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Effect of Simulation-based Inquiry with Dual-situated Learning Model on Change of Student's Conception

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Abstract. Numerous researches in science education have reported that many students displayed learning difficulties in understanding and hold unscientific conceptions about sound wave although sound is an everyday phenomenon that we constantly observe. Moreover, their common alternative conceptions about wave phenomena of sound are often resistant to change into correct physics of thought. To investigate effect of the teaching method of simulation-based inquiry with dual-situated learning model (SimIn-DSLM) on student's conceptual understanding of sound wave, 38 of Grade 11 secondary school students participated in learning physics with computer-simulated experiment. Both quantitative and qualitative data of conceptual understanding and conceptual change were collected, and analyzed aiming to understand their conceptual status at before, after, and a month after the use of SimIn-DSLM teaching method. The results showed that the method of SimIn-DSLM explicitly influenced their conceptions in physics of sound wave into correct physics. This finding suggests that the SimIn-DSLM method could be used to induce mechanism of change within students' conceptual knowledge of sound wave phenomena and the change of their conceptions could place them into meaningful conceptual framework of basic scientific knowledge.

Keywords: Computer simulation, open inquiry, dual-situated learning model, conceptual change

1. Introduction

In the past decades, science educators have widely studied alternative conceptions held by students at all levels and how to bring about process of change of their alternative conceptions into scientific conceptions. Many science education researchers have reported a critical important finding that students' alternative conceptions in science are highly resistant to change through undersign (conventional) classroom instruction (She, 2004). To account student's unscientific conception, new innovative instructional methods and media have, recently, been developed to solve the problematic issue in order to help students the learning of science concepts. However, there is still a lack of sufficient empirical study to support any instructional approach that would contribute to students' conceptual change. Conceptual change can be subdivided into differentiation in which new concepts emerge from more general concepts, class extension in which existing concepts become cases of another subsuming concept, and re-conceptualization in which nature of and relationship between concepts changes significantly (Dykstra, Boyle and Monarch, 1992). This study employed the Dual Situated Learning Model (DSLM) (She, 2003) to examine the changes in understanding of science concepts and it becomes the core subject of the present study. The DSLM developed by She (2003) has been carried out in order to reveal whether or not this model has positive effects in student's learning of science concepts and this model show that is very effective in grasping science concepts meaningfully and reducing misconceptions (She, 2002, 2003, 2004).

In the last few years, recent educational research has indicated that the structural mode (highly structured labs that provide questions, theory, and experimental and analytical procedures) of inquiry is not sufficiently effective for developing scientific performance in science learning (Srisawasdi, 2012a;

Zion and Sadeh, 2007), and engaging student into more flexible mode of scientific inquiry is more emphasizing in recent science education (Srisawasdi, 2012a; 2012b). Additionally, computerized technological tool is so commonplace in the practice and advancement of science education community, and computer simulation has been increasing into the context of science teaching, and also considered as a cognitive tool for student's learning in science. There is abundant evidence that computer simulation is critical to assist students' visualization of scientific phenomena and there has been associated with gains in scientific conceptual understanding among science students in areas (Srisawasdi, 2008). Based on the pedagogical practice of She's DSLM, various methods of instruction can use with the model. In this present study, instructional method of inquiry-based science incorporated with instructional media of interactive computer simulation was chosen to create a unique learning environment for student's science learning, called "Simulation-based Inquiry with Dual-situated Learning Model (SimIn-DSLM)" for student's science learning. Thus, this study uses the SimIn-DSLM to promote conceptual development of sound wave by enhancing process of conceptual change. Numerous difficulties in student's understanding of sound wave have been identified (Barman, Barman and Miller, 1996; Linder, 1987, 1992, 1993; Linder and Erickson, 1989; Maurines, 1992, 1993; Merino, 1998a, 1998b; Wittmann, 2001; Wittmann, Steinberg and Redish, 1999). Within sound wave as a topic, we decided to concentrate on its nature such as properties of and speed of sound wave for two reasons. It is the best defined problematic sub domain of sound wave, and it also promises the most in an attempt to find underlying principles that govern the set of alternative conceptions on sound wave phenomenon, especially its nature and property.

