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An Evaluation of Macro-Micro Representation-based Computer Simulation for Physics Learning in Liquid Pressure: Results on Students' Perceptions and Attitude

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Abstract: Computer simulation has been widely used to enhance teaching and learning for last decades and researchers mentioned that the use of computer-simulated experimentation can actively engage and enhance student's meaningful learning in subject contents. As such, a computer simulation for physics learning in liquid pressure has been created with regarding the interplay among macro- and micro representation of physical knowledge. To evaluate the developed simulation, 40 twelve-grade students were recruited to participate with the simulation. A Likert-scale perception and attitude questionnaires were administered to the students before the participation as pre-test. The perception questionnaire was, only, distributed to the student as post-test. The repeated-measures MANOVA results indicated that there was no significant main effect on gender and interaction effect between gender and time (pre-test/post-test), but there were significant main effect on time. That is, there was no effect of gender difference on students' perceptions towards physics learning through computer simulation. Moreover, Pearson's correlation indicated that the computer simulation could be used to promote physics learning experience for all students even if they have a negative or positive attitude toward physics lessons

Keywords: Computer simulation, interactive experience, physics learning, content representation

1. Introduction

Currently, innovative technologies in science teaching and learning is growing continuously. The use of learning technologies such as computer simulation offers students an interactive learning experience and allows students to learn on their own way (Vreman-de Olde et al. 2013). Computer simulations have become increasingly powerful and available to teachers in the past decade (Trundle and Bell, 2010). In community of science and technology education, computer simulation is recognized as a pedagogical tool to support conceptualization of science concepts and facilitate process of scientific inquiry or discovery by visualizing and interacting with dynamics models of natural phenomenon (Ton and Joolingen, 2012; Perkins et al., 2006; Wieman, Perkins and Adams, 2008). These technology offer idealized, dynamic and visual representations of invisible phenomena and experiments which would be dangerous, costly or otherwise not possible in school laboratories (Hennessy, 2007). In addition, researchers found that a learning environment with computer simulation has the advantages that students can systematically explore hypothetical situations, in a realistic environment without stress, in comparison with textbooks and lectures (Rutten, Joolingen, and Veen, 2012).

In physics education, pressure of liquid is a fundamental concept for student's comprehension about fluid mechanics concepts. A few studies have reported that students often encounter learning difficulties and hold unscientific understanding of this concept. There were many misconceptions about the liquid pressure among high school students (Kariotoglou and Psillos, 1993). For example, most of students believed that the shape of the container and amount of the liquid is effective on liquid pressure (Sahina, Çepni, and Ipek, 2010). According to this problem, this study aims to develop a macro-micro representation-based computer simulation for physics learning in liquid pressure to facilitate student's conceptual comprehension of these physics concepts. In this study, a preliminary findings on secondary school students' perceptions was reported.

2. Application of Computer Simulation in Science Education.

Computer simulations are a powerful instructional tools which has been recognized by the community of science education by presenting theoretical, experimentation, models of real-world components, phenomena, processes in science, for students in order to observe, explore, recreate, and receive immediate feedback about phenomena and processes. To support effective science learning activities, computer simulation was used to facilitate their learning difficulties and abstract and complicated content as conceptual learning tools. (Chen et al. ,2011; Colella, 2000; de Jong and Van Joolingen, 1998). In an addition, computer simulation helps learners to understand chemical or biological phenomena which are not able to observe directly (Cook 2006; Wu and Shah 2004). To create awareness through higher-order thinking skill, function of real-time data displays related to a dynamic phenomenon and information on how change parameters synchronously were employed into simulation-based teaching and learning. (de Jong and van Joolingen, 1998; Ronen and Eliahu, 2000).

Even student hold alternative conceptions about science-related phenomena, computer simulation could be used to support a more meaningful learning in science concepts through the process of conceptual change (Srisawasdi and Kroothkeaw, 2014). Computer simulation has significant potential as a supplementary tool for effective conceptual change learning based on the integration of technology and appropriate instructional strategies. There are several educational values that computer simulation adds into science learning activities (Hennessy et al. 2006). As such, successful concepts of simulation-based teaching and learning have been reported by means of discovery learning (de Jong and van Joolingen, 1998; de Jong, Linn, and Zacharia, 2013) and inquiry-based learning (Perkins et al., 2006; Srisawasdi and Kroothkeaw, 2014; Wieman, Perkins, and Adams, 2008). With the importance, computer simulations are effectively linked to pedagogy as well. (Flick and Bell 2000). Following these class types, student can discover the principles, rules, and characteristics of scientific phenomena through change variable values and observe effects to form scientific conclusions in computer simulation (Veemans et al., 2006). Therefore, the use of computer simulation with theses pedagogical approaches could be as instructional line for teaching and learning in school science.

