Research in Social Sciences and Technology (RESSAT)
E-ISSN: 2468-6891

Learning with Simulations: Influence of a Computer Simulation with Hands-on Activities on Students' Learning of the Physics Capacitors' Concepts

Fouad M. Yehya[1], Aziz M. Barbar[2] & Suzanne Abou- Rjeili[3]

Abstract

Physics is a tough and challenging topic. Facilitating the learning of physics requires an innovative and constructivist view of teaching that promotes an active learning environment and an effective implementation of educational technology. The purpose of the study is to investigate whether the use of computer simulations combined with hands-on activities are more effective than simulation alone to students´ learning of physics concepts. Interactive computer simulation (Crocodile simulation) was used to spread over the aim of this study. Eighty-seven grade 11 learners from the scientific sections and two physics teachers from two different schools participated in the quantitative experimental study. This attempt assesses via posttest the progress in understanding the concepts charging/ discharging of capacitors after four periods of 200 minutes in two different scenarios: 1- using only a computer simulation; 2- using computer simulation with hands-on activities. The results of both descriptive and inferential statistics show that the learners' understanding of capacitors' concepts were highly achieved when learners used the computer simulation combined with hands-on activities. The use of hands-on activities was identified as the major cause of this differentiation.

Keywords: *Computer simulation, Hands-on activities, Learning physics, Charging/ discharging capacitors.*

Introduction

Learning physics concepts are perceived as one of the toughest missions in the secondary schools (Colletti, 2010). The difficulty in learning many of physics concepts is attributed to their abstract nature, complexity and its microscopic features that lead to various misconceptions (Chen et al., 2013). Research results show that learners' misconceptions are comforting, persisting and highly resistant to change through traditional interventions. Learners do not enter the classroom as blank states, but with inconsistent views with the scientific concepts that lead them not to understand situations and laboratory demonstrations in their courses.

[1] Dr. Fouad Yehya*, Saint Josef University, Beirut, 17-5208 Lebanon, fouad.yehya@net.usj.edu.lb
[2] Dr. Aziz M. Barbar, American University of Science and Technology, Beirut, 16-6452 Lebanon, abarbar@aust.edu,lb
[3] Dr. Suzanne Abou-Rjeili, Lebanese University, Beirut, 17-5208 Lebanon, suzanne.abourjeily@usj.edu.lb

Although the capacitors concepts are important in physics learning, there is a lack of the studies that focus on the effects of teaching strategies on learners' understanding of these concepts. Bilal and Erol (2009) in an experimental study over 177 undergraduate students by means of an electricity concept test (ECT) aimed to determine university learners' conceptions about some electricity concepts showed that half of the learners have clear difficulties of understanding capacitor effects and capacitance. The study showed that the main conceptual students' confusion is about inserting an insulator between two conductor parallel plates. Many of learners believe that inserting an insulator between two conducting parallel plates prevents any current going through the circuit or from one plate to another. Moreover, the results of ECT revealed the evidence that the most common learners' confusion that was determined about a basic RC circuit was the importance of the order of the elements in the circuit: the capacitor filled with charge flowing through one part of the circuit only. Most of the studies have been described, with the aim of highlighting learners' misconceptions.

It is difficult to avoid misconceptions through general instruction (Chen et al., 2013) and learning activities that have to be designed for conceptual change is a point that should be taken into consideration. In front of these difficulties related to the nature of concepts and the used learning strategies, there is no doubt that the following questions are very important to be raised by physics teachers and educators for improving science teaching and learning: Can the use of different learning approaches and ICT tools in education be a significant advantage to enhance learning for capacitors' concepts? How can technological tools and hands-on materials be effectively used?

The literature that is relevant to facilitate physics learning revealed the effectiveness of many learning design approaches and strategies for effective meaningful learning and improving learners' understanding of physics concepts (Carmichael et al., 2010; Ma & Nickerson, 2006; Liu, 2006). Many studies investigate the effectiveness of technology-use, hands-on approach, and combination of both on learners' learning of science concepts (Ekmekci & Gulacar, 2015). Both computer-based and hands-on activities can improve students' understanding of science concepts (Sarabando et al., 2016).

Thus, from one side, hands-on activities can play an effective role in learning physics concepts (Zhang, 2018; Zacharia et al., 2008). According to Bulunuz (2012) hands-on approach can provide authentic learning experiences for learners. However, the effectiveness of hands-on approach should not be taken for granted (Klahr et al., 2007). It should be a form of active learning in which learners think and discuss the concepts related to capacitor circuits and actively perform activities and away from the cookbook type of activities performed in traditional science classrooms. Hands-on experience in which learners are just expected to follow the steps provided by a lab instructor or a textbook neglect important science teaching and learning principles (Ekmekci & Gulacar, 2015).

From the second side, the evidence based on several experimental studies suggests that learning can be improved by integrating new technologies of information and communication (ICT) (Tarman & Dev, 2018; Salas-Pilco & Law, 2018), particularly computer simulations as a possible contribution on topics that learners find conceptually difficult in exploring them in more depth and interactive ways (Sarabando et al., 2016). Computer simulations as educational technology tools have become increasingly powerful and available to teachers in the past three decades (Yehya et al., 2018; Taher & Khan, 2015; Trundle & Bell, 2010) and presently physics teachers can select from a wide range of computer simulations available through the internet. They are open learning environment and effective engaging tool that may support traditional instruction and teachers' understanding to how student think about and learn the physics material and identify what students ask and response due to the communication with their peers (Wieman et al., 2008). They offer an educational environment that aims to enhance teachers' instructional potentialities and facilitate students' active engagement (Taher & Khan, 2014; Karamustafaoğlu, 2012).

Preceding studies have shown the plentiful benefits of computer simulations in facilitating teaching and learning and increasing learners' capacities (Sharma, 2015). Many of these studies focused on the role of computer simulation on acquiring knowledge of the specific content and developing skills of questioning and reasoning (Chang et al., 2008). According to Rutten, Joolingen & Veen (2012) after a review for 17 studies categorized under the title "Enhancement of traditional instruction using computer simulations" reported that traditional instruction and learners' cognitive focus can be improved by using computer simulations. Computer simulations improve motivation and creativity and create a challenging learning environment enhances teachers' instructions and facilitate learners' engagement (Gill et al., 2014; Karamustafaoğlu, 2012; Gulbahar and Guven, 2008; Hockiko, 2009).

Additionally, Computer simulations can replace the dangerous, delicate, expensive apparatus or materials that are impossible to be in physics classrooms (Gill et al., 2014) such as processes inside nuclear reactors and mass spectrometers. They show what cannot ordinarily be visible (happened quickly, too slowly, not readily observed as the flow of electrons through circuit and the connection between the rate of this flow and the current). Moreover, they are flexible to take lab anywhere and at any time and decrease lab spaces, time, requirement for teacher assistant, need for equipment. (Ratompomalala & Bruillard, 2011; Wieman et al., 2008; Condie & Munro, 2007; Cox et al., 2003).

Moreover, Computer simulations, in comparison with textbooks and lectures, offer a great variety of opportunities for teaching models and processes involving physics concepts (Heard & Aravind, 2010; McKagan et al., 2009; Stern et al., 2008; Wieman et al., 2008). They could be used complementary or alternative to other instructional tools in order to facilitate student understanding of physics concepts and improve their achievement as well as their attitudes towards these subjects (Calik, 2013; Karamustafaoğlu, 2012). They enable learners to experiment new and more constrictive pedagogies (Taher & khan, 2014) and provide them with an exploratory learning environment where students will be able to generate hypotheses, design experiments, predict outcome, interpret data and reconsider hypotheses (Hursen & Asiksoy, 2015).

Furthermore, Ekmekci & Gulacar (2015) show that a combination of simulation and hands-on approaches is effective in learning. Liu (2006), for example, studied the effects of a combination of hands-on and computer modeling activities, in chemistry, on student understanding of gas laws. The study showed that computer-based activities and hands-on activities were more effective when used in combination rather than separately in terms of understanding gas laws. The combination of these activities enhanced students' understanding of the particulate and macroscopic representations of gases by giving them the opportunity to study gases not only at the macroscopic level, but also in the virtual space of the simulation where they are able to see beyond the physical world, invisible to naked eyes, and work directly at the atomic scale in an abstract model of the system. Also Zacharia, et al. (2008) indicated that experimenting with the combination of physical manipulations and virtual manipulations enhanced students' conceptual understanding of heat and temperature more than experimenting with physical manipulation alone. Thus the combination between simulation and hands-on activities is more effective in learning than the use of simulation or hands-on approaches alone.

To sum up, the literature supports the effectiveness of both simulation and combination of simulation and hands-on approaches in learning process. Though, what is the extent of the relative effectiveness of the combination of simulation and hands-on activities versus computer simulation? In other words, is one approach more effective than the other in terms of learners' learning for capacitors' concepts outcomes and overcoming their difficulties and misconceptions?

Thus, this paper investigates if there is a difference between the effectiveness of the combination of simulation and hands-on activities and the use of simulation alone in terms of improving learners' understanding of capacitors' concepts and what affordances each approach might provide.

Aim of the study:

The current paper aimed to compare the improvement in learners' understanding for some capacitors' concepts between experimental groups and control groups. The study compared two- different actions situated within a constructivist learning environment: learners of experimental groups learn by using the combinations of computer simulation and hands-on activities (CS+HA) and learners of control groups learn by using computer simulation (CS).

