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Promoting Students' Physics Motivation by Blended Combination of Physical and Virtual Laboratory Environment: A Result on Different Levels of Inquiry

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Abstract: In science and technology education community, technology-based pedagogy in science learning has been mentioned its effectiveness for facilitating scientific inquiry in school science. As such, this study investigated an effect of inquiry-based learning process into a blended combination of hands-on microcomputer-based laboratory and computer-simulated laboratory on secondary school students' physics motivation. Study participants were 66 eleventh-grade students of diverse learning abilities in a public school in Northeastern region of Thailand. They were measured intrinsic motivation (IM), career motivation (CM), self-determination (SDT), self-efficacy (SEC), and grade motivation (GM) in physics learning by using a 25-item questionnaire both before and after participating the intervention. To evaluate the intervention, repeated-measures MANOVA was performed to examine its effects regarding type of inquiry (open- and guided inquiry) and time (pre- and post-test). The results showed that students' physics motivation for pre- and post- test were significantly different and their motivation were improved after participating with blended combination of hands-on microcomputer-based laboratory and computer-simulated laboratory for both types of inquiry. This evidence indicated that inquiry-based physics learning with the blended laboratory environment (physical and virtual lab) influenced students' progression of physics motivation. As such, blended combination of hands-on microcomputer-based laboratory and computer-simulated laboratory could be considered as a pedagogic technology-based laboratory environment for teaching and learning of science by inquiry.

Keywords: Sound wave interference, Microcomputer Based Laboratory (MBL), Computer simulation, and Motivation

1. Introduction

Several students have experienced difficulty in physics course due to misconceptions in many physics contents (Singh, Singh, Kumari, and Kumar, 2011), especially properties of sound wave. By the nature, properties of sound wave involve reflection, interference, reflection, diffraction, and also propagation of sound wave. Meanwhile, sound wave interference is invisible, complicated, and boring (Hola, 2007). Normally, teachers' teaching in a regular classroom can encourage students to succeed in school and unable to motivation to learn as interact in complex ways to lead learning (Schunk, 2005). Teacher's teaching approaches also depress motivation of students and decrease students' learning performance in physics. Recently, most researchers have been concentrated on the scientific conceptions. The issues of motivation to learn physics has been attended in respect of science achievement and scientific conceptions (Hamzah and Mdzain, 2010). However, it's difficult to achieve this ultimate goal because many learners are treated with a lack of motivation to learn science (Glynn, Brickman, Armstrong, and Taasoobshirazi, 2011).

In the recent year, students are educating a shift from passive sitting and listening to a more dynamic learning experience. Several active-teaching methods are introduced to solve those problems. Inquiry-based approach is a verity of instructional methods to apply with high school students. Science educators also confirmed methods of inquiry are more effective and valued to both teaching and learning (Guzey and Roehrig, 2009; Sadeh and Zion, 2011). The use of inquiry-based approaches is strongly subscribed to teaching and learning of science (Minstrell and VanZee, 2000), student-centered, providing students with opportunities to formulate and conduct their own scientific investigations (Singer, Marx, and Krajcik, 2000). Scientific inquiry tasks play an important role for students in the process of conceiving scientific problems and questions, formulating hypotheses, designing experiments, gathering and analyzing data, and drawing conclusions (Hofstein, Navon, Kipnis, and Naaman, 2005).The researchers also revealed that the cookbook-laboratory activities do not promote the development of students' higher order thinking skills. On the other hand, in inquiry-based laboratory students are more associated with, and usually have positive attitudes regarding their laboratory experience (Abd-El-Khalick and Akerson, 2004)