3. Purpose

The goals of this study were to investigate students' perceptions towards computer-simulated physics experimentation and correlation between attitude toward physics and physics motivation after interacting with the computer-simulated physics experimentation. Specifically, the following questions were answered:

(1) Do the students engaged in computer-simulated physics experimentation perform significantly better by perceive learning, flow of learning experience, enjoyment, perceive ease of use, perceive of satisfaction, and perceive of usefulness?

(2) How were the influence of physics attitude on students' perceptions after interacting with computer-simulated physics experimentation?

4. Method

4.1 Participants

A total of 40 twelfth grade students (female = 25, male = 15), age ranging from 17 to 18 years, in a local public school at the northeastern region of Thailand participated in this study. They were attending a physics course for basic education level. Regarding to prior learning experience, they have no experience yet using computer-simulated experiment in physics. This implied that they are heterogeneous on perception towards computer-simulated physics experimentation before interacting with the present experimental study.

4.2 Instructional Materials

The design of computer-simulated experimentation in physics of liquid pressure provides a rich context of representations where macro- and micro-scale representations were employed coordinately to visualize how the physical phenomena works. In additions, the computer-simulated physics experiment on liquid pressure has been produced by examining the attributes of the physics concept to provide information in which essential mental sets are needed to construct a scientific view of the concepts. According to this step, a concept map associated to learning liquid pressure simulation was constructed in hierarchical order of attributes. After the attributes and essential underlying concepts were identified by the researchers and two experts. As such, it involved three essential parameters (i.e. depth of water, shape of container, and density of liquid) which related to liquid pressure phenomenon, as shows in Figure 1.

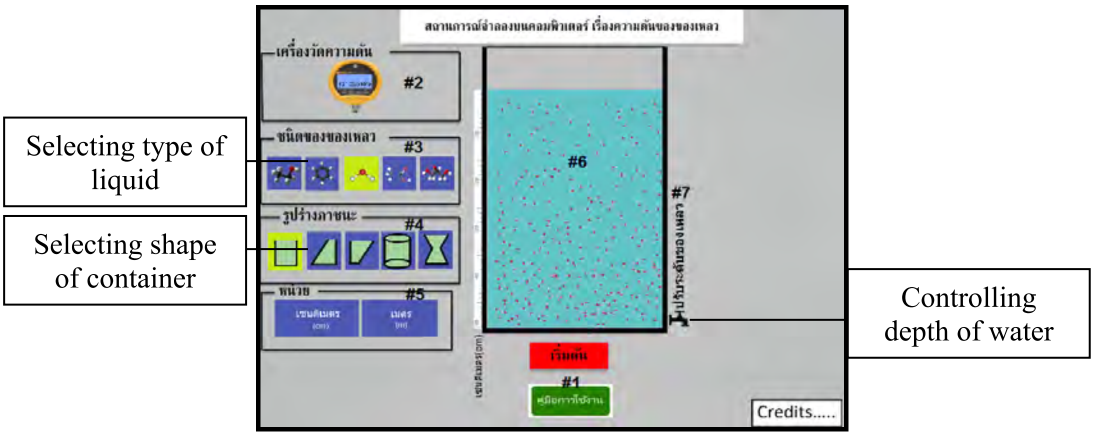

Figure 1. Example of screen interface of computer-simulated physics experiment on liquid pressure

For the parameter of depth of water, the computer-simulated physics experiment on liquid pressure prepares to build student's conceptual knowledge on relationship between the depth of water and pressure, and serves physical understanding on what would happen to pressure if height of water is changed. In this part, student could interact with controlling levels of liquid and then measure its pressure by using a pressure gauge. Moreover, they could also see whether the liquid molecules behave relating to the depth. Figure 2 displays an example of interactive features in the computer-simulated physics experiment on relationship between liquid pressure and depth.