The main research question was: - **Are computer simulations combined with hands-on activities more effective than simulations alone in improving learners' learning about the notions of capacitors**?

Thus, based on the research question, the research's dimensions will involve the integration of computer simulation with or without hands-on activities as independent variables while Learning capacitors' concepts as the dependent variables.

To investigate the best implementation of the computer simulation in physics instructional setting in the context of the research question. It is hypothesized that:

H1: Learners, who apply simulations with hands-on activities, show significantly higher conceptual knowledge achievement in capacitors' concepts than peers who only use simulations.

Method

Research Design

This study used a quantitative experimental approach to examine the difference between the use of simulation with hands-on activities and the use of simulation alone on learning the concepts of capacitors' charging and discharging. The design of the study was shown in the table 1.

Table 1.

Study design

Lesson about charging and discharging of	**Academic Year**	**Participating**	
		Teacher	**Learners**
	2016/ 2017	Teacher A	Section A (21learners) (E 1)

capacitors (200 minutes)		School 1	Section B (22 learners) (C 1)
		Teacher B School2	Section A (23learners) (E 2)
			Section B (21 learners) (C 2)
	Posttest (30 minutes)		

Table 1 shows the participating for two teachers denoted by A and B and four groups from two secondary schools. The study was done in academic years 2016/2017, during the study of the chapter "Capacitors" in grade 11 scientific section in Lebanese secondary schools for four periods (200 minutes). During the lesson explanation, learners in each secondary school in both groups (control "C" and experimental "E") were subjected to the same content and experimental activities and taught by the same teacher. The only difference between the participated groups is the way of conducting the activities. The control groups performed activities only manipulating with laboratory equipment where the experimental groups performed the same activities using laboratory equipment and the PhET computer simulation. At the end of lesson, students were subjected to the same posttest to access their learning. The study did not give any consideration for pre-test to characterize learners' pre-knowledge about capacitors' concepts since these concepts are not discussed before in previous classes according to the Lebanese curriculum.

Population and Sampling

The population that was considered in this study was the 11th grade learners in the scientific section of the Lebanese secondary schools without gender discrimination.

This experimental research involved the participation of two grade 11 secondary physics teachers, who teach two different 11th grade sections in their schools to remove the probability of different results between the experimental and the control groups due to the difference in teachers' expertise and their style and to ascertain that the difference between the groups is due to the used treatments.

In this context, purposive sampling process was used. Several teachers were invited, from secondary schools that have two 11th grade sections in the geographical area where the researchers were based after they were informed about the study aims, and all aspects that should be taken into consideration during the learning process with students in the classroom and the laboratory. Five teachers, from five secondary schools, accepted the invitation to participate in this research. Two schools out of them were chosen by random sampling to form a sample of 87 learners, grouped in four groups taught by two physics teachers. So, each teacher taught two 11^{th} grade classes denoted by (Experimental E1 (21 learners) and control C1 (22 learners) and experimental E2 (23 learners) and control C2 (21 learners). Learners in the participated groups were not selected by random sampling since they are already grouped into sections and it was not possible to redistribute them randomly for the different treatments.

Data Collection Tools

1. Hands-on Activities

The employment of hands-on activities involved the use of many instruments as oscilloscope, capacitor box, switches, source of DC voltage, resistors and rheostat in the aim to find out the relationship between the physical quantities that affect the functioning of the capacitors in Direct current (DC) electric circuits.

2. Computer Simulation

A powerful feature for the computer simulation is its multiple representations that allow users to create, visualize, and interact with analytical and graphical representations of the studied phenomena. The computer crocodile interactive simulation was used to build the circuits needed. The computer simulation used in this study addresses the flexibility in circuit construction and measurements which is hard to be done practically with the experimental teaching of the concepts of charging and discharging which would involve practice with an oscilloscope.

3. Interview

Data about how the lesson is conducted and how the activities were applied in the context of constructivism learning theory during the learning process was discussed with the participating teachers two weeks before instruction. The interview lasted an average duration of 60 minutes with each teacher.

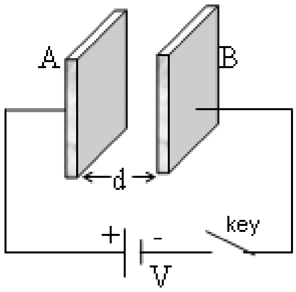
4. Posttest

To assess students' learning of the concepts of charging and discharging, the conceptual posttest test was directed. The Exercises of the posttest were adopted from the research done by Bilal & Erol (2009) "Investigating Students' Conceptions of Some Electricity Concepts" aimed determine university students' conceptions about some electricity concepts and developed and refined by the researchers. The posttest used the items that were related to capacitors concepts, and the only modification done on these items was the replacement of the word "key" by "switch" to be aligned with the Lebanese curriculum. The posttest questions were formed of 2 sets (table 2). Each set has one stem related to three exercises dealt with the capacitors' concepts and integrated into the Lebanese Curriculum for the 11th grade.

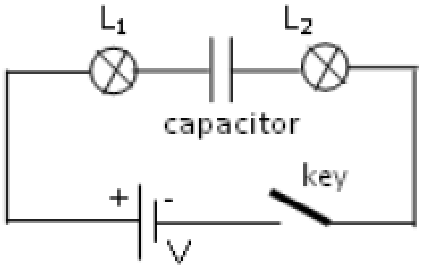
Moreover, the posttest was examined by 30 11th grade learners who had not participated the study. The attained reliability using Cronbach's alpha coefficient was 0.773 confirming that the used posttest was appropriate to measure precisely and consistently what it measures.

Table 2

Posttest exercises

Set 1	
Use this stem to solve exercises: 1-1, 1-2 and 1-3. A parallel plate capacitor is formed by using the identical metallic plates A and B. The distance between the plates is d and the space between the plates is empty. The capacitor is connected to a battery by means of a key.  	
1-1	Which one is correct relating to the amount of charge on the plates when the switch is closed? A) Plate A has a positive charge and plate B has the same amount of negative charge. B) Plate A has a negative charge and plate B has the same amount of positive charge. C) Only plate B is charged negatively. D) None of the plates is charged. Justify your answer:
1-2	What happens if the free space between the plates A and B is filled with a conducting matter when the key is closed? A) Plate A has a positive charge and plate B has the same amount of negative charge. B) Plate A has a negative charge and plate B has the same amount of positive charge. C) Only plate B is charged negatively. D) None of the plates is charged. Justify your answer:
1-3	The switch is closed a long time to fully charge the plates, then the switch is opened and a dielectric block is replaced between the plates. Which one is correct relating to the capacitance? A) Capacitance decreases to a certain level. B) Capacitance increases. C) Capacitance does not change D) Capacitance decreases to zero. Justify your answer:
Set 2:	
Use the following stem to solve exercises 2-1, 2-2 and 2-3.	

<table>
<tr><td colspan="2">The circuit shown is formed by using two identical lambs, L1 and L2, a capacitor, a switch and a battery of that internal resistance is negligible.



</td></tr>
<tr><td>2-1</td><td>Which lambs shine at the moment that the switch is closed?

A) Only lamb L1.
B) Only lamb L2.
C) Lamb L1 and L2.
D) None.
Justify your answer:</td></tr>
<tr><td>2-2</td><td>After the key is closed and the capacitor is fully charged which lambs shine?

A) Only lamb L1.
B) Only lamb L2.
C) Lamb L1 and L2.
D) None.
Justify your answer:</td></tr>
<tr><td>2-3</td><td>After the capacitor is fully charged, the battery is moved from the circuit and the circuit is reconnected with a wire. When switch is closed, which lambs(s) shine?

A) Only lamb L1.
B) Only lamb L2.
C) L1 and L2.
D) None.
Justify your answer:</td></tr>
</table>

Note 1. *Adopted from ''Investigation Students' Conceptions of Some Electricity Concepts" by Bilal & Erol (2009)*

Learners' posttest answers were analyzed according to the criteria found in Table 3. These criteria were applied to the justification that the learners provided in their answers. These answers were analyzed independently by the researcher and the two participated teachers obtaining in all cases a degree of agreement exceeding 95.0%. In situations where there was disagreement with the classification of the responses, the discrepancy was classified in the second level.

Table 3.

Criteria used to describe the conceptual understandings

Level	Criteria
3	- Answer that includes all the components of the validated answer
2	- Answer that shows some understanding of the concepts
1	- Answer incorrect or irrelevant, illogical, or an answer that is not clear, or blank answer

Data Collection

The posttest was used as a regular formal graded test for learners by both teachers to consider it seriously. It was done the next week after the completion of the lesson for 30 min duration. The two participated groups in each school did the posttest at the same time.

Data Analysis

Data was managed using Statistical Package for Social Sciences (SPSS v19). The descriptive statistics was used in summing the data including percentages, frequency, mean and standard deviation. Moreover, the inferential statistical theory was used to ascertain the significant difference between the participated groups and make appropriate inferences concerning the utility of computer simulation in the 11th grade capacitor courses at Lebanese secondary schools.

Findings

The research main question was "Are computer simulations combined with hands-on activities more effective, than simulations alone, in approving students' learning about capacitors' concepts?