2. Theoretical Background

2.1 Dual-situated Learning Model (DSLM) for Science Learning

Over the past three decades, many instructional models for science learning were grounded on theoretical aspects of conceptual change. The DSLM is one of the models which facilitated the conceptual change theory. The DSLM (She, 2003, 2004) considers students' alternative conceptions to be a very important consideration in providing students the opportunity to be actively involved in the process of reconstructing their alternative conceptions and of moving toward a more complete and advanced scientific conception. She and Liao (2010) have detailed features of DSLM by emphasizing that the process of conceptual change, firstly, should be situated on the nature of science concepts and students' beliefs about these science concepts in order to determine which essential mental sets are needed to construct a more scientific view of the concepts. Secondly, probing students' beliefs about the particular science concept may achieve a deeper understanding of characteristics and causes of students' alternative conceptions, and providing the new mental set on the platform of which knowledge reconstruction can occur. Thirdly, the information on which and how many particular mental sets the students lack for restructuring the science concept would determine which and how many specific dual situated learning events need to be designed to supplement this deficiency and to foster conceptual change. The last feature provides an opportunity to challenge students to see whether they can actually apply the mental sets that they have revised or constructed to another situation, thus achieving a successful conceptual change.

2.2 Science Teaching with Computer Simulation

Computer simulations have become more widespread in science classroom. By contemporary definitions, computer simulation is a computer-based visualization technology which can imitate dynamic systems of objects in a real or imginated world supporting to the quality of the visual aids. Computer simulation has been used extensively as a visual representation tool to advocate presenting dynamic theoretical or simplified models of real-world components, phenomena, or processes, enlarging students to observe, explore, recreate, and receive immediate feedback about real objects, phenomena, and processes. There are several educational values that computer simulation adds into science learning activities (Hennessy, Deaney and Ruthven, 2006), especially in activity type of inquiry-based science.

Now, technological developments such as computer simulations can implement more effective inquiry learning. Inquiry learning with computer simulations is learning through experimentation and scientific reasoning. Within simulations, students change variable values and observe effects to form conclusions. Through this process students discover principles, rules, and characteristics of scientific phenomena (de Jong, 2006).

2.3 Simulation-based Open-inquiry Science Learning

In recent years, more and more evidence indicates that structured inquiry, highly structured laboratory practices that provide questions, theory, experimental and analytical procedures, is not sufficient in developing scientific thinking (Zion and Sadeh, 2007). This type of investigation produces a robotic style of thinking that is less effective than teaching deductive reasoning, detailed in-depth thought processes, and logic (Srisawasdi, 2012a). According to the evidence, engaging learners into more flexible of scientific inquiry through conducting laboratory experiment is more emphasizing in recent science education. Therefore, science teachers who have a critical role in implementing inquiry-based learning, especially in case of open-ended inquiry, need to know and practice to build up increasingly open-inquiry science learning process for students. Recently, the meaning of open inquiry is quite not clear yet and inquiry practitioners are still discussing about its characterizations. Buck, Bretz and Towns (2008) described open inquiry in a way that can be used by both secondary school practitioners and university researchers as an investigation where instructor provides the inquiry question or problem and basic background, but the remaining characteristics are left open to the student, in where learners have to develop their own procedure, analysis, communication, and conclusions to address an instructor provided question.

According to Buck, Bretz and Towns (2008)'s idea, the learning process of open-inquiry science with computer simulation could possibly be proposed in a combination of open-inquiry components and computer-based inquiry activities, in order to creating a unique learning environement of open-inquiry learning with computer simulation technology, as display in Table 1.

Table 1: A matrix of simulation-based open-inquiry learning process for science laboratory learning

<table>
<tr><td colspan="2"></td><td colspan="3">Simulation-based laboratory component</td></tr>
<tr><td colspan="2"></td><td>Pre-lab</td><td>Laboratory</td><td>Post-lab</td></tr>
<tr><td rowspan="6">Open-inquiry component</td><td rowspan="2">Teacher</td><td>Open-ended Problem/Question</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>Basic Background/Theory</td></tr>
<tr><td rowspan="4">Student</td><td rowspan="4"></td><td>Procedure/Design</td><td rowspan="2"></td></tr>
<tr><td>Result analysis</td></tr>
<tr><td rowspan="2"></td><td>Result communication</td></tr>
<tr><td>Conclusion</td></tr>
</table>