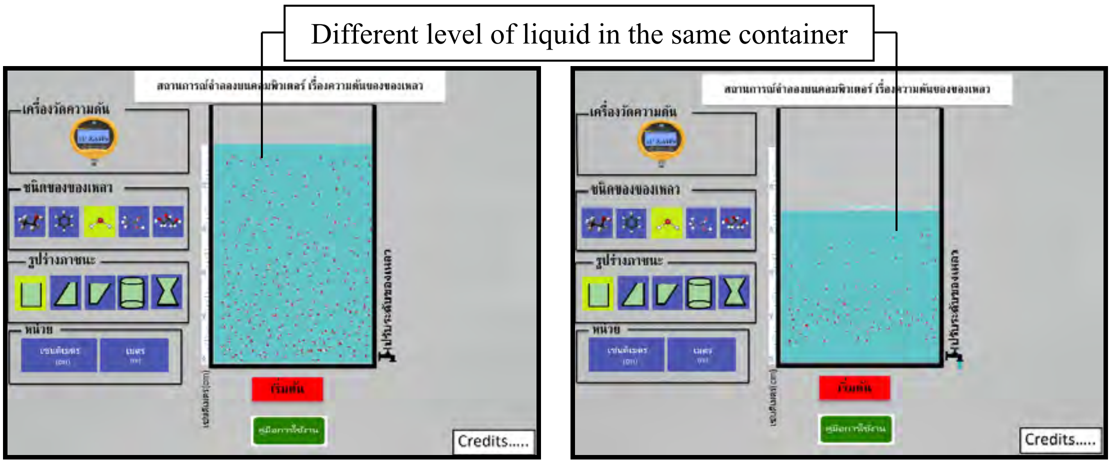

Figure 2. Interactive feature of different levels of liquid in the liquid pressure simulation on relationship between liquid pressure and depth

To facilitate student's conceptual knowledge on impact of liquid density on its pressure, the computer-simulated physics experiment on liquid pressure provides opportunity to select different types of liquid (i.e. ethanol, benzene, water, acetic acid, and glycerin) for investigating the concept. In this part, student could interact with selecting types of liquid and then measure its pressure. Moreover, they could also see whether the liquid molecules behave relating to the type of liquid. Figure 3 displays an example of interactive features in the computer-simulated physics experiment on relationship between density of liquid and its pressure.

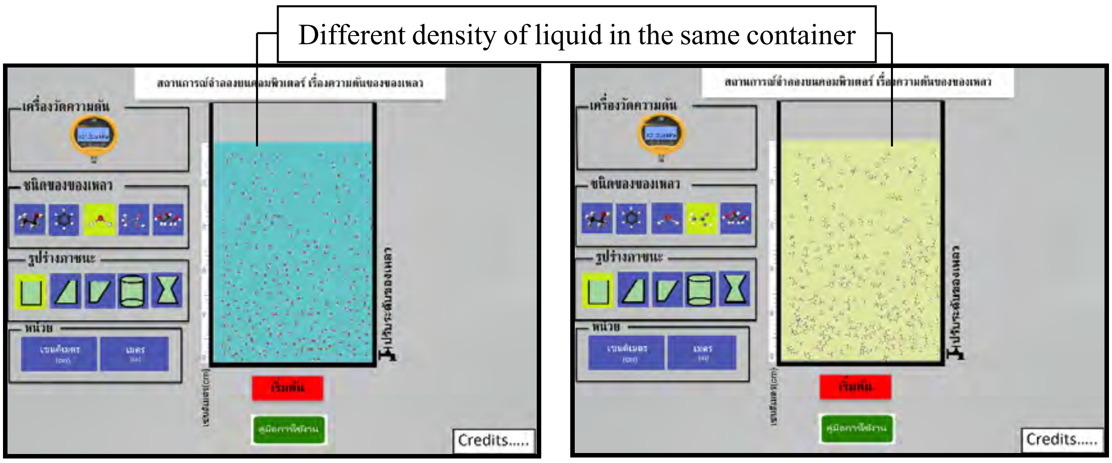

Figure 3. Interactive feature of different densities of liquid in the liquid pressure simulation for measuring the liquid pressure

Visualizing an effect of shape of container on liquid pressure was an aim for creating this computer-simulated experimentation. Figure 4 displays an example of interactive features in the computer-simulated physics experiment on relationship between shape of container and liquid pressure. Student could interact with the experiment by selecting a shape of container and then measure its pressure by using a pressure gauge. This part prepares to build student's conceptual knowledge on what would happen to pressure if shape of container is changed.