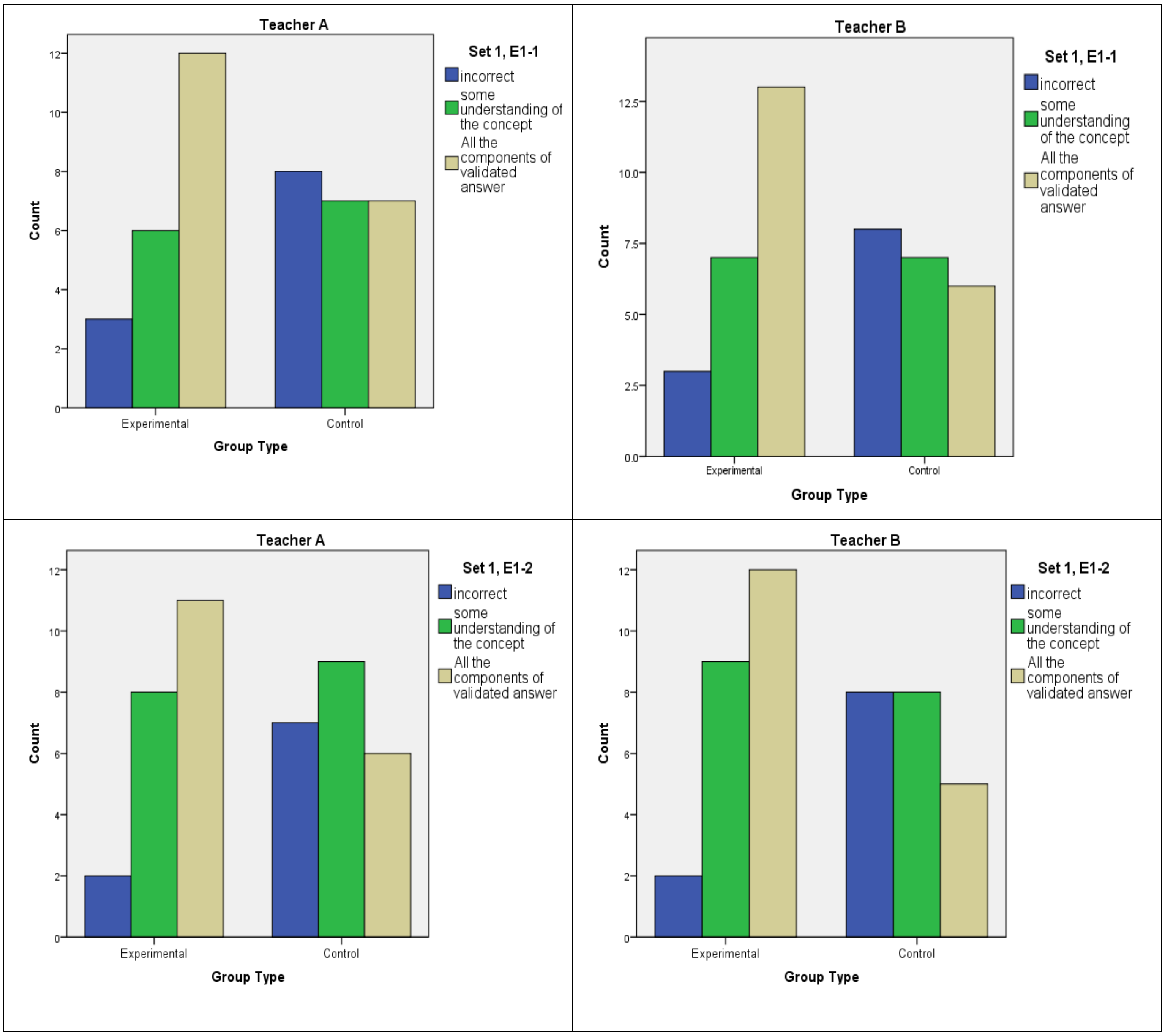
The following section revealed separately the results of the posttest exercises in the context of the research main question to come up finally with a discussion that examine the influence of a computer simulation with hands-on activities verses the only use of computer simulation on students' learning of the physics concepts of charging and discharging of capacitors.

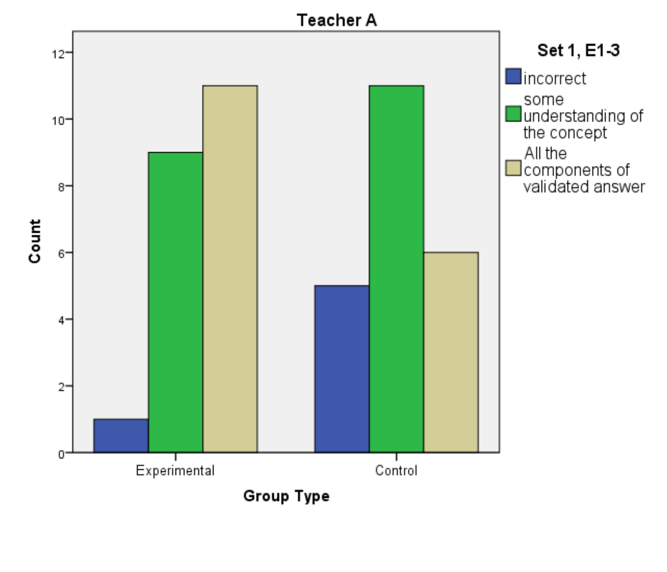
The posttest, as mentioned before, is formed of two sets of exercises. Set 1, examine learners' understanding of charging two metallic plates. Learners were asked to relate the amount of charges on the plates of the capacitor to the existence of metallic and dielectric materials between the plates. Validated answers should include knowledge that the amount of positive charges equal to the amount of negative charges and the existence of dielectric material between the plates increases the capacitance of the capacitors. The Exercises of set 2 were designed to investigate students' understanding on current during the charging and discharging of the capacitor. Students were asked what happens to the brightness of the lamps in different situations and if the order of the elements in the RC mattered. Validated answers should include knowledge that the order of the elements are not mattered with the current in the circuit.

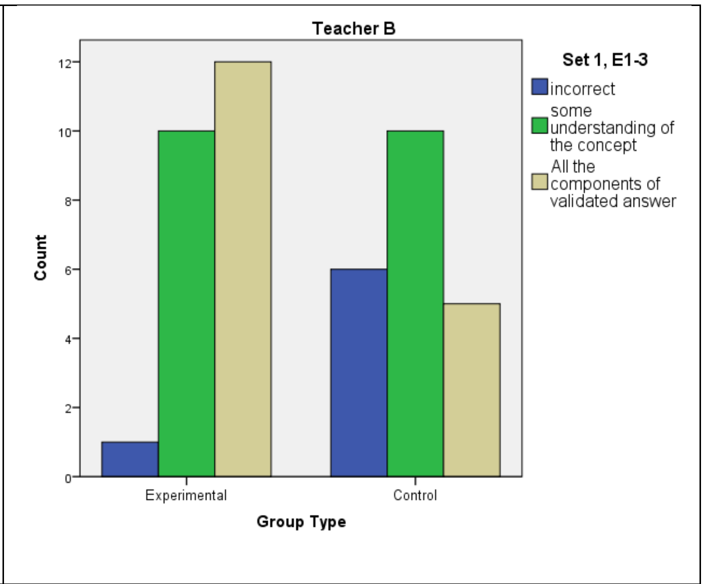
Scores of the used posttest of the experimental group were compared to the scores of the control group in each of the two schools, and statistical results were revealed in the coming sections for the two participated schools. All the results were revealed and discussed separately in the coming section.

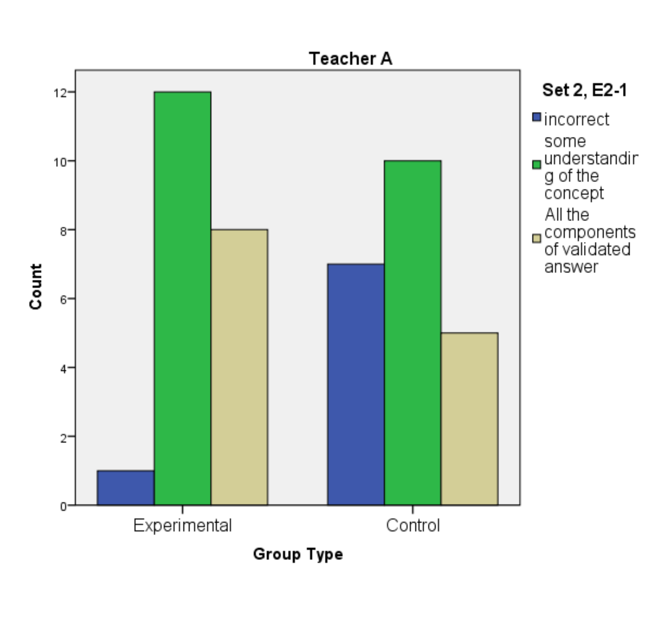
1. *Comparing the Learners' Answering Level Between the Experimental and Control Groups in Each School*

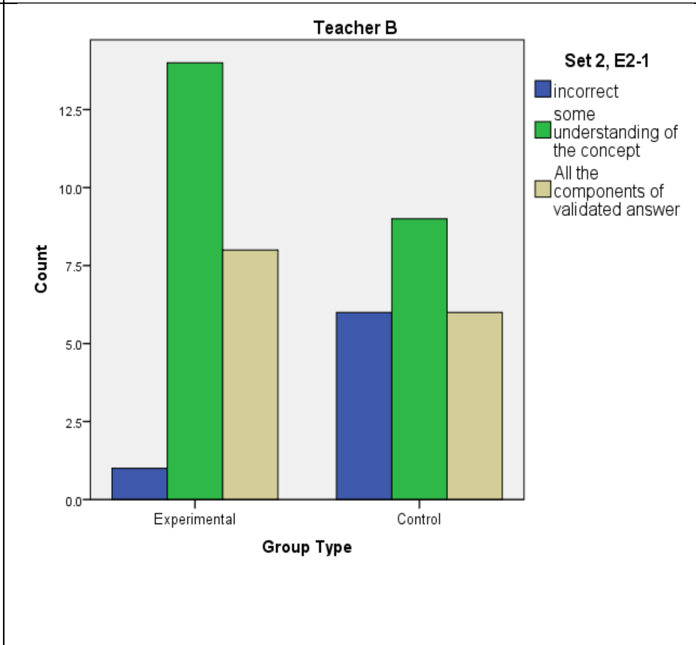
Learners' level of answering in each school by teachers A and B for each exercise in set 1 (exercises1-1, 1-2 and 1-3) and set 2 (exercises 2-1, 2-2 and 2-3) were revealed by the bar charts of figure 1, where the cross tabulation for the level of answering in each school were shown in appendix A.

