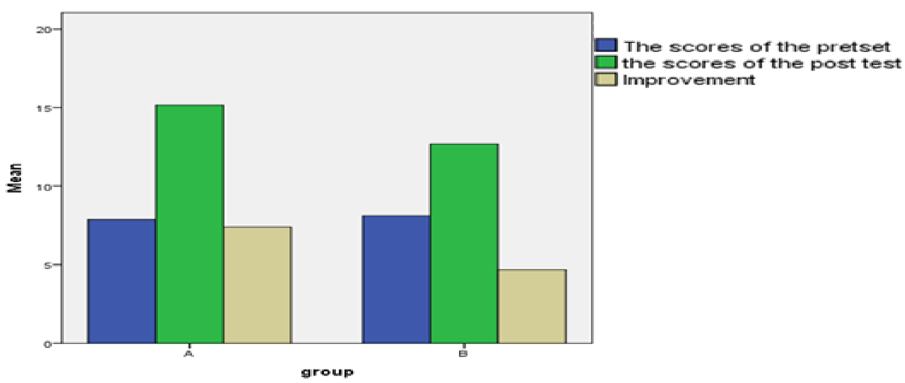

Figure 1. Mean scores of pre and post DIRECT test

Table 4. Independent samples t-test comparing DIRECT pre-test scores

		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	95% Confidence Interval of the Difference	
									Lower	Upper
The scores of the pre-test	Equal variances assumed	1.048	.311	-.321-	48	*.750*	-.240-	.748	-1.743-	1.263
	Equal variances not assumed			-.321-	46.605	.750	-.240-	.748	-1.744-	1.264

Table 5. Paired t-test conducted on DIRECT pre and post-test

		Paired Differences					t	Df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	The scores of the experimental group "A" on the pre-test - The scores of the experimental group "A" on the post-test	-7.280-	4.067	.813	-8.959-	-5.601-	*-8.949-*	24	*.000***
Pair 2	The scores of the control group "B" on the pre-test - The scores of the control group "B" on the post-test	-4.560-	3.874	.775	-6.159-	-2.961-	*-5.886-*	24	*.000***

In the aim to compare the conceptual understanding of the direct current electric circuit of the students in the control group to that in the experimental group, the researcher conducted, an independent T-test on the scores of the DIRECT post-test. A significant difference was found between the scores of the two groups (p = 0.031) as appear in table 6.

Table 6. Independent samples t-test comparing groups' DIRECT post-test scores

		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	95% Confidence Interval of the Difference	
									Lower	Upper
the score of the post-test	Equal variances assumed	.340	.563	*2.217*	48	*.031**	2.480	1.119	.231	4.729
	Equal variances not assumed			2.217	47.934	.031*	2.480	1.119	.231	4.729

*. Significant at the 0.05 level (2-tailed).

Further analysis on the scores of each objective was done. The score of each objective was calculated as the sum of the scores of the questions that covered it. The result of the independent T-test conducted on the scores of the objectives of the DIRECT post-test (Table 7), showed that there was a significant difference between the two groups only on the scores of the objective 7 (p = 0.001) and the scores of objective 8 (p = 0.014).

Table 7. Independent samples t-test comparing DIRECT objectives post-test scores

		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	95% Confidence Interval of the Difference	
									Lower	Upper
the score of the objective 1	Equal variances assumed	12.473	.001	.755	48	.454	.160	.212	-.266-	.586
	Equal variances not assumed			.755	32.116	.456	.160	.212	-.272-	.592
the score of the objective 2 & 3	Equal variances assumed	1.282	.263	.000	48	1.000	.000	.165	-.332-	.332
	Equal variances not assumed			.000	45.280	1.000	.000	.165	-.332-	.332
the score of the objectives 1 & 3 combined	Equal variances assumed	.000	1.000	.000	48	1.000	.000	.123	-.248-	.248
	Equal variances not assumed			.000	48.000	1.000	.000	.123	-.248-	.248
the score of the objective 4	Equal variances assumed	.193	.663	.894	48	.376	.240	.269	-.300-	.780
	Equal variances not assumed			.894	47.996	.376	.240	.269	-.300-	.780
the score of the objective 5	Equal variances assumed	2.912	.094	.491	48	.626	.120	.244	-.371-	.611
	Equal variances not assumed			.491	47.362	.626	.120	.244	-.372-	.612
the score of the objective 6	Equal variances assumed	3.646	.062	.687	48	.496	.120	.175	-.231-	.471
	Equal variances not assumed			.687	45.382	.496	.120	.175	-.232-	.472
the score of the objective 7	Equal variances assumed	2.395	.128	3.494	48	*.001***	.680	.195	.289	1.071
	Equal variances not assumed			3.494	44.471	*.001***	.680	.195	.288	1.072
the score of the objective 8	Equal variances assumed	.020	.889	2.558	48	*.014**	.680	.266	.146	1.214
	Equal variances not assumed			2.558	47.956	*.014**	.680	.266	.145	1.215
the score of the objective 9	Equal variances assumed	.860	.358	1.155	48	.254	.400	.346	-.297-	1.097
	Equal variances not assumed			1.155	47.852	.254	.400	.346	-.297-	1.097
the score of the objectives 6 & 9 combined	Equal variances assumed	1.137	.292	.568	48	.573	.080	.141	-.203-	.363
	Equal variances not assumed			.568	47.946	.573	.080	.141	-.203-	.363