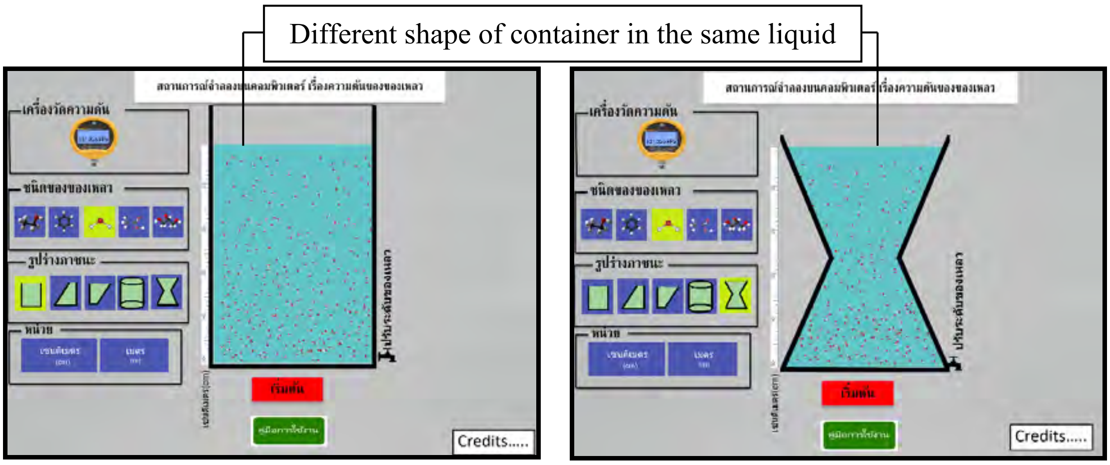

Figure 4. Interactive feature of different shapes of container in the liquid pressure simulation

4.3 Instrument

A 21-item Likert-scale questionnaire was developed to use in this study for examining students' perceptions towards the computer-simulated physics experiment on liquid pressure on six subscales: flow, enjoyment, perceived learning, perceive ease of use, perceive of usefulness, perceive of satisfaction. All of these 5-point Likert scale items obtained from (Cheng, 2014) and Barzilai and Blau (2014). From the English version, an identical version in Thai was constructed, and one expert was recruited to identify communication validity of the items. The respondents were required to consider each possible reason for computer simulation and rate how much the respondent agree with into five scale (1-strongly disagree; 2-disagree; 3-neutral; 4-agree; 5-strongly agree). The reliability for the overall questionnaire was 0.88 and for each subscale was presented in Table 1.

Table 1: Example items of perception questionnaire for each construct.

Dimension	Sample items	α
Perceive learning	▪ The simulation added to my knowledge. ▪ I learned new things from the simulation. ▪ The simulation will help me remember the things I learned.	0.803
Flow	▪ I lost track of time when I played. ▪ I really got into the simulation. ▪ I was very involved in the simulation.	0.822
Enjoyment	▪ I enjoyed the simulation. ▪ I had fun playing the game. ▪ Playing the simulation was pleasant.	0.745
Perceive ease of use	▪ It is easy for me to learn how to use simulation. ▪ The user interface of simulation is easy to use. ▪ I can easily accomplish what I need to do in simulation.	0.737
Perceive of usefulness	▪ Simulation can help me learn more effectively. ▪ Simulation can improve my course performance. ▪ It is useful to study the course content with simulation.	0.842
Perceive of satisfaction	▪ I feel comfortable to use simulation. ▪ I enjoy the experience of using simulation. ▪ I am willing to continue using simulation for learning in other courses	0.774

In an addition, a 25-item Likert-scale questionnaire obtained from Ayyıldız and Tarhan (2013) was applied to measure attitude towards physics lessons. All items were classified into four scales, including interest in chemistry lessons (6 items), understanding and learning physics (10 items), importance of physics in real-life (5 items), and occupational choice related to physics (4 items). Its cronbach's alpha reliability coefficient of this instrument was 0.88, implying that it is reliable. Each scale has cronbach's alpha reliability coefficient from 0.52 to 0.82. Table 2 shows the sample item and description for four scales.