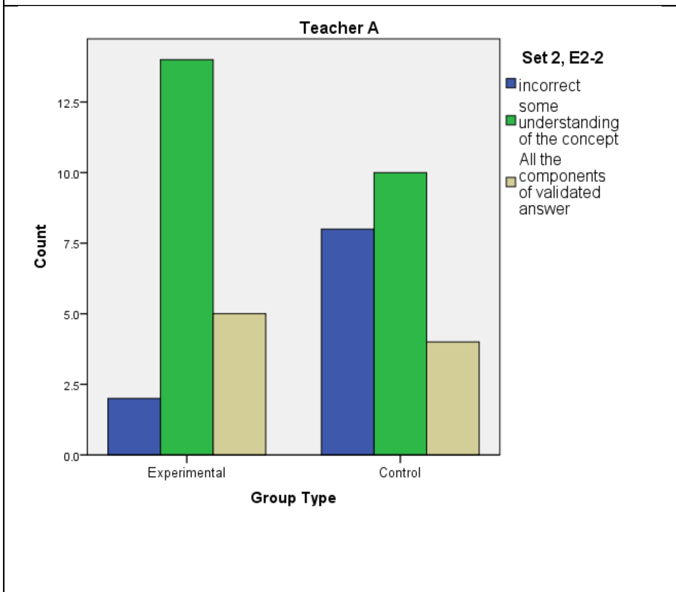


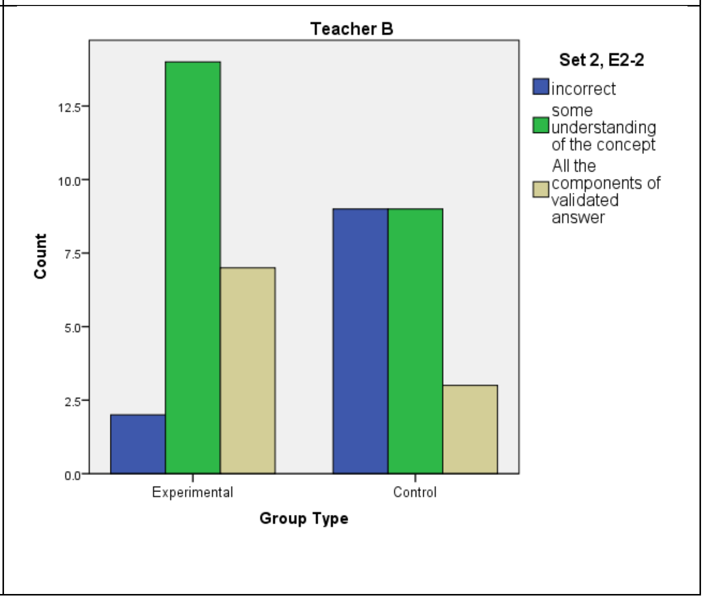

Teacher A
Set 1, E1-3
incorrect
some understanding of the concept
All the components of validated answer
Count
Experimental
Control
Group Type


Teacher B
Set 1, E1-3
incorrect
some understanding of the concept
All the components of validated answer
Count
Experimental
Control
Group Type


Teacher A
Set 2, E2-1
incorrect
some understandir g of the concept
All the components of validated answer
Count
Experimental
Control
Group Type


Teacher B
Set 2, E2-1
incorrect
some understanding of the concept
All the components of validated answer
Count
Experimental
Control
Group Type


Teacher A
Set 2, E2-2
incorrect
some understanding of the concept
All the components of validated answer
Count
Experimental
Control
Group Type


Teacher B
Set 2, E2-2
incorrect
some understanding of the concept
All the components of validated answer
Count
Experimental
Control
Group Type

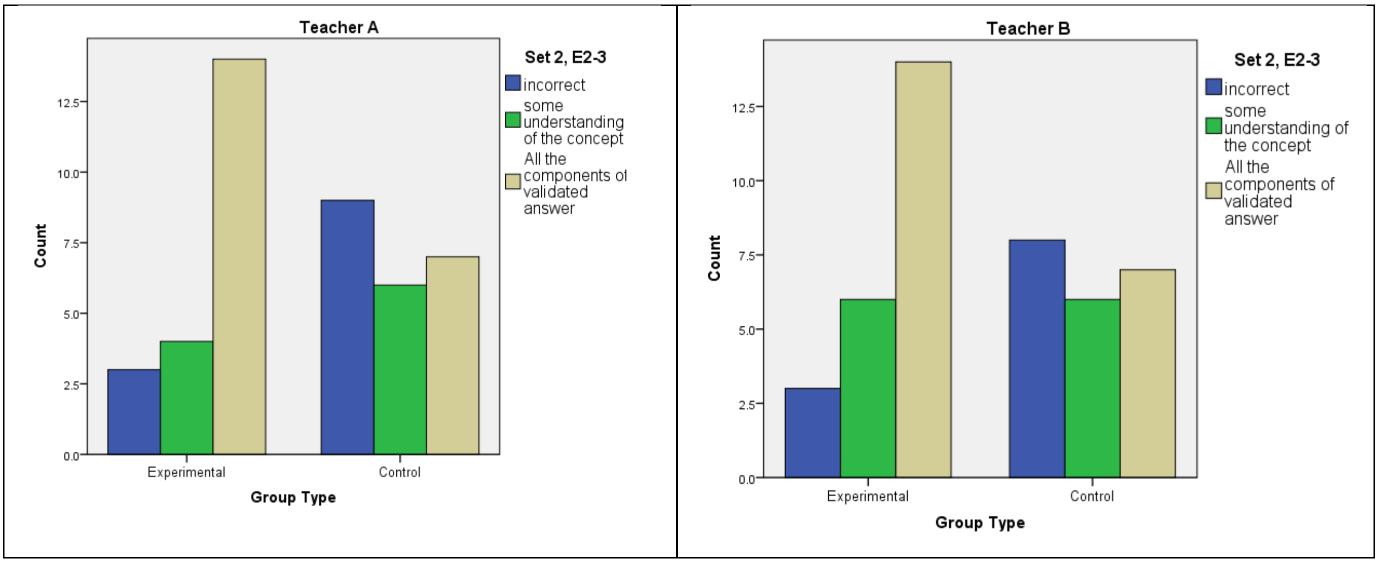


Figure 1: Compare learners' answering between participated groups

Bar charts reveal that in all the exercises of the posttest, and in both participated schools, the incorrect answers of the learners of the experimental groups are less than the incorrect answers of the learners of the control group. Also, the completely validated correct answers submitted by the learners of the experimental group are much more than the validated correct answers submitted by the learners of the control group.

Thus, the overall posttest's findings indicate that ensuing to learners' participating in respective treatments by same teacher, the majority of learners in experimental group in both participated schools showed scientifically better understanding for the concepts of the distribution of charges in the plates of the capacitors, the effect of introducing different kinds of materials between the plates on the amount of charges and the concept of charging and discharging than learners of control group.

Furthermore, table 4 provides a summary of the frequencies in percentage for the three levels of understanding of all the exercises in the posttest for all the learners of teachers A and B.

Table 4.

Frequency in percentage for the three levels of understanding the charging and discharging capacitors concepts

Exercises	LEVEL	Teacher A (School 1)		Teacher B (School 2)	
		Experimental 1	Control 1	Experimental 2	Control 2
1-1	3	57.1	31.8	56.5	28.5
	2	28.5	31.8	30.4	33.3
	1	14.2	36.3	13	38
1-2	3	52.3	27.2	52.1	23.8
	2	38	40.9	39.1	38
	1	9.5	31.8	8.6	38

1-3	3	52.3	27.2	52.1	23.8
	2	42.8	50	43.4	47.6
	1	4.7	22.7	4.5	28.5
2-1	3	38	22.7	34.7	28.5
	2	57.1	45.4	60.8	42.8
	1	4.7	31.8	4.3	28.5
2-2	3	23.8	18.1	30.4	14.2
	2	66.6	45.4	60.8	42.8
	1	9.5	36.3	8.6	42.8
2-3	3	66.6	31.8	60.8	33.3
	2	19	27.2	26	28.5
	1	14.2	40.9	13.6	38

All the results highlighted that the learners of the experimental groups in both schools showed more correct answers that includes all the components of the validated answer than the learners of the control group (Level 3 answers, see Table 4). More than 52% of the learners of the experimental verses 25% of the learners of the control group answered the questions of set 1 (1-1, 1-2 and 1-3) correctly with full explanation. Also, 36% of the learners of the experimental group verses 25% of the learners of the control group provide a full explanation for exercise 2-1, 27% of the learners of the experimental group verses 16.2% of the learners of the control group provide a full explanation for exercise 2-2 and 63% of the learners of the experimental group verses 32% of the learners of the control group provide a full explanation for exercise 2-3. Furthermore, learners of both groups showed approximately the same percentages in showing some understanding of the concepts (Level 2 answers, see Table 4).