On top of that, this learning process is a wide range of efficient technological environments and applications including animations, simulations and modeling tools, microcomputer-based laboratories (MBL), intelligent tutoring systems, web resources and environments, spreadsheets, scientific databases, for instance, in the science education community of practice. Using as tools, MBL and computer simulation are subject to introduce students' cognitive development and result in students' positive response (Hola, 2007) because they facilitated to understand the scientific conceptions that confront them (Mulder, Lazonder, and Jong, 2011; Russell, Lucas, and McRobbie, 2003). It was not until third decade ago, MBL was reported to understand and integrate learners the sophisticated topics of physics including temperature probe, heat energy (Russell et al., 2003), and properties of sound wave (Gunhaart and Srisawasdi, 2012). Furthermore, the capacity of MBL enable learners to immediately transform data from each experiment into graph, the most powerful form of presentation. Learners will be engaged a construct and had conceptualized change after all. In the interval, computer simulations are examined to be the most technically complicated option for offering various benefits for the teaching and learning of science (Blake and Scanlon, 2007). For this reason, a well-designed computer simulation used within MBL as educational technology and inquiry learning as instructional process can be very effective in promoting meaningful learning in scientific concepts (Bell and Trundle, 2008)

This research utilized both tools to engage learners a meaningful learning of sound wave interference. Conceptualized change was expected to achieve by measuring five components involving Intrinsic motivation (IM), Career motivation (CM), Self-determination (SDT), Self-efficacy (SEC), and Grade motivation (GM). Inquiry types were examined as dependent variables for motivation.

2. Literature Review

2.1 Inquiry

In Thailand, instructors popularly recommend to use inquiry-based learning as one of many instructional strategies to implement in science education. Theoretically, inquiry-based learning is defined as the creation of a classroom where students are engaged in essentially open-ended, student-centered, hands-on activities involving asking questions about the world around them, gathering evidence, and providing explanations (Colburn, 2000). It is restricted that solely activities, e.g. building a model of an atom, cannot be referred to inquiry-based learning if they are conducted in the absence of research questions as a part of inquiry process. The inquiry-learning literature tends to be more closely associated with the acquisition of science process skills or the scientific thinking and reasoning patterns that scientists use to construct (Bunterm et al., 2014)

Researchers typically discriminate between different levels of inquiry-based learning depending on the amount of specific instructions given to students. (Buck, Bretz, and Towns, 2008). Buck (2008) proposed a fifth-level model. At the first level (Confirmation), the problem, procedure, analysis, and correct interpretations of the data are all provided to the students. At the second level (Structured inquiry), the laboratory manual provides the problem, procedures, and analysis by which students can discover relationships or reach conclusions that are not already known from the manual. At the third level (Guided inquiry), the laboratory manual provides the problem and procedures, but the methods of analysis, communication, and conclusions are for the student to design. At the fourth level (Open inquiry), the problem and background are provided, but the procedures/design/methodology are for the student to design, as are the analysis and conclusions. At the highest level (Authentic inquiry), the problem, procedures/design, analysis, communication, and conclusions are for the student to design.

This investigation compared two kinds of inquiry-based processes: guided versus open inquiry. Learners will be engaged to have a construct with providing the problem and procedures for guided inquiry but providing just the problem for open inquiry. Sadeh and Zion (2011) examined the influence of these two different inquiry learning processes on the attitudes of Israeli high school Biology learners toward their inquiry project. It is found that there were significant differences between the two groups. Learners were more satisfied and felt they gained benefits from implementing the project to a greater extent for open inquiry. On the other hand, they conducted more documentation for Guided inquiry. Bunterm et al. (2014) examined the effects of guided against structured inquiry on secondary students' learning of science with three schools in north-eastern Thailand. In comparison, students in the guided-inquiry condition showed greater improvement in both science content knowledge and science process skills. Any moment now, researchers have been subject inquiry-based learning using MBL and computer simulation as tools for conceptual understanding and change in physical science to middle and high school students, pre-service teachers to enhance learners' meaningful learning in the area of scientific concepts (Gunhaart and Srisawasdi, 2012).