Table 2: Scale descriptions and sample items for the physics attitude questionnaire

Scale	Description	Sample item
Interest in physics lesson	Extent to which student preferred physics learning.	I would like the teaching period of the physics lesson more often.
Understanding and learning physics	Extent to which student developed themselves and implicated in physics easily.	I find using symbols in physics to be easy.
The importance of physics in real life	Extent to which student thought physics were appropriate to real-life.	I believe that physics knowledge helps us interpret seriously events in our daily life.
physics and occupational choice	Extent to which student use the information learned in the physics classroom for the futuristic work.	My career could be physicist/ physics teacher/ engineer.

4.4 Data Collection and Analysis

The participants were asked to complete the perception questionnaire, to measure their pre-perceptions towards the computer-simulated physics experiment on liquid pressure, and the physics attitude questionnaire, to measure attitude towards physics lessons, for 15 minutes. After completing the instrument, they were exposed to interact dependently with the experiment for 25 minutes. After completing the experiment, the students' post-perceptions were examined by the same questionnaire for 10 minutes. The statistical data techniques selected for analyzing students' science motivation was repeated-measures MANOVA in SPSS to compare effect of intervention considering gender (female/male) and time (pre-test/post-test). In an addition, Pearson's correlation was used to investigate relationship between physics attitude (interest in physics lesson, understanding and learning physics, importance of physics in real-life, physics and occupational choice) and their perceptions (flow, enjoyment, perceived learning, perceive ease of use, perceive of usefulness, perceive of satisfaction).

5. Results

The MANOVA indicated no significant main effect for gender (Wilks' lambda=0.875, F (6, 33) =0.783, p=0.589, partial η^2 = 0.125). There was no significant difference on perceived towards learning science through computer simulation between females and males. The univariate results on gender revealed none of the six subscales on perceived towards learning science through computer simulation reached a statistical significance between females and males. That is both females and males performed indifferently with regard to perceive learning (PL), flow (Fl), enjoyment (Ej), perceive ease of use (PE), perceive of usefulness (PU), perceive of satisfaction (PS). Also, there was no significant interaction effect between gender and time (Wilks' lambda=0.915, F (6, 33) =0.795, p=0.085, partial η^2 = 0.090). This means that the learning module has similar effects on perceived towards learning science through computer simulation for females and males. However, there was a significant main effect for time (Wilks' lambda=0.475, F (5, 40) =5.201, p<0.005, partial η^2 = 0.525). The multivariate eta squared, η^2, indicates the effect size, and a value of 0.525 means that about 52.5% of multivariate variance of the dependable variables was associated with time. The results of the univariate test for females and males students are summarized in Table 3.

Table 3: The students' perceptions towards computer-simulated physics experiment by time and univariate MANOVA.

Dimension	Time		F	Sig.	η^2
	Pre-test	Post-test			
Perceive learning (PL)	10.82 (3.16)	13.85(2.09)	21.170	0.000***	0.385
Flow (Fl)	12.86 (3.50)	15.62 (2.549)	12.322	0.001**	0.245
Enjoyment (Ej)	8.54 (2.47)	9.82 (2.11)	4.647	0.038*	0.109
Perceive ease of use (PE)	8.06 (2.23)	9.56 (1.93)	10.263	0.030*	0.213
Perceive of usefulness (PU)	8.69 (2.40)	9.94 (1.71)	6.230	0.017*	0.141
Perceive of satisfaction (PS)	8.74 (2.73)	10.79 (1.96)	14.158	0.000***	0.227

Note. $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$

As can be seen in Table 3, The univariate MANOVA on the six dimension scores of perceived towards learning science through computer simulation were significant differences across time, from pre-test to post-test. The univariate results revealed a significant effect on PL ($F_{1,38} = 21.170$, $p < 0.05$, partial $\eta^2 = 0.385$), Fl ($F_{1,38} = 12.333$, $p < 0.05$, partial $\eta^2 < 0.245$), Ej($F_{1,38} = 4.647$, $p < 0.05$, partial $\eta^2 = 0.109$), PE ($F_{1,38} = 10.263$, $p < 0.05$, partial $\eta^2 = 0.213$), PU ($F_{1,38} = 9.940$, $p < 0.05$, partial $\eta^2 = 0.141$) and PS ($F_{1,38} = 14.158$, $p < 0.05$, partial $\eta^2 = 0.227$). According to aforementioned results, the overall result suggested that the increase of perceived towards learning science through computer simulation regarding perceive learning, flow, enjoyment, perceive ease of use, perceive of usefulness and perceive of satisfaction from the pre-test to post-test was homogeneous both females and males after participating with the computer simulation. That is, there was no effect of gender difference on perceived towards learning physics, through computer simulation learning.

