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Independent Study Simulations versus Practical Experiments: A study of 5E Model Effects as Conceptual Change Strategy in Physics

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Abstract

This study identifies and describes and treats physics misconceptions held by pre-service teachers. 30 pre-service teachers (undergraduate students) from Palestine participated in this study. Multiple choice test was used to examine misconceptions among the participants before and after participating in a conceptual change workshop designed depending on the 5E model. Pre-test and Post-test results indicated that 5E model (both by independent study simulations and practical experiments) was effective in eliminating teachers' misconceptions. Through this conceptual change workshop, the participants were also able to transfer learning and improve their understanding of untreated Physics misconceptions.

Keywords: 5E model, conceptual change strategy, physics misconceptions.

Introduction

Physics is a subject that studies the natural phenomena of the world around us, most countries support heavily teaching and learning Physics at university and school levels. However, many learners have alternative concepts that impedes understanding physics concepts. Students usually face difficulties in performing formal operations fundamental to understand physics because they hold alternative concepts (Demirci, 2005). The result is misunderstanding of important topics such as electricity, magnetism, and mechanics (McDermott & Redish, 1999). Overcoming these deficiencies is crucial in achieving effective and permanent Physics learning (Osborne & Freyberk, 1996).

Main sources of students' misconceptions are: personal experiences, textbooks, language, and teachers. In this context, misconceptions are not only to be observed in students work; even teachers have misconceptions that is similar to their students (Arslan, Çiğdemoğlu and Moseley, 2012). Therefore, teacher education programs that tackle Physics misconceptions is deemed necessary to prepare successful teachers and enhance the learning process (Kaltakçı & Eryilmaz, 2010).

The Conceptual Change Model.

Posner, Strike, Hewson, and Gertzog (1982) developed a framework of learning as conceptual change. This framework was used to change learners' conceptions in addition to help them learn new knowledge. This constructive approach emphasizes transform learning conditions and context to help students experience change and give it meaning. To apply this framework: First, students should be *dissatisfied* with the existing concept. They must discover that their present concepts are not working and they need to take action. Second, students should find the replacing concept *intelligible*. They must "understand alternative views offered as substitutes for existing ideas" (Schwartz, Shapiro & Gregory, 2013). Third, students should find the replacing concept *plausible*. They must find new knowledge reasonable to replace the previous one. And finally, students should find the replacing concept *fruitful* so that it opens a new area of inquiry. They must use this knowledge to address new questions.

The previous steps describe Piaget's idea of disequilibrium. Piaget see "disequilibrium" as a step to build a powerful "equilibrium state" through a process of "auto-regulation" (Piaget, 1985). Since students usually unaware of the conflict between their concepts and the scientific ones, educators search ways to provoke cognitive conflict (Lee & Byun, 2012; Vosniadou; 2008). And explore how to apply this process and what strategies can support it (Vosniadou, 2008; Durmus & Bayraktar, 2010). For example, Howe, Devine, and Tavares (2013) argued that scientific experiments usually fail to create necessary data for conceptual change and apply clear steps of conceptual change framework.

The 5E model is an instructional strategy that helps learners understand new concepts in comprehensive way through using their previous knowledge to discover new concepts. This model has clear procedure that could be used to create and maintain conceptual change. The following table (Table 1) present 5E model as conceptual change framework (Guzel, 2016; Mayer, 2008).

Table 1

5E Model as Conceptual Change Framework

5E model Stages	**Conceptual Change Framework**
Engage: This stage aims to help learners reveal their preconceptions and opinions. It is important to urge learners ask questions during this stage.	Learners consciously discover that they have misconceptions.
Explore: This stage aims to help learners undertake actions to answer their previous questions. Learners conduct research activities such as data collection, observation, formulating hypotheses and testing predictions.	Learners understand more information and integrate it to previous knowledge.
Explain: This stage aims to help learners put together their new experiences and reveal their concepts. Learners should clarify their concepts using their observations in scientific words.	
Elaborate: This stage aims to help learners apply their new concepts and skills to new similar cases. Learners should solve problems and make decisions to reinforce new concept learning.	Learners use their own words to think through their concepts change.
Evaluate: This stage aims to help learners validate their understanding of the concepts and assess their own progress. Learners can use concept maps, drawings, and diagnostic trees to assess their conceptual change.	Learners use the new concept as building blocks for more advanced concepts.