2.2 Microcomputer based Laboratory(MBL) and Computer simulation for science instruction

At this moment in time, computational technologies are increasing attention among science educators because of their potentials to support new variety of science classroom (Srisawasdi, 2008). MBL and computer simulation are taking participant their own prominent rules in thinking and reflecting learning input for an instructor and a conceptual construct respectively. Serving as alternative software for teaching assistant tool, MBL is widely used for instructional activities to stimulate students' curiosity as a learning motivator, develop students' scientific skills, foster collaborative network, understand in scientific concepts, and establish students' cognitive construct (Srisawasdi & Kroothkaew, 2014).

Additionally, Redish, Saul, and Steinberg (1997) investigated that active-engagement tutorials using MBL equipment were replaced for traditional problem-solving recitations in introductory calculus-based mechanics classes for engineering students at the University of Maryland. Two specific tutorials, on the concept of instantaneous velocity and Newton's third law, were performed with eleven lecture classes taught by six different teachers with and without tutorials. Classroom achievement tests were probed by using standard multiple choice questions and a free-response final exam question. The result shows that the MBL tutorials originated in a remarkable improvement compared to the traditional recitations. Russell et al. (2003) designed and provided experiments with grade 11 physics classes of 29 students. The research distinguished the learners and illustrated the patterns of interactions in the MBL. Analysis of students' discourse and actions identified kinematics in multiple ways. The finding is that MBL activities likely catalyzed students' construction of understanding. Students were able to design the research questions, predictions, designing experiments, collecting data, and drawing conclusions.

In addition, Gunhaart and Srisawasdi (2012) used MBL as a tool for scientific thinking and computer simulation as a cognitive tool for conceptual learning to improve the construction of physics conceptual understanding on properties of sound wave at macroscopic (observable) level. The results show achievement caused them importantly obtaining a better conceptual score at the end of their learning. In addition, the qualitative analysis suggests the students had changed their conceptual understanding on physics of sound wave properties in three characteristics including differentiation, class extension, and reconceptualization. Srisawasdi (2012) introduced MBL and computer simulation to cover basic science concepts including three physical science activities; air resistance of falling objects, heat of fusion for ice and photosynthesis and respiration for 26 second year pre-service teachers in Thailand. Results indicate that all the groups did not perceive differently the goal and the support of computerized science laboratory. The highest attitude group realized the ease of use, self-learning, and value greater than the medium and the low attitude groups, but the medium attitude group possessed the most satisfaction with the laboratory.

2.3 Motivation

Motivation stands for an internal state that activates, guides, and maintains behavior, students' drive to learn and achieve to their potential at school. There are five components of motivation to learn science (Glynn et al., 2011) including; First, intrinsic motivation (IM) involves learning science for its own sake. Second, career motivation (CM) included the relevance of science to one's career is a leading theme in students' explanation. Third, self-determination (SDT) as dimension refers to the control students' believe that they have over their learning of science. Forth, self-efficacy (SEC) is an achievement by predisposing students to work harder, persist longer, and overcome barriers when pursuing academic goals and finally, grade motivation (GM) as the students' competition often associate with grade.

In term of science education, motivation to learn is the engagement related to the achieving goals, students' understanding of science and the activation of strategies for action (Lee & Brophy, 1996). Due to the relationship between motivation, cognitive engagement and conceptual change, motivation to learn is a particular issue to concern in science education. Pintrich, Marx, and Boyle (1993) have suggested that the construction of new knowledge in science is strongly influenced by prior knowledge, conceptions gained prior to formal learning. Consequentially, conceptual change is much tougher because it requires new information to engage at an adequately deep level to recognize conflicts between existing understanding and new information (DeBacker and Nelson, 2000). Confirmation persuades that decisions to engage in endeavored learning might be affected by individual students' motivation including engaging goals in an activity, beliefs in abilities and the nature of the task, and valuing of the task (Miller, Greene, and Montalvo, 1996; Nolen and Haladyna, 1990). In addition, learning environment, especially laboratory maybe the key factors affecting motivation differences.