*. Significant at the 0.05 level (2-tailed).
**. Significant at the 0.01 level (2-tailed).

Results Related to Research Question Two

First, an independent T-test was conducted to compare the PAS pre-test total scores and scores of the subscales, for the two groups. The results of the total score (p = 0.720), the confidence subscale score p = 0.879, the usefulness subscale score (p = 0.911), and the teacher perception subscale score (p = 0.409) did not present any significant difference between the two groups as shown in table 8. These results revealed that the two groups did not differentiate regarding the attitude before the implementation of the study.

In the aim of investigating whether the contribution of each teaching method (virtual lab versus interactive demonstrations using real lab) produced a better positive attitude towards physics, the researcher compared the means of the total score of PAS as well as the score of each of its subscales, before and after the implementation of the study, for both control and experimental group. Figure 2 displays, for each of the two groups, the mean of the total score of PAS of the pre-test and the post-test as well as the mean score of each subscale. Comparing the pre and the post-test scores of PAS, the result of the paired T-test (table 9) for the experimental group (p = 0.000) presented a significant difference. However, no significant difference was presented for the control group (p=0.238).

Table 8. Comparison between PAS and its subscales pre-test scores

		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	95% Confidence Interval of the Difference	
									Lower	Upper
the score of the pre-test	Equal variances assumed	1.124	.294	-.361-	48	.720	-1.920-	5.319	-12.614-	8.774
	Equal variances not assumed			-.361-	45.079	.720	-1.920-	5.319	-12.632-	8.792
the total of subscale *Co*	Equal variances assumed	1.699	.199	-.153-	48	.879	-.400-	2.610	-5.649-	4.849
	Equal variances not assumed			-.153-	46.561	.879	-.400-	2.610	-5.653-	4.853
the total of subscale *U*	Equal variances assumed	1.688	.200	-.113-	48	.911	-.240-	2.126	-4.514-	4.034
	Equal variances not assumed			-.113-	44.438	.911	-.240-	2.126	-4.523-	4.043
the total of subscale *T*	Equal variances assumed	.341	.562	-.833-	48	.409	-1.280-	1.537	-4.370-	1.810
	Equal variances not assumed			-.833-	47.933	.409	-1.280-	1.537	-4.370-	1.810