For examining correlation between their physics attitudes and perceptions towards the experiment, Table 4 shows Pearson's correlation of interest in physics lesson (IPL), understanding and learning physics (ULP), importance of chemistry in real-life (IPR), physics and occupational choice (POC), and perceive learning (PL), flow (Fl), enjoyment (Ej), perceive ease of use (PE), perceive of usefulness (PU), perceive of satisfaction (PS). Mean and standard deviation are also presented in Table 3.

Regarding Pearson's correlation analysis of each variable, the result showed that there were no significant correlation between students' physics attitudes and perceptions towards the computer-simulated physics experiment. Thus, the result implied that the experiment could be used for all students even if they have a negative or positive attitude toward physics lessons.

Table 4: Descriptive and correlation for Attitude toward physics lesson and perceptions.

Variable	IPL	ULP	IPR	POC	PL	Fl	Ej	PE	PU	PS
IPL	-									
ULP	0.56^{**}	-								
IPR	0.02	0.26	-							
POC	0.25	0.30	0.09	-						
PL	-0.09	-0.22	0.07	-0.27	-					
FL	0.10	-0.07	0.09	-0.06	0.55^{**}	-				
EJ	-0.03	-0.12	-0.00	-0.16	0.64^{**}	0.79^{**}	-			
PE	0.01	-0.23	-0.10	-0.10	0.26	0.53^{**}	0.33^{*}	-		
PU	0.05	-0.16	0.23	-0.25	0.48^{**}	0.70^{**}	0.65^{**}	0.45^{**}	-	
PS	-0.12	-0.10	0.14	-0.06	0.53^{**}	0.52^{**}	0.59^{**}	0.30	0.70^{**}	-
Mean	15.38	28.03	15.65	10.43	13.58	15.48	9.80	9.58	9.93	10.73
SD	2.77	4.71	3.17	2.51	2.09	2.54	2.11	1.93	1.71	1.96
Note. *p < 0.05, **p < 0.01										

6. Discussions

This study reports an impact of an innovative technological tool for physics instruction, a computer-simulated experimentation on liquid pressure, for promoting students' perceptions and attitude towards physics lessons. This tool was developed by emphasizing the interplay between macro- and micro-scale representations to induce cognitive process on construction of conceptual understanding and mental model. The result shows an increasing of students' perceptions scores from pre-test to post-test reached a statistically significant effect across the time, and gender different had no significantly effect on the increasing of perceptions. This finding could be argued that in physics concept made progress throughout their experiencing with the computer-simulated experimentation on liquid pressure. This indicates that the experimentation successfully helped students getting better perceptions for physics learning of liquid fluid. The result is consistent with the research findings that students performed better achievements with learning from computer simulation (Tuan Soha, et. al., 2010). Based on attitude theory, Zimbardo and Leippe (1991) stated that attitudes can be either negative or positive and these attitudes can affect both perceptions and behavior. However, this study indicated contradict with the theory that there was no effect of students' prior physics attitudes on their perceptions towards computer-simulated experimentation.

7. Conclusion

A macro-micro representation-based computer simulation for physics learning in liquid pressure has been developed to promote students' conceptual comprehension and motivate them to learn physics more meaningfully. To preliminary evaluate its effectiveness for physics teaching and learning, this study employed the physics computer simulation to students and findings revealed that (i) gender difference has no effect on students' perceptions towards learning of physics through macro-micro representation-based computer simulation, and (ii) their attitudes towards physics lessons have no effect on the use of the computer simulation for physics learning in liquid pressure. As such, it is clear that both females and males increased their perceptions on perceive learning, flow, enjoyment, perceive ease of use, perceive of usefulness, and perceive of satisfaction after interacting with the simulation. Moreover, their attitudes towards physics lessons cannot intervene perceptions when they learn from the computer simulation. These findings could be used as a basis to develop an alternative computer simulation for promoting physics instruction by emphasizing an interplay of macro- and micro-scale representations.

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