3. Methodology

3.1 Research Objective

this study aims to investigate students' physics motivation delivered in blended combination of hands-on microcomputer-based laboratory and computer-simulated laboratory for physics learning of sound wave. Specifically, the main research questions for this study was that do the students engaged in blended combination of hands-on microcomputer-based laboratory and computer-simulated laboratory perform significantly better by students' physics motivation?

3.2 Study Participants

The total of 66 students-respondents in their eleventh grade (16-17 years old) were recruited in this present study. They were divided into two experimental groups which received different learning process in blended combination of hands-on microcomputer-based laboratory and computer-simulated laboratory: open-inquiry laboratory learning (N=31) and guided-inquiry laboratory learning (N=35) groups. Both groups were assigned to learn a physics lesson on sound wave. The researchers conducted an informal interview with physics teacher in two regular classes, and the results showed that all of students have basic skills on using computer. However, all of them have never experience yet using hands-on microcomputer-based laboratory and computer-simulated laboratory in physics class.

3.3 Instrument

In this study, a 25-item science motivation questionnaire was used to measure students' motivation to learn physics on five subscales: intrinsic motivation (IM), self-determination (SDT), self-efficacy (SEC), career motivation (CM), and grade motivation (GM) (Glynn et al., 2011). The questionnaire was originally developed by Glynn et al. (2011) and then adapted into Thai version to assess students' motivation to learn science. From 25 items English version, the translation an identical version in Thai was constructed and Cronbach's alpha of Thai version were 0.79, 0.81, 0.89, 0.81 and 0.85 for IM, SDT, SEC, CM and GM respectively (Srisawasdi, submitted).

3.4 Data Collection

For investigating students' physics motivation in whether they perform inquiry-based learning process with a blended combination of hands-on microcomputer-based laboratory and computer-simulated laboratory on sound wave phenomena. The study participants were asked to response the 25-item 5-point Likert-scale questionnaire for 10 minutes at both before and after interacting with the blended lab. On each item, respondents were assigned to rate how much the respondent agree with into five scale, from 1-strongly disagree to 5-strongly agree. In the blended lab class, both groups participated physics learning of sound wave through inquiry-based learning process for 480 minutes. Figure 1 and 2 illustrate example of blended lab activity for physics learning of sound wave.

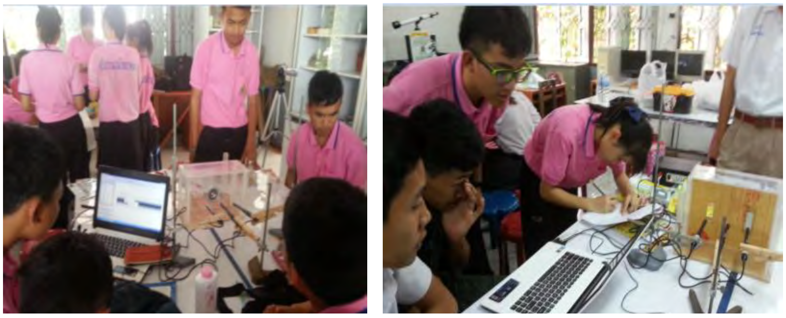

Figure 1. Illustrative example of classroom learning activity through hands-on MBL guided (Left) and open (Right) inquiry laboratory