Thus, results reveal that learners of the experimental groups who integrate simulation with hands-on activities have better conceptual understanding of capacitors' concepts than the learners of the control groups who use simulation alone.

2. Comparing the Learners' Mean Score Between the Participated Groups

Comparing the mean score and the standard deviation for the posttest for both groups can be a lens that can magnify learners' recognizing for the tested concepts. Accordingly, the mean can highlight the difference in learners' abilities to retain knowledge in the posttest exercise between the two participated groups. The mean of scores M and the standard deviation SD for the whole posttest for both experimental and control groups were calculated and showed in the table below (table 5).

Table 5.

Compare the means between the participating groups in the posttest

Report

Final grade

Group Type	Mean	Std. Deviation	N
Experimental	13.82	3.021	44
Control	9.43	4.043	42
Total	11.67	4.168	86

The analyses of the results were based on the following criteria:

- The score of mean M greater than 12 ($M > 12$) was considered as a good score
- The score of mean M between 9 and 12 ($9 < M < 12$) was considered as an acceptable score
- The score of mean M between 6 than 9 ($6 < M < 9$) was considered as a low score
- The score of mean M less than 6 ($M < 6$) was considered as very low score.

Results revealed clearly that the mean of the scores of the experimental group in the whole posttest was M= 13.8 with a standard deviation SD = 3 that were considered as good score. Whereas the mean of the scores of the control group was M= 9.4 with SD = 4 that were considered as an acceptable score. The result indicated that the mean difference between the mean of the experimental group from the mean of the control group is 4.4.

Additionally, the Independent Samples t-test (table 6) was conducted to examine if the difference in the mean of the scores was significant in validating the stated hypotheses between the control and experimental groups after the treatment. It provided that the p-value of Levene's test for homogeneity of variances was $F(1,84) = 6.5$, $p = 0.012$. Thus, t- test assuming non-equal variances was calculated. Results of "t- test for equal variance not assumed" showed that there is a significant difference at the 5% level in students' grades means of the experimental group compared the that in the control group, $t(75.8) = 5.6$, $p = 0.001$ ($p < 0.05$) in the participated schools on a 95% confidence interval. Thus, there is a significant impact of the combination of computer simulation and hands-on activity on conceptual knowledge achievement in capacitors of the experimental group compared to that of control group in the participated schools.

Table 6:

Independent t test to examine the mean difference between the participated groups for the participating schools

Independent Samples Test

		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
Final grade	Equal variances assumed	6.576	.012	5.721	84	.000	4.390	.767	2.864	5.916
	Equal variances not assumed			5.682	75.817	.000	4.390	.772	2.851	5.928

Thus, these results exposed that learners of the experimental group attained better retention and recognition than that of the control group. These results suggest that when learners used simulation with hands-on activities, they have better recognition for the charging and discharging capacitors concepts than who used simulation only.

Discussions, Conclusion and Implications

The main concern of this study is to compare between the effectiveness of the use of computer simulation with hands-on activities and the use of computer simulation alone on learning some capacitors' concepts. Because the result is dynamic to be applied in the context of the widespread of computer simulation in academic area, this study was commenced.

In the context of the research question, the study focused on comparing learners' achievement in different ways of simulation usage to verify the research hypothesis. The research hypothesized that learners who apply simulations with hands-on activities show significantly higher conceptual knowledge achievement in capacitors' concepts than peers who only use simulations.

Learners' different achievement for some concepts of capacitors for the two treatment groups (Control group using simulation alone and experimental group using simulation with hands-on activities) was examined using posttest adopted from a conceptual test named "Electricity Concepts test (ECT)".

The findings of this study indicate, in general, that computer simulations are effective learning tools. The use of the computer simulation helps learners to learn the physics concepts of capacitors, either used alone or combined with hands-on activities. These findings are consistent with the previous research of Rutten et al. (2012), Smetana & Bell (2012), Trundle & Bell (2010), Sahin (2006) and many others.

Moreover, the posttest results demonstrated that learners who use simulation combined with hands-on activities of the experimental group had better conceptual understanding and mastery to provide answers that include all the validation components of capacitors' concepts than the learners of the control group. The analysis of the results revealed that the mean score of the learners who use simulation alone of the experimental group in the posttest is much better than that of the learners of the control group. Additionally, the independent t test also indicated that there was a significance difference between the experimental group and the control group in the both participated schools.

Accordingly, the posttest results of this study confirm that the efficacy of computer simulations depends on its combinations with the hands-on activities. The combination of simulation with hands-on activities enables learners to experiment with new and more constrictive pedagogies and provide them with an exploratory learning environment where they will be able to learn different physics concepts (Hursen & Asiksoy, 2015) and overcome scientifically incorrect conceptions about the capacitors' concepts. Thus, simulations become more effective when its use was integrated with hands-on activities. This result contradicts the results of Sarabando et al. (2016) who proved that the use of only computer simulation was more effective than the computer simulation used together with hands-on activities. However, this result aligns with the finding by Taher and Khan (2014) who revealed that simulation by itself is not very effective in promoting student learning; it becomes effective when it is followed by hands –on activities.

Thus, it was found that simulation usage with hands-on activities by physics teachers may promote leaners conceptual understanding of some capacitors' concepts than the use of simulation alone. Consequently, improving learners' physics learning highly recommends that the use of computer simulation alone can be replaced by combinational computer simulation and hands–on activities instructional strategy.

Limitation of the Study:

In any case, we should note that the achievement obtained by learners in this study may be considered quite reasonable taking in consideration the documented difficulties in learning the capacitors' concepts as mentioned in the introduction. The implication of this research for educators and educational researchers is that the combinational computer simulation and hands-on activities as instructional strategy can improve students' understanding about the capacitors' concepts. Despite this high expectation for combinational computer simulation and hands–on activities as instructional strategy, it should be noted that we cannot guarantee an overall conclusion about its effectiveness. The results from this experimental research are limited because they are based on just one topic (capacitors) and the usage of one interactive computer simulation and this limits the research results. Hence, it is recommended that future studies should be conducted to validate the findings of the current study by incorporating a larger sample size, longer implementation period and other physics topics.

References

Bilal, E., & Erol, M. (2009). Investigating students' conceptions of some electricity concepts. *Latin-American Journal of Physics Education*, 3(2), 1.

Bulunuz, M. (2012). Motivational Qualities of Hands-on Science Activities for Turkish Preservice Kindergarten Teachers. *Eurasia Journal of Mathematics, Science & Technology Education*, 8(2).

Calik, M. (2013). Effect of technology-embedded scientific inquiry on senior science student teachers' self-efficacy. *Eurasia Journal of Mathematics, Science & Technology Education,* 9(3), 223-23

Carmichael, A., Chini, J. J., Rebello, N. S., & Puntambekar, S. (2010, October). Comparing Student Learning in Mechanics Using Simulations and Hands-on Activities. In *AIP Conference Proceedings* (Vol. 1289, No. 1, pp. 89-92). AIP.

Chang, K. E., Chen, Y. L., Lin, H. Y., & Sung, Y. T. (2008). Effects of learning support in simulation-based physics learning. *Computers & Education*, 51(4), 1486-1498.

Chen, Y. L., Pan, P. R., Sung, Y. T., & Chang, K. E. (2013). Correcting Misconceptions on Electronics: Effects of a simulation-based learning environment backed by a conceptual change model. *Journal of Educational Technology & Society, 16*(2).

Colletti, L. (2010). On dragons and turkeys: Physics for future citizens. *School Science Review, 91*(337), 93-96.

Condie, R., & Munro, B. (2007). The impact of ICT in schools-a landscape review. Becta research. Retrieved August, 5, 2017.

Cox, M., Abbott, C., Webb, M., Blakeley, B., Beauchamp, T., & Rhodes, V. (2003). ICT and attainment: A review of the research literature. *Coventry: Becta (ICT in Schools Research and Evaluation Series)*.

Ekmekci, A., & Gulacar, O. (2015). A Case Study for Comparing the Effectiveness of a Computer Simulation and a Hands-On Activity on Learning Electric Circuits. *Eurasia Journal of Mathematics, Science & Technology Education, 11*(4).

Gill, S. E., Marcum-Dietrich, N., & Becker-Klein, R. (2014). Model My Watershed: Connecting Students' Conceptual Understanding of Watersheds to Real-World Decision Making. *Journal of Geoscience Education, 62*(1), 61-73.

Gulbahar, Y., & Guven, I. (2008). A survey on ICT usage and the perceptions of social studies teachers in Turkey. *Journal of Educational Technology & Society, 11*(3).

Heard, J. W., & Aravind, V. R. (2010). Physics by simulation: Teaching circular motion using applets. *Latin-American Journal of Physics Education, 4*(1), 6.

Hockicko, P. (2009). Useful computer software for physical analysis of processes. In *Proceedings of the 2009 Information and Communication Technology in Education. Annual Conference, 15th–17th September*.