Literature Review

Although there are many studies that documented pre-service teachers' misconceptions in Physics, there are few studies that eliminated them through conceptual change strategies (Bailey & Slater, 2004; Summers & Mant, 1995). The following are summary of the conceptual change literature:

First, the 5E learning cycle model was more effective for conceptual change than traditional method (e.g. Bektas, 2011; Ceylan, 2008; Garcia, 2005; Lindgren & Bleicher, 2005; Pabuccu, 2008). For example, Artun and Coştu (2013) applied 5E model as conceptual change strategy to enhance pre-service teachers' conceptual understanding of diffusion and osmosis in a science methods course. This study showed that 5E model was more effective to promote conceptual understanding than traditional method. Similar results were found in the study of matter and solubility concepts (Ceylan, 2008), and acids and bases concepts (Akar, 2005).

Second, students' misconceptions usually need more than one "conceptual change method" to be corrected (Urey and Calik, 2008). For example, Bektas (2011) applied 5E model with analogy, role playing, and concept mapping to enhance students understanding of matter concepts. He found this approach was more effective when compared with traditional method. Similar results were found by Kaymakci (2016) who embedded analogical reasoning into 5E model and found that this intervention increased students' achievement and improved their science process skills when learning solar system.

Finally, computer-assisted teaching (simulations) is also more effective than traditional methods in eliminating math and science misconceptions (Gürbüz & Birgin, 2012; Çepni, Taş, & Köse, 2006). For example, Özmen and Naseriazar (2017) investigated computer simulations enhanced with conceptual change texts effects on pre-service teachers understanding of chemical equilibrium. The results indicated that computer simulations enhanced with conceptual change texts were successful way for students to understand chemical equilibrium and remediating their alternative conceptions. Baser (2006) also investigated simulations effect for conceptual change. He used a free open source software (Qucs) with pre-service teachers to promote their conceptual change when learning current electricity circuits. The results showed that the participants progress on understanding of direct current electricity was significant.

Even though simulations have positive impact on conceptual change, to achieve maximum impact of simulations, it should be challenging, focused on developing thinking skills, and presented in well-designed activities. In other words, simulations should present active instructional strategy to be more effective in tackling learners misconceptions (Demirci, 2005). Therefore, integrating simulations with conceptual change method embedded within the 5E model could be effective tool in eliminating pre-service teachers' and students' misconceptions in Physics.

The purpose of this study is to determine Physics misconceptions among a group of pre-service teachers in Palestine, and investigate the 5E learning cycle model effectiveness by both computer simulation and practical experiment in modifying misconceptions among the pre-service teachers.

Methodology

A mixed method approach (Figure 1) was used in this study. One group experimental design followed by a focus group was implemented to collect the required data and answer the research questions.

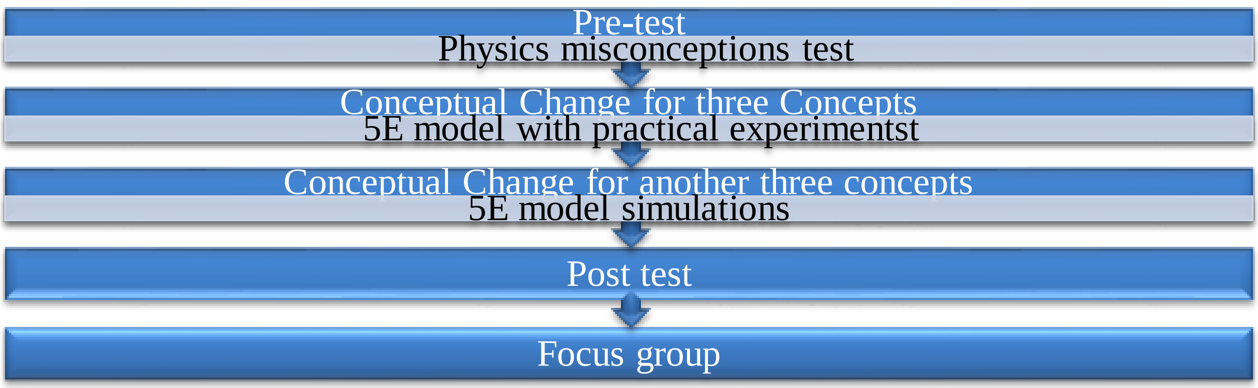

Fig. 1. Research design

Participants

The target population of this study consisted of first year undergraduate students at a Palestinian University. The following table (Table 2) present demographic data of the participants.