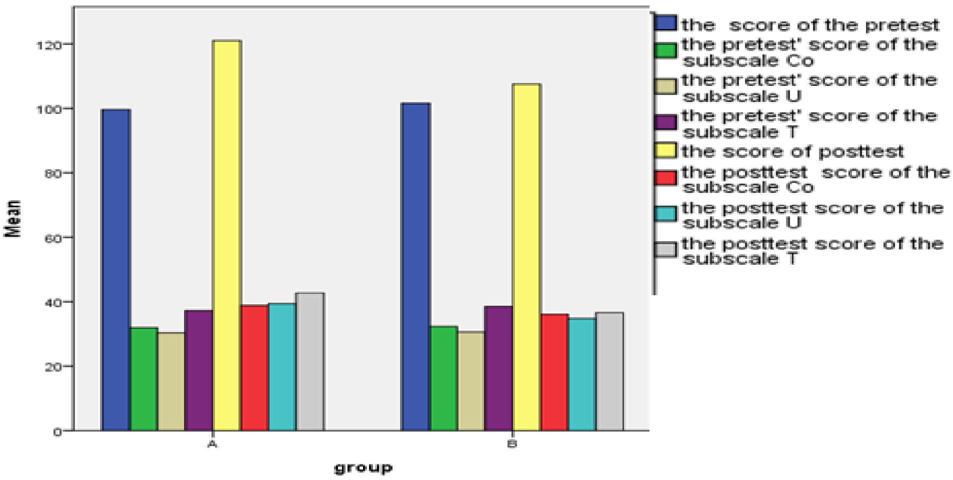

Figure 2. Means of the PAS and each subscale scores

Table 9. Paired t-test conducted on PAS pre and post-test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	the total score of the pre-test of the group A - the total score of the post-test of the group A	-21.360-	23.668	4.734	-31.130-	-11.590-	-4.512-	24	*.000***
Pair 2	the total score of the pre-test of the group B - the total score of the post-test of the group B	-5.920-	24.447	4.889	-16.011-	4.171	-1.211-	24	.238

**. Significant at the 0.01 level (2-tailed).

In order to investigate whether the use of virtual laboratory produced positive attitudes towards Physics, the total scores and the subscales scores of the PAS post-test were analysed. The mean of the experimental group was slightly greater than the mean of the control group as appears in table 10. On the other hand, as shown in table 10, the mean scores of the subscales of the experimental groups were slightly higher than those of the control group. However, as shown in table 11, the result of the independent T-test conducted on the total scores of the PAS post-test did not present significant difference nor regarding students' attitudes towards physics between the two groups, neither regarding the subscales, except in the teacher perception subscale (p = 0.046).

Table 10. Descriptive statistics of the PAS post-test scores

	group	N	Mean	Std. Deviation	Std. Error Mean
the score of the PAS post-test	A	25	121.00	31.278	6.256
	B	25	107.48	34.328	6.866
the score of post-test of the subscale *Co*	A	25	38.88	10.948	2.190
	B	25	36.08	12.430	2.486
the score of post-test of the subscale *U*	A	25	39.40	11.225	2.245
	B	25	34.76	11.837	2.367
the score of post-test of the subscale *T*	A	25	42.72	10.188	2.038
	B	25	36.64	10.743	2.149

Table 11. Comparison between PAS post-test and its subscales scores

		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	95% Confidence Interval of the Difference	
									Lower	Upper
the score of post-test of PAS	Equal variances assumed	.535	.468	1.456	48	.152	13.520	9.288	-5.155-	32.195
	Equal variances not assumed			1.456	47.590	.152	13.520	9.288	-5.159-	32.199
the score of post-test of the subscale *Co*	Equal variances not assumed			1.456	47.590	.152	13.520	9.288	-5.159-	32.199
	Equal variances not assumed			.845	47.247	.402	2.800	3.313	-3.863-	9.463
the score of post-test of the subscale *U*	Equal variances assumed	.161	.690	1.422	48	.161	4.640	3.263	-1.920-	11.200
	Equal variances not assumed			1.422	47.865	.161	4.640	3.263	-1.920-	11.200
the score of post-test of the subscale *T*	Equal variances assumed	.301	.586	2.053	48	*.046**	6.080	2.961	.126	12.034
	Equal variances not assumed			2.053	47.866	*.046**	6.080	2.961	.126	12.034

*. Significant at the 0.05 level (2-tailed).

Discussion

Discussion Related to the First Research Question

Data collected from the DIRECT test were addressed to answer the first research question. The analysis of the DIRECT post-test results showed that students of the experimental group that used the virtual laboratory performed significantly better than those of the control group who were taught through interactive demonstrations using real lab equipment. In spite of the small size of the sample, testing by the DIRECT test showed clearly that the use of virtual laboratory induced a considerable change in students' conceptual understanding of the direct current electric circuit. The significant difference between the two groups appeared mainly in the questions of the objective 7 and the objective 8 that are related to the microscopic aspect of the electric current and the relation between the current, the resistance in the circuit, and the potential difference applied. This result may be due to the property of the Circuit Construction Kit (CCK) simulation of PhET that explicitly explains the microscopic aspect of the direct current. The CCK represents the invisible electrons with blue spheres and shows their supposed motion inside the circuit, and how this motion can be affected with the resistance in the circuit of the potential difference of the source; therefore, it demonstrates how the light of the bulb changes and then how the amount of current changes with the previous mentioned factors. Such visualizations cannot be done by means of traditional real lab (Perkins et al., 2006). Therefore, the importance of virtual laboratories has lied in its ability to introduce the concepts by referring to the microscopic level in contrast to the real lab that only shows the macroscopic properties (Wieman & Perkins, 2005).