Hursen, C., & Asiksoy, G. (2015). World Journal on Educational Technology. *World, 7*(1), 87-98.

Karamustafaoglu, O. (2012). How computer-assisted teaching in physics can enhance student learning. *Educational Research and Reviews*, *7*(13), 297.

Klahr, D., Triona, L. M., & Williams, C. (2007). Hands on what? The relative effectiveness of physical versus virtual materials in an engineering design project by middle school children. *Journal of Research in Science teaching*, *44*(1), 183-203.

Liu, X. (2006). Effects of combined hands-on laboratory and computer modeling on student learning of gas laws: A quasi-experimental study. *Journal of Science Education and Technology, 15*(1), 89-100.

Ma, J., & Nickerson, J. V. (2006). Hands-on, simulated, and remote laboratories: A comparative literature review. *Computing Surveys, 38*(3), 1-24.

McKagan, S. B., Handley, W., Perkins, K. K., & Wieman, C. E. (2009). A research-based curriculum for teaching the photoelectric effect. *American Journal of Physics, 77*(1), 87-94.

Ratompomalala, H., & Bruillard, É. (2011, March). ICT and pre service teacher training in physics and chemistry: a survey in France. In *Society for Information Technology & Teacher Education International Conference* (pp. 1651-1656). Association for the Advancement of Computing in Education (AACE).

Rutten, N., Van Joolingen, W. R., & Van Der Veen, J. T. (2012). The learning effects of computer simulations in science education. *Computers & Education*, *58*(1), 136-153.

Sahin, S. (2006). Computer simulations in science education: Implications for Distance Education. *Online Submission*, *7*(4).

Salas-Pilco, S. Z., & Law, N. W. (2018). ICT Curriculum Planning and Development: Policy and Implementation Lessons from Small Developing States. In *ICT-Supported Innovations in Small Countries and Developing Regions* (pp. 77-98). Springer, Cham.

Sarabando, C., Cravino, J. P., & Soares, A. A. (2016). IMPROVING STUDENT UNDERSTANDING OF THE CONCEPTS OF WEIGHT AND MASS WITH A COMPUTER SIMULATION. *Journal of Baltic Science Education*, *15*(1).

Smetana, L. K., & Bell, R. L. (2012). Computer simulations to support science instruction and learning: A critical review of the literature. *International Journal of Science Education, 34*(9), 1337-1370.

Stern, L., Barnea, N., & Shauli, S. (2008). The effect of a computerized simulation on middle school students' understanding of the kinetic molecular theory. *Journal of Science Education and Technology*, *17*(4), 305-315.

Taher, M., & Khan, A. (2015). Comparison of simulation-based and hands-on teaching methodologies on students' learning in an engineering technology program. *QScience Proceedings*, 58.

Tarman, B., & Dev, S. (2018). Editorial: Learning Transformation through Innovation and Sustainability in Educational Practices. *Research In Social Sciences And Technology*, *3*(1), i-ii. Retrieved from http://ressat.org/index.php/ressat/article/view/363

Trundle, K. C., & Bell, R. L. (2010). The use of a computer simulation to promote conceptual change: A quasi-experimental study. *Computers & Education*, *54*(4), 1078-1088.

Wieman, C. E., Perkins, K. K., & Adams, W. K. (2008). Oersted Medal Lecture 2007: Interactive simulations for teaching physics: What works, what doesn't, and why.

Zacharia, Z. C., Olympiou, G., & Papaevripidou, M. (2008). Effects of experimenting with physical and virtual manipulatives on students' conceptual understanding in heat and temperature. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *45*(9), 1021-1035.

Yehya, F., Barbar, A., & Rjeily, S. A. (2018). Diagnosing the barriers for integrating Educational Technology in Physics courses in Lebanese secondary schools. *Research in Social Sciences and Technology*, *3*(2), 14-39.

Zhang, L. (2018). Withholding answers during hands-on scientific investigations? Comparing effects on developing students' scientific knowledge, reasoning, and application. *International Journal of Science Education*, *40*(4), 459-469.

Appendices

Appendix A

The cross tabulation for the level of answering in each school by SPSS:

Group Type * Set 1, E1-1 * Teacher Crosstabulation

Count

Teacher			Set 1, E1-1			Total
			incorrect	some understanding of the concept	All the components of validated answer	
teacher A	Group Type	Experimental	3	6	12	21
		Control	8	7	7	22
	Total		11	13	19	43
teacher B	Group Type	Experimental	3	7	13	23
		Control	8	7	6	21
	Total		11	14	19	44
Total	Group Type	Experimental	6	13	25	44
		Control	16	14	13	43
	Total		22	27	38	87

Group Type * Set 1, E1-2 * Teacher Crosstabulation

Count

Teacher			Set 1, E1-2			Total
			incorrect	some understanding of the concept	All the components of validated answer	
teacher A	Group Type	Experimental	2	8	11	21
		Control	7	9	6	22
	Total		9	17	17	43
teacher B	Group Type	Experimental	2	9	12	23
		Control	8	8	5	21
	Total		10	17	17	44
Total	Group Type	Experimental	4	17	23	44
		Control	15	17	11	43
	Total		19	34	34	87

Group Type * Set 1, E1-3 * Teacher Crosstabulation

Count

Teacher	Set 1, E1-3	Total

			incorrect	some understanding of the concept	All the components of validated answer	
teacher A	Group Type	Experimental	1	9	11	21
		Control	5	11	6	22
	Total		6	20	17	43
teacher B	Group Type	Experimental	1	10	12	23
		Control	6	10	5	21
	Total		7	20	17	44
Total	Group Type	Experimental	2	19	23	44
		Control	11	21	11	43
	Total		13	40	34	87

Group Type * Set 2, E2-1 * Teacher Crosstabulation

Count

Teacher			Set 2, E2-1			Total
			incorrect	some understanding of the concept	All the components of validated answer	
teacher A	Group Type	Experimental	1	12	8	21
		Control	7	10	5	22
	Total		8	22	13	43
teacher B	Group Type	Experimental	1	14	8	23
		Control	6	9	6	21
	Total		7	23	14	44
Total	Group Type	Experimental	2	26	16	44
		Control	13	19	11	43
	Total		15	45	27	87

Group Type * Set 2, E2-2 * Teacher Crosstabulation

Count

Teacher			Set 2, E2-2			Total
			incorrect	some understanding of the concept	All the components of validated answer	
teacher A	Group Type	Experimental	2	14	5	21
		Control	8	10	4	22
	Total		10	24	9	43
teacher B	Group Type	Experimental	2	14	7	23
		Control	9	9	3	21
	Total		11	23	10	44
Total	Group Type	Experimental	4	28	12	44
		Control	17	19	7	43
	Total		21	47	19	87

Group Type * Set 2, E2-3 * Teacher Crosstabulation

Count

Teacher			Set 2, E2-3			Total
			incorrect	some understanding of the concept	All the components of validated answer	
teacher A	Group Type	Experimental	3	4	14	21
		Control	9	6	7	22
	Total		12	10	21	43
teacher B	Group Type	Experimental	3	6	14	23
		Control	8	6	7	21
	Total		11	12	21	44
Total	Group Type	Experimental	6	10	28	44
		Control	17	12	14	43
	Total		23	22	42	87

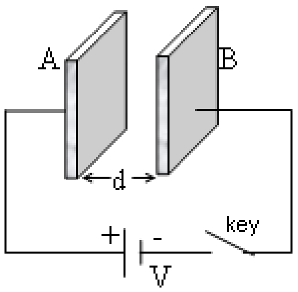
Tables and Figures

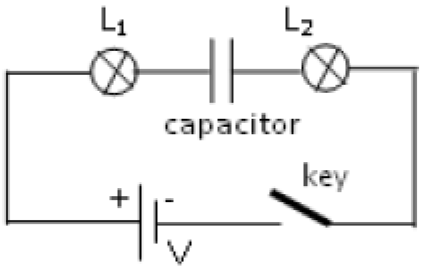
Tables

Table 1: Study design

Lesson about charging and discharging of capacitors (200 minutes)	**Academic Year**	**Participating**	
		Teacher	**Learners**
	2016/ 2017	Teacher A School 1	Section A (21learners) (E 1)
			Section B (22 learners) (C 1)
		Teacher B School2	Section A (23learners) (E 2)
			Section B (21 learners) (C 2)
	Posttest (30 minutes)		

Table 2: Posttest exercises adopted from ''Investigation Students' Conceptions of Some Electricity Concepts" by Bilal & Erol (2009)

Set 1	
Use this stem to solve exercises: 1-1, 1-2 and 1-3. A parallel plate capacitor is formed by using the identical metallic plates A and B. The distance between the plates is d and the space between the plates is empty. The capacitor is connected to a battery by means of a key. 	
1-4	Which one is correct relating to the amount of charge on the plates when the switch is closed? A) Plate A has a positive charge and plate B has the same amount of negative charge. B) Plate A has a negative charge and plate B has the same amount of positive charge. C) Only plate B is charged negatively. D) None of the plates is charged. Justify your answer:
1-5	What happens if the free space between the plates A and B is filled with a conducting matter when the key is closed? A) Plate A has a positive charge and plate B has the same amount of negative charge. B) Plate A has a negative charge and plate B has the same amount of positive charge.