Table 2

Demographic data of the participants.

Specialty	Gender
Applied Math Education	Male:10
	Female:8
Computer Science Education	Male:6
	Female:6

Data Collection Method

The following procedure was used to conduct this study: 1) A test to measure pre-service teachers' Physics misconceptions was designed by the researcher. This test consisted of 18 items. 2) The test was used with Nineteen pre-service teachers to assess their physics misconceptions. Among them, fifteen participated in the conceptual change workshop. 3) Six concepts (with low scores in the pre-test) were selected to be taught to the participants in the conceptual change workshop. 4) A conceptual change lessons were designed depending on the 5E model to teach the concepts by the researcher. 5) The six physics concepts were randomly assigned to two phases. 5E model with practical experiments were used to teach three misconceptions in phase one. While 5E model with independent study computer simulations were used to teach the other three concepts in phase two. 6) The conceptual change workshop was conducted in both the science lab and the computer lab. The time on task was one hour for learning each concept. Worksheets, and misconception test were used as data collection tools to answer the research questions.

Data Analysis

Statistical Package for Social Science was used to analyze collected data. The following table (Table 3) presents pre-service teachers' scores on the post-test and the pre-test. The test measure misconceptions before and after participating in the conceptual change workshop.

Table 3

Pre-service Teachers' incorrect responses rate in both the pre-test and the post-test.

NO	CONCEPT	CODE	Pre-test Results %	Post-test Results %	Treatment Method
1	The relation between movement and kinetic energy.	RBMKE	47	53	No treatment
2	The acceleration of circular motion with constant speed.	ACMCS	40	53	No treatment
3	The acting forces on vertical projectiles.	AFVP	27	93	5E by simulation

4	Converting between temperature measurements systems.	CBTMS	40	47	No treatment
5	The relation between heat capacity and mass.	RBHC M	47	53	No treatment
6	The factors that effects on coefficient of expansion.	FECE	40	53	No treatment
7	Calculating the distance of free falling objects.	CDFFO	27	87	5E by simulation
8	The effect of air resistance on different free falling objects.	EARDE EO	33	87	5E by Practical exp.
9	Inertia Concept	IC	53	60	No treatment
10	The net force in Newton's third law	NFNTL	47	60	No treatment
11	The relation between atmospheric pressure and water pressure.	RBAP WP	33	87	5E by Practical exp.
12	Comparing between weights in outdoors.	CPWO	47	60	No treatment
13	The measuring unit of atmospheric pressure.	MUAP	47	60	No treatment
14	The difference between distance and displacement.	DBDD	53	60	No treatment
15	The difference between specific heat of water and ice.	DBSH WI	33	87	5E by Practical exp.
16	The relation between volume, density, and temperature of water.	RBVDT W	20	93	5E by simulation
17	Calculating the weight of floating objects.	CWFO	67	73	No treatment
18	The acceleration of vertical projectiles at maximum height.	AVPM H	67	87	No treatment

The previous table (Table 3) showed that the highest six Physics misconceptions among pre-service teachers were: The relation between volume, density, and temperature of water (RBVDTW), The acting forces on vertical projectiles (AFVP), The relation between heat capacity and mass (RBHCM), The effect of air resistance on different free falling objects (EARDFFO), The relation between atmospheric pressure and water pressure (RBAPWP), and the difference between specific heat of water and ice (DBSHWI).

Learning cycle model (5E) by computer simulation was used to teach three concepts: CDFFO, RBVDTW, and AFVP for all participants. While learning cycle model (5E) by practical experiment was used to teach the other three concepts: DBSHWI, RBAPWP, and EARDEEO.

Shapiro-Wilk test was used to test data normality since the number of participants in this study is small (N=15). The results revealed that the data was normally distributed *(P=.098 >.05)* and t-test can be conducted.

The t-test was conducted to compare pre-service teachers scores on the physics misconceptions test on all the eighteen test items before and after participating in the 5E learning cycle model conceptual change workshop. The results revealed that there is significant difference at the 0.05 level on the participants scores as seen from Table 4.