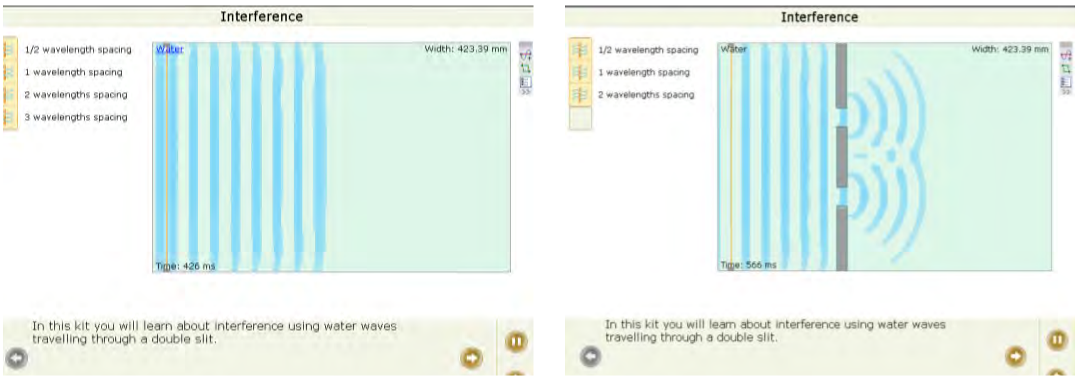

Fig. 2 Illustrative interface the bending interference of sound wave simulation (obtained from PhET) for computer-simulated guided and open inquiry laboratory

The statistical data techniques selected for analyzing students' perceptions was repeated-measures MANOVA in SPSS 21.0.

4. Results

The results for the repeated-measures MANOVA indicated significant main effect for different levels of inquiry (guide- and open inquiry) (Wilks' lambda=0.755, $F(5, 60) = 3.887$, $p = 0.004$, partial $\eta^2 = 0.245$). There was significant difference on students' physics motivation between guided- and open-inquiry learning process. According the significance, the univariate results was performed and it revealed that all of the five subscales on physics motivation reached a statistically significant difference between guided- and open-inquiry learning process. That is, both guided- and open inquiry in blended combination of hands-on microcomputer-based laboratory and computer-simulated laboratory performed differently with regard to IM, CM, SDT, SEC, and GM. In additions, there was a significant interaction effect between different levels of inquiry and different times measured (pre- and post-test) (Wilks' lambda = 0.717, $F(5, 60) = 4.738$, $p = 0.001$, partial $\eta^2 = 0.283$). This means that different levels of inquiry had similar effects on students' physics motivation in the blended lab.. In addition, there was a significant main effect for different time measured (Wilks' lambda = 0.483, $F(5, 60) = 12.855$, $p < 0.000$, partial $\eta^2 = 0.517$). This suggests that, on average, the students' physics motivation have changed over inquiry-based learning experience with blended combination of hands-on microcomputer-based laboratory and computer-simulated laboratory. Univariate analyses of variances on each subscale were conducted as follow-up tests to the one-way MANOVA. The results of the univariate test regarding different time measured are summarized in Table 1.

Table 1: The students' subscale means of physics motivation by time and univariate MANOVA

Subscale	**Time**		**F**	**Sig.**	η^2
	Pre-test	**Post-test**			
Intrinsic motivation (IM)	17.58 (3.123)	19.85(2.562)	29.920	0.000	0.319
Career motivation (CM)	17.17 (3.580)	19.92 (2.668)	39.803	0.000	0.383
Self-determination (SDT)	17.23 (2.971)	18.21 (2.551)	5.675	0.020	0.081
Self-efficacy (SEC)	14.55 (3.398)	15.91 (3.703)	11.467	0.001	0.152
Grade motivation (GM)	19.33 (2.879)	21.21 (2.551)	24.289	0.000	0.275

As displayed Table 1., The univariate MANOVA on the five subscale scores of physics motivation were significant differences across time, from pre-test to post-test. The univariate results revealed a significant effect on IM ($F_{1,64} = 29.920$, $p < 0.001$, partial $\eta2 = 0.319$), CM ($F_{1,64} = 39.803$, $p < 0.001$, partial $\eta2 < 0.383$), SDT ($F_{1,64} = 5.657$, $p < 0.05$, partial $\eta2 = 0.081$), SEC ($F_{1,64} = 11.467$, $p < 0.01$, partial $\eta2 = 0.152$), and GM ($F_{1,64} = 24.289$, $p < 0.001$, partial $\eta2 = 0.275$). According to aforementioned results, the overall result suggested that the increase of physics motivation regarding intrinsic motivation, career motivation, self-determination, self-efficacy, and grade motivation from the pre-test to post-test was homogeneous for both guided- and open-inquiry learning process after participating with blended combination of hands-on microcomputer-based laboratory and computer-simulated laboratory. That is, there was effect of different levels of inquiry on students' physics motivation for learning with blended combination of hands-on microcomputer-based laboratory and computer-simulated laboratory.