	C) Only plate B is charged negatively. D) None of the plates is charged. Justify your answer:
1-6	The switch is closed a long time to fully charge the plates then the switch is opened and a dielectric block is replaced between the plates. Which one is correct relating to the capacitance? A) Capacitance decreases to a certain level. B) Capacitance increases. C) Capacitance does not change D) Capacitance decreases to zero. Justify your answer:
Set 2:	
Use the following stem to solve exercises 2-1, 2-2 and 2-3. The circuit shown is formed by using two identical lambs, L1 and L2, a capacitor, a switch and a battery of that internal resistance is negligible. 	
2-1	Which lambs shine at the moment that the switch is closed? A) Only lamb L1. B) Only lamb L2. C) Lamb L1 and L2. D) None. Justify your answer:
2-2	After the key is closed and the capacitor is fully charged which lambs shine? A) Only lamb L1. B) Only lamb L2. C) Lamb L1 and L2. D) None. Justify your answer:
2-3	After the capacitor is fully charged, the battery is moved from the circuit and the circuit is reconnected with a wire. When switch is closed, which lambs(s) shine? A) Only lamb L1. B) Only lamb L2. C) L1 and L2. D) None.

	Justify your answer:

Table 3: Criteria used to describe the conceptual understandings

Level	Criteria
3	- Answer that includes all the components of the validated answer
2	- Answer that shows some understanding of the concepts
1	- Answer incorrect or irrelevant, illogical, or a answer that is not clear, or blank answer

Table 7: Frequency in percentage for the three levels of understanding the charging and discharging capacitors concepts

Exercises	LEVEL	Teacher A (School 1)		Teacher B (School 2)	
		Experimental 1	Control 1	Experimental 2	Control 2
1-1	3	57.1	31.8	56.5	28.5
	2	28.5	31.8	30.4	33.3
	1	14.2	36.3	13	38
1-2	3	52.3	27.2	52.1	23.8
	2	38	40.9	39.1	38
	1	9.5	31.8	8.6	38
1-3	3	52.3	27.2	52.1	23.8
	2	42.8	50	43.4	47.6
	1	4.7	22.7	4.5	28.5
2-1	3	38	22.7	34.7	28.5
	2	57.1	45.4	60.8	42.8
	1	4.7	31.8	4.3	28.5
2-2	3	23.8	18.1	30.4	14.2
	2	66.6	45.4	60.8	42.8
	1	9.5	36.3	8.6	42.8
2-3	3	66.6	31.8	60.8	33.3
	2	19	27.2	26	28.5
	1	14.2	40.9	13.6	38

Table 5: Compare the means between the participating groups in the posttest

Report

Final grade

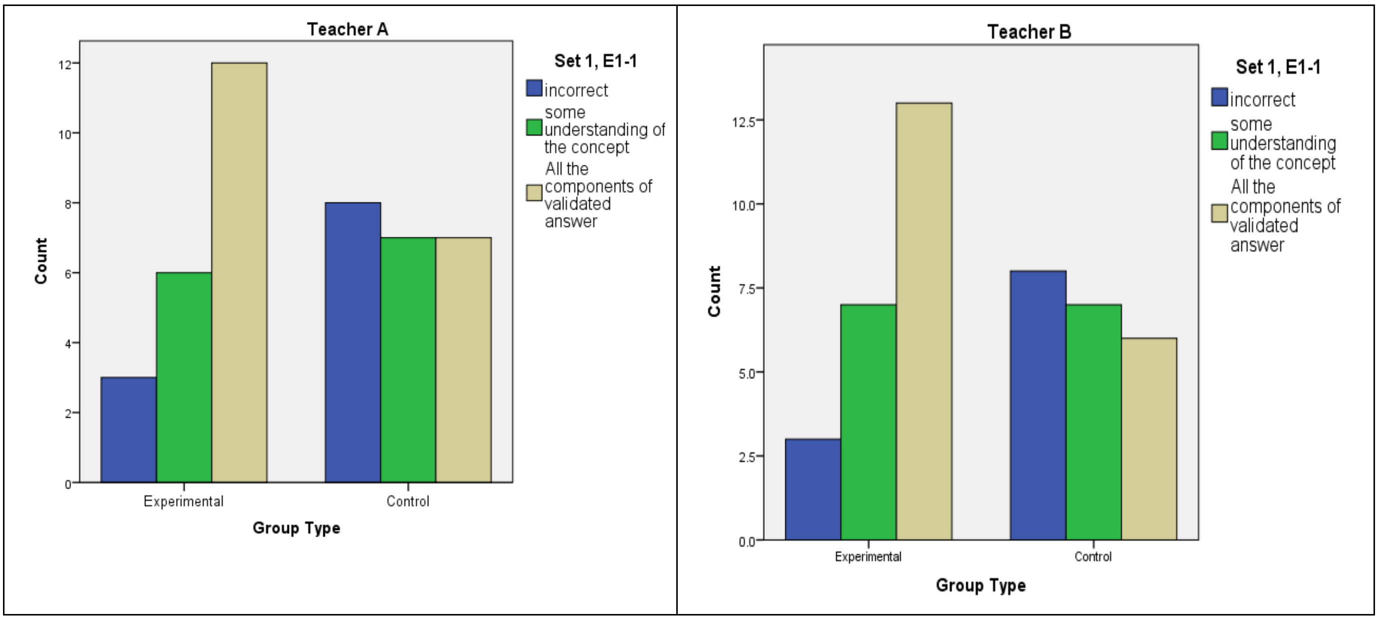
Group Type	Mean	Std. Deviation	N
Experimental	13.82	3.021	44
Control	9.43	4.043	42
Total	11.67	4.168	86

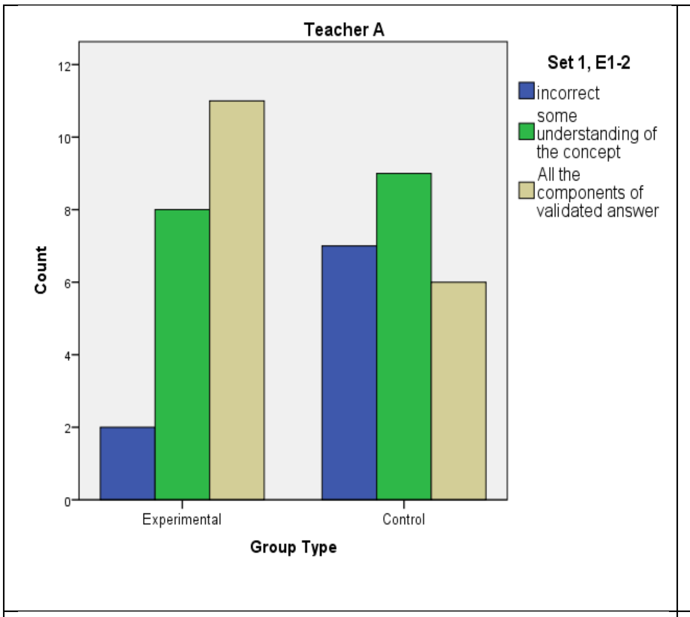
Table 6: Independent t test to examine the mean difference between the participated groups for the participating schools

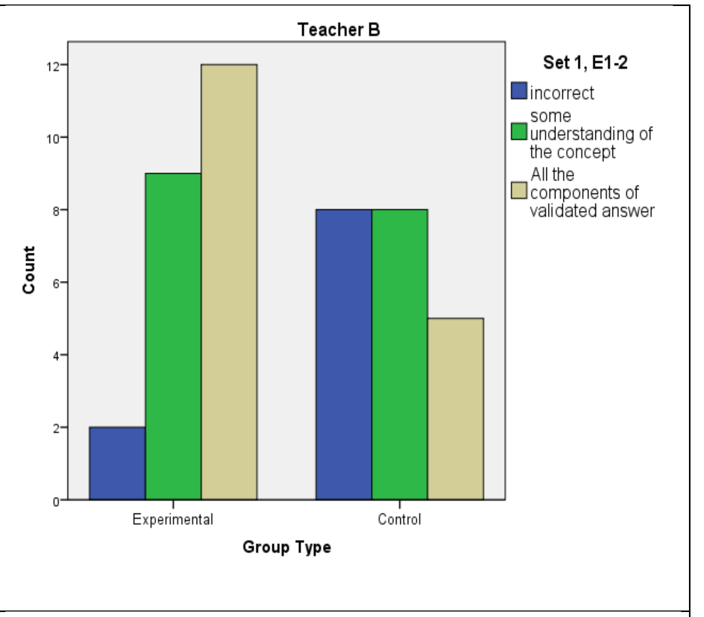
Independent Samples Test

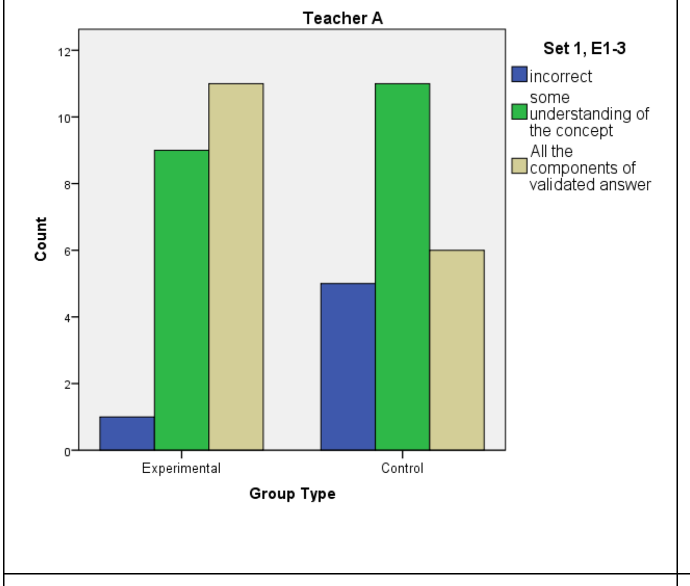
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Final grade	Equal variances assumed	6.576	.012	5.721	84	.000	4.390	.767	2.864	5.916
	Equal variances not assumed			5.682	75.817	.000	4.390	.772	2.851	5.928