Table 4

T-test results comparing participants scores before and after participating in the workshop

5E Conceptual Change Model	N	Mean	SD	t	Sig
Before Participating	30	43	.11	-.694	.00
After Participating	30	70	.10		

P >.05

T-test was also conducted to compare the post-test results of the three physics misconceptions that have been taught by practical experiments with the other three physics misconceptions that have been taught by computer simulations. The results revealed that there is no significant difference at the 0.05 level on the participants scores as seen from the following table (Table 5).

Table 5

T-test results comparing participants scores on the two conceptual change models

5E Conceptual Change Model	N	Mean	SD	t	Sig
By Computer Simulation	30	91	.19	-.595	.556
By Practical Experiments	30	87	.21		

P >.05

A focus group was also conducted with ten participants to shed more light on the major finding of this study. A summary of the responses and the questions follows.

Question 1: Do you think it was easy for you to use 5E model steps? Why or why not?

The majority (80%) of the participants in the focus group considered that learners can easily use and understand the 5E model steps. One of the participants said, "The worksheets were clear enough for me to understand what is required and figure out the physics concept." Another one added. "both lessons (lab and simulations) have clear steps that helped me understand relationship between Physics concepts."

Question 2: Compare between learning by 5E model with laboratory experiments and simulations? Explain.

A majority (70%) of the focus group participants found that conducting the lab experiments was hard experience when compared to the simulations. One of them said “It took me time to find suitable apparatus and start data collection’’. Another participant added “simulations gave us more control on physics parameters.”

Questions 3: What are the benefits that you gained from this learning experience? Explain.

Most of the participants in the focus group (80%) mentioned that they had an exciting experience. Majority of them were able to conduct the required experiment and follow the 5E model steps in the worksheets. One of the participants said, “following the 5E model steps helped me follow thinking procedure when linking physics concepts to each other” another one added “I started thinking deeply and connect between physics concepts before answering questions.”

Discussion

This study determined Physics misconceptions among a group of pre-service teachers and investigated the 5E learning cycle model effectiveness in modifying these misconceptions. Analysis of the results revealed that pre-service teachers have many physics misconceptions with different degree levels (Table 3). The t-test results (Table 4) showed that the 5E learning cycle model was effective conceptual change strategy (both by practical experiment and independent study simulations). This result was supported by Abdulkadir (2013), Artun and Coştu (2013), and Syuhendri (2017) who found in their studies that 5E learning cycle model have positive impact in modifying misconceptions. The researcher proposed this result to some advantages of the 5E model. The model worksheets helped the learners express their current thinking and reflect on them. This process was effective in helping the participants realize their own unscientific opinions and correct them. Second, it seems that the 5E model as conceptual change strategy provided the participants with thinking process that helped them think scientifically and figure out relationship between Physics concepts. As one of the participants in the focus group mentioned “following the 5E model steps helped me follow thinking procedure when linking physics concepts to each other”.

After participating in the workshop, the participants were able not only to correct the highest score six misconceptions, but also to transfer learning and correct other untreated misconceptions as seen from Table 3. Both 5E learning cycle conceptual change strategies (through independent study simulations and practical experiments) were effective in eliminating physics misconceptions with no statistical difference between them as seen from Table 4 and Table 5. In other words, the independent study simulations can be as effective as real practical experiments in eliminating pre-service teachers’ misconceptions when designed depending on effective conceptual change strategy (5E model). This result was supported by Demirci (2005), James and Lamb (2000) and Weaver (2000) who found positive impact of simulations on understanding concepts. The focus group could explain this result since one of the participants mentioned that simulations gave the participants control on physics parameters. It seems that independent study simulations gave the participants an opportunity to learn through a step by step procedure and interact with a dynamics physics concept. This opportunity creates an effective way equal to real laboratory experiences in helping learners conceptualize Physics phenomena.

Conclusion

This study revealed some problematic issues concerning teaching physics in Palestine as evidenced by the fact that the pre-service teachers have many physics misconceptions. Identifying the sources of misconceptions is difficult at best. While this study focused primarily on the 5E model as conceptual change strategy (both by computer simulation and practical experiment) other strategies like predict, observe and explain POE could be effective in developing pre-service teachers’ misconceptions. It is imperative, then, educators develop and apply these strategies to examine their effectiveness in eliminating teachers’ and students’ misconceptions. Independent study simulations seem to be as effective as real laboratory experiments in eliminating misconceptions when designed based upon an effective instructional model (5E model). Instructional technology specialists can design simulations based on other instructional models to apply them as conceptual change strategies and examine their effectiveness.

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