5. Discussion

This research reports an effect of innovative teaching and learning of physics, inquiry-based learning process in a blended combination of hands-on microcomputer-based laboratory and computer-simulated laboratory, on promoting students' physics motivation. The result indicated an increasing of students' physics motivation scores considering from before and after participating with the intervention. This finding could be discussed that inquiry types subjecting to five subscales of physics motivation are shown in Table 1. In cases of guided inquiry with innovatively effective tools of MBL and computer simulation persuaded students to particularly focus on given content, interference of sound wave and delivered them opportunities to construct knowledge with team groups (Zion, Cohen, and Amir, 2007) and prospectively achieved conceptual change after students attended this learning process. This indicated that learners were more satisfied to explore a knowledge construct themselves with MBL. This study showed time as the main effect of the learning process to the students' motivation on sound wave interference. According to the results, there were statistical significant effect in all subscales of the students' physics motivation. This result implied that the learning process which were MBL and computer simulation could motivate the student to learn physics. Due to learning using both MBL and computer simulation, the students had higher scores of the motivation. Considering to MBL, this method allows students to learn trough actual laboratory using technology as tools supporting their learning process (Russel, 2003) and computer simulation by which they had background of sound wave interference that invisible in micro level(Srisawasdi, 2008). The result consistent with the research findings that students perform better in physics concepts with learning from integrating of MBL and computer simulation(Gunhaart and Srisawasdi, 2012) . A possible explanation for why learners made develop on physics motivation from before to after is that the teaching and learning could induce learners into the problem solving (Russell et al., 2003; Thornton and Sokoloff, 1989)

Considering different levels of inquiry (open- and guided inquiry), the findings introduced to acquire more effective process. One of the best findings was that open-inquiry laboratory learning was more effective learning process to motivate student in physics learning of sound wave than that of guided-inquiry laboratory learning. The results showed there was a significant difference for all of motivational subscales in both inquiry levels. This evidence is consistent with the claims that the inquiry are a well designed learning process for science learning and can engage mindful investigation in doing science (Bunterm et al., 2014; Sadeh a Zion, 2011). Moreover, open-inquiry learning through computer simulation affected students revising unscientific understanding and improving their physics outcomes (Srisawasdi, 2014). Also, Srisawasdi (2012) has mentioned that hands-on microcomputer-based laboratory support improvement of attitude and perception toward learning. Therefore, this implied that using inquiry-based could support the students' leaning in affective domain such as motivation. Especially, open-inquiry laboratory learning process where student have opportunity to design, collect and analysis data, discuss with peers, make conclusion and communicate findings by their own way delivered them a novel learning process of science can motivate to learn physics greater than prescribed physics experimentation.

6. Conclusion

This study investigated an effect of inquiry-based learning process into a blended combination of hands-on microcomputer-based laboratory and computer-simulated laboratory on secondary school students' physics motivation. After implementing the intervention, the results show that; (i) both guided- and open-inquiry learning process in blended combination of hands-on microcomputer-based laboratory and computer-simulated laboratory improved students' intrinsic motivation, career motivation, self-determination, self-efficacy, and grade motivation towards physics learning across time; and (ii) open-inquiry laboratory learning process was more effectively to enhance students' physics motivation than the guided inquiry. To this end, blended combination of physical, hands-on microcomputer-based laboratory, and virtual, computer-simulated laboratory, environment could be used to motivate student in learning of physics by inquiry. However, to address students' conceptual learning performance we are going to investigate how to use the inquiry-based learning process through blended lab for facilitate development of mental model and ability of scientific reasoning.

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