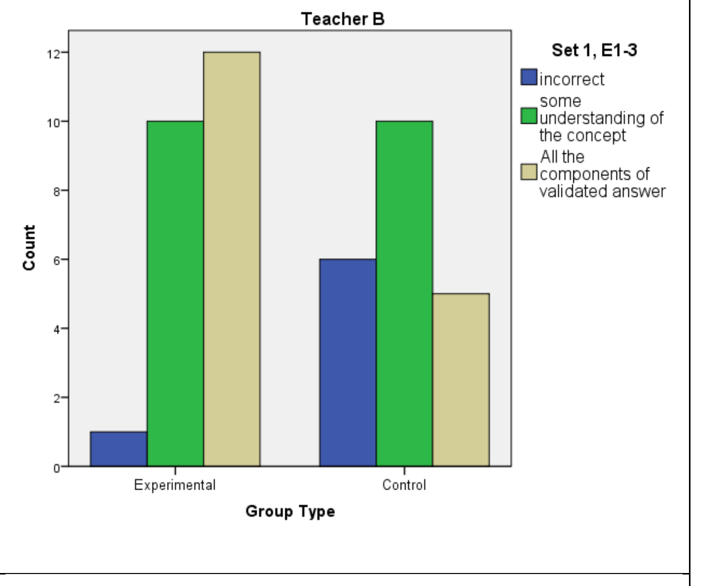
Figures:

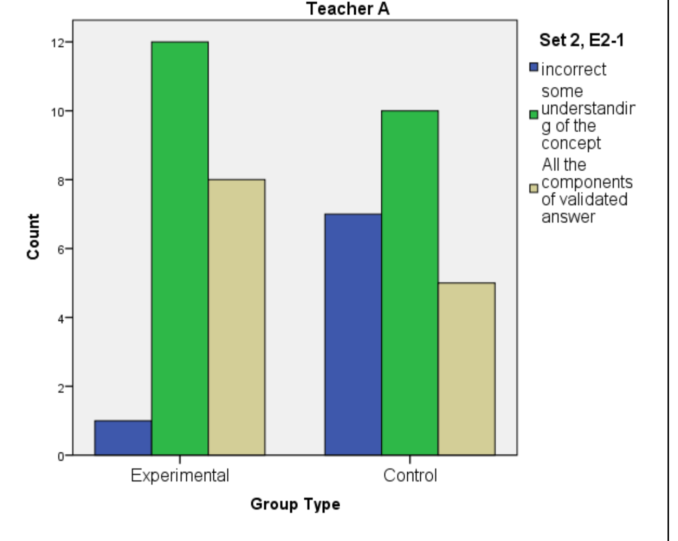


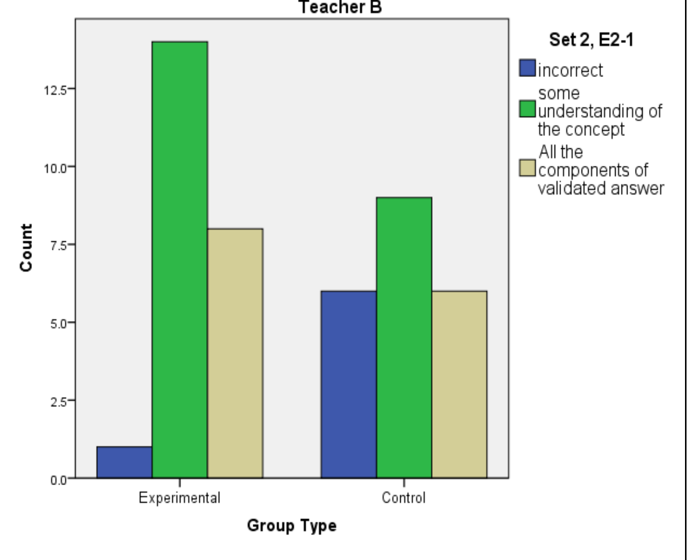

Teacher A
Count
0
2
4
6
8
10
12
Experimental
Control
Group Type
Set 1, E1-2
incorrect
some understanding of the concept
All the components of validated answer


Teacher B
Count
0
2
4
6
8
10
12
Experimental
Control
Group Type
Set 1, E1-2
incorrect
some understanding of the concept
All the components of validated answer


Teacher A
Count
0
2
4
6
8
10
12
Experimental
Control
Group Type
Set 1, E1-3
incorrect
some understanding of the concept
All the components of validated answer


Teacher B
Count
0
2
4
6
8
10
12
Experimental
Control
Group Type
Set 1, E1-3
incorrect
some understanding of the concept
All the components of validated answer


Teacher A
Count
0
2
4
6
8
10
12
Experimental
Control
Group Type
Set 2, E2-1
incorrect
some understandin g of the concept
All the components of validated answer


Teacher B
Count
0.0
2.5
5.0
7.5
10.0
12.5
Experimental
Control
Group Type
Set 2, E2-1
incorrect
some understanding of the concept
All the components of validated answer

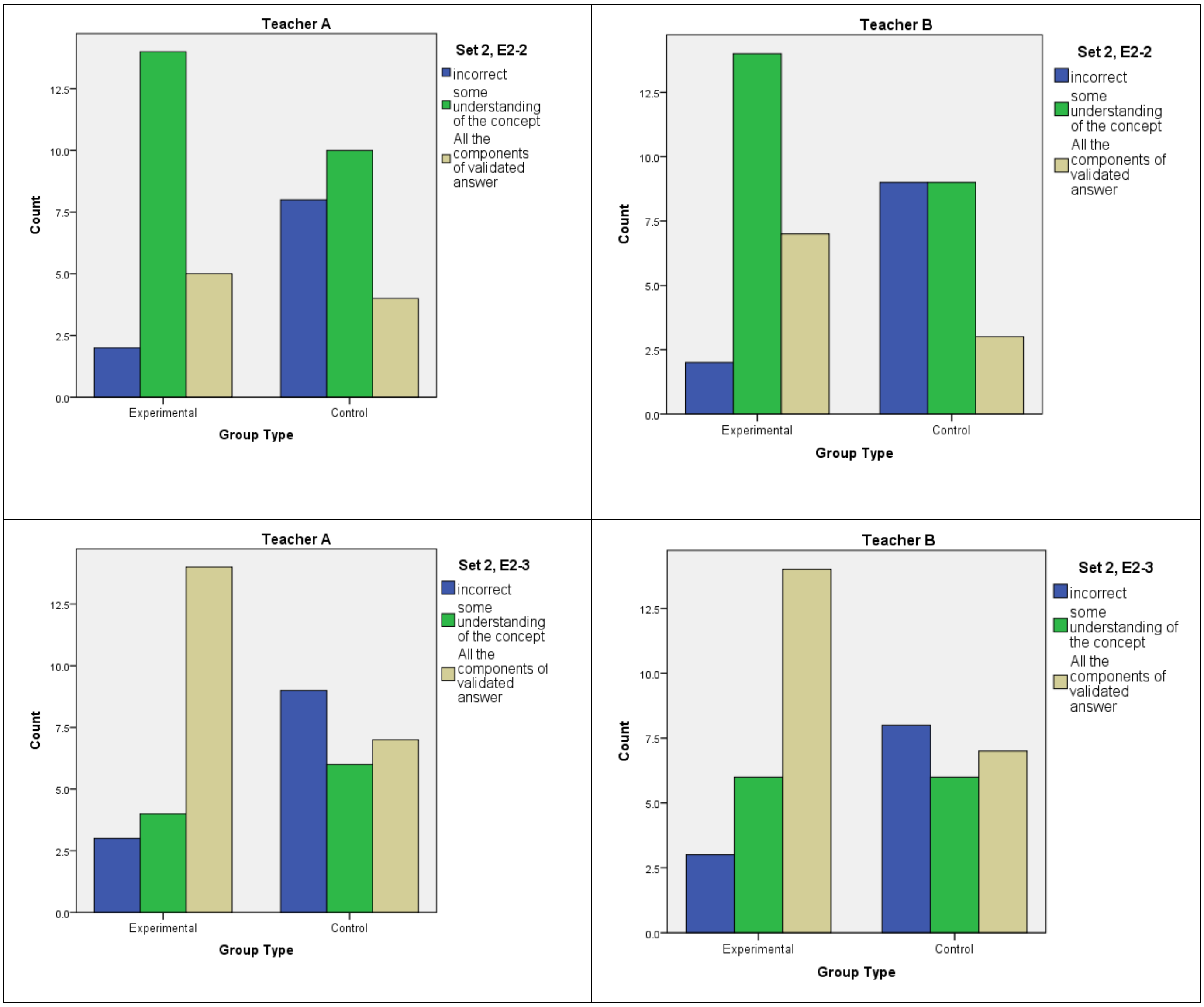


Figure 1: Compare learners' answering between participated groups