The findings of this research affirm the ones of previous studies such as Finkelstein et al. (2006), Shegog et al. (2012), Tüysüz (2010), Tsihouridis, Vavougios, and Ioannidis (2013), and Zoubeir (2000). However, the results of this research are not compatible with some previous researches such as those done by ACS (2011), NSTA (2007), Quinn et al. (2009), Tsihouridis et al. (2014), and Zacharia (2007). The inconsistency in this study's findings with some earlier researches may be due to the type of the concepts taught, type of the virtual laboratory used, the intervention of extraneous variables, the size of the sample, the various designs used, the statistical analysis and many other reasons. Consequently, more researches are needed in this domain.

Discussion Related to the Second Research Question

To assess the effect of the use of virtual laboratory on students' attitude towards physics, data collected from PAS were analysed. Results indicated that attitudes of the experimental group students towards physics significantly improved after the treatment in a general perspective, and in subscales perspective. However, except for the usefulness subscale, there was no significant improvement in the attitudes of the control group students in general, neither in the other two subscales. However, there were no significant differences between the experimental and the control group regarding students' attitudes towards physics. This finding is similar to the results of some studies such as Shegog et al. (2012), and Zoubeir (2000). However, it contradicts the results of the study done by Bozkurt and Ilik (2010), and Tüysüz (2010), where attitudes of students towards chemistry have improved and positively influenced when compared to those of the traditional teaching. The lack of significant difference between the experimental group and the control group regarding students' attitudes towards physics may be due to many reasons. One of these reasons can be attributed to language problems. It may be difficult for non-English speakers to understand the questions of PAS that are related to their confidence to learn physics, to their beliefs about usefulness of physics, and to students' perception of their physics teachers and what their teachers think of the students' physics levels.

Regarding the subscales of PAS, there was no significant difference between the two groups in the confidence and the usefulness subscales. However, in the experimental group, the third subscale that measures the students' perception of their teachers' attitudes towards them as learners was significantly better than that of the control group. This may be due to the previous teaching approaches used in the former classes. Most of the participating students came from public schools that, according to Zgheib (2013), lack the presence of integrated technology system. The use of virtual laboratory might have stimulated the students to realize experiments. Many students conducted at home various un-required experiments and activities, using the various PhET simulations that were installed on their own laptops, and had discussed it in the next day with the teacher who continuously encouraged them to seek new knowledge by all the possible means. Students showed, through this discussion, an enthusiasm to learn and to explore. All this may have affected their perception about the teacher and thus have produced the remarked significant different in the teacher perception subscale.

Conclusion

The analysis of the gathered data clearly presents that after 10 weeks of treatment, students significantly improved in term of conceptual understanding of the direct current electric circuit in both experimental and control groups. Moreover, the mean score of the experimental group students was better and showed some difference compared to that of the control group. Regarding the attitudes towards physics, the collected data did not show any significant difference between the two groups except in the teacher perception subscale. These results led to the conclusion that:

- The use of either teaching method (virtual laboratory or interactive demonstrations using real lab) enhances the conceptual understanding of students.
- The use of virtual laboratory has a better effect than the interactive demonstrations using real lab equipment regarding the conceptual understanding of the direct current electric circuit.
- the use of virtual laboratory does not influence the attitudes more than the real lab does.
- the use of virtual laboratory promotes the students' perception of their teachers' attitudes towards them as learners.

Recommendations

The findings of this study may be a platform for further future researches.

First, three chapters of the electricity unit were the fertile fuel of this study. In order to be able to generalize the results it is important to investigate the effect of virtual laboratory on other domains like mechanics, waves, optics, or in the domains where experiments cannot be conducted in the school lab like relativity and radioactivity.

Second, the DIRECT post-test was administrated to the students directly after the implementation of the study. It is highly recommended to detect the degree of the retention this sample of students will still have after a long period of time by testing the long term retention of the gained concepts, for the same sample of students, at the end of the academic year or even at the beginning of their next academic year in grade 11.

Third, many researchers highlighted the point related to students' practical laboratory skills that may be negatively affected by using virtual laboratory. It is necessary to guide a research that investigates how the use of virtual laboratory may affect these skills.

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