3. Methods

3.1 Study Participants

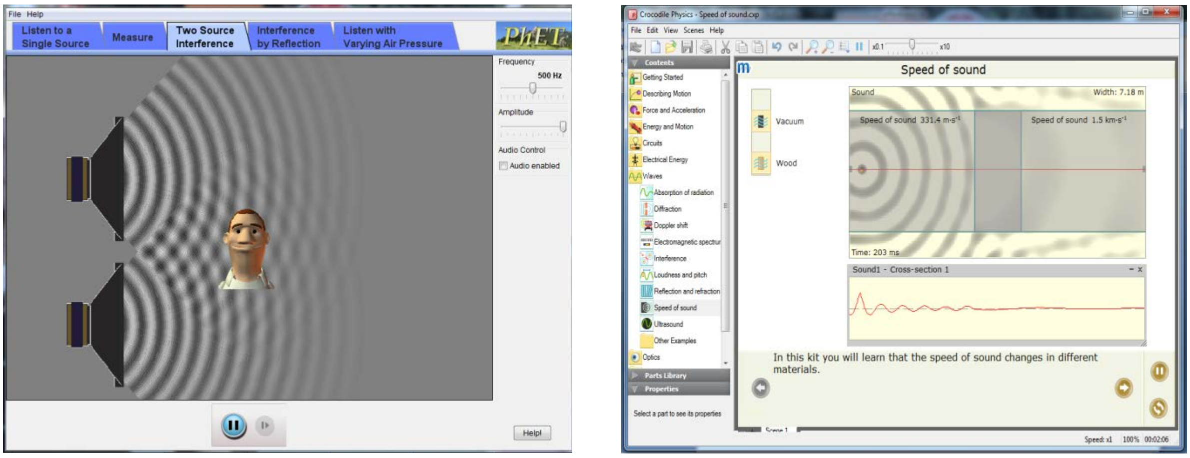
The participants for this study included 38 of Grade 11 students in a local public school at Northeast region of Thailand. They were attending a physics course for basic education level and they were invited to participate in this research. The participants were aged 17-18 years. All of them did have satisfactory basic computer and information and communication technology skills but they had not any experience with using computer in physics learning before.

3.2 Domain of Conceptual Learning Events

Based on DSLM instructional procedures, there were seven of designed learning events of sound wave that used to cover students' alternative conceptions of the concept consisting of: reflection of sound wave (C_1); diffraction of sound wave (C_2); interference of sound wave (C_3); refraction of sound wave (C_4); speed of sound wave in different kinds of medium (C_5); and speed of sound wave in different temperature of medium (C_6).

3.3 Interactive Computer Simulation on Sound Wave Phenomena

In order to facilitate students' learning of sound wave concepts through the designed learning events as mentioned previously, interactive simulations on sound wave from Physics Education Technology (PhET) research group and Crocodile Physics were used as a conceptual tool for student's inquiry learning, as display in Figure 1. It is clear that students' common alternative conceptions of sound wave are due to the invisibility of amount involved and their nature, making it more difficult to construct concepts related to nature of sound wave. Therefore, the sound wave simulations was designed and developed on the common alternative conceptions held by students at all level, and emphasizes providing students with visualizations of the sound wave phenomenon to help them build more scientific views of property of sound wave and speed of sound wave concepts.



<u>Figure 1.</u> Illustrative interface examples of sound wave simulations from PhET (Left) and Crocodile Physics (Right)

3.4 Data Collection

For investigating students' conceptual change in this study, a series of open-ended question items was administered to examine their conceptual understanding before their attending with the SimIn-DSLM teaching method. The SimIn-DSLM method was implemented to them four three-hour weekly lecture in classroom and there were included seven conceptual learning events on sound wave phenomenon. After that, the same question items was administered to them again for exploring their exiting conceptual understanding and also investigate change of their conceptual understanding happened from the intervention. Moreover, the same question items, two months after the post-test, were administered to them for examining their conceptual retention. In addition, video and sound recorders were simultaneously used to collect students' discourse. Their conversational negotiations were both audiotaped and videotaped during their interacting with the SimIn-DSLM in class period. The audiotaped transcripts were used for the bulk of the transcripts, the videotapes provided additional information detailing students' expressing conceptual ideas as they reacted to the SimIn-DSLM during the class period.

3.5 *Data Analysis*

To investigate impacts of the SimIn-DSLM teaching method on students' conceptual change of sound wave phenomena, both quantitative and qualitative analysis methods were conducted to verify its impact. For analysis of students' conceptual understanding on sound wave phenomena, the content analysis was primarily used for writing protocol of their answers to each open-ended question item both pre-test, post-test, and retention test. For students' conceptual change analysis, the qualitative changes of their conceptual understanding between pre-test to post-test, and pre-test to retention-test, were measured and quantified into five categories (She & Liao 2010) including: (1) Progress (PG) - to what extent the student's conceptions improved; (2) Maintain-correct (MTC) - to what extent the student's conceptions were maintained correctly: (3) Maintain-partial correct (MTPC) - to what extent the student's conceptions were maintained as partially correct; (4) Maintain-incorrect (MTIC) - to what extent the student's conceptions were maintained as partially incorrect; (5) Retrogression (RTG) - to what extent the student's conceptions retrogressed. Each student's conceptual understanding in test was analyzed by percentage for PG, MTC, MTPC, MTIC, and RTG from pre-test to post-test, and then post-test to retention-test. In an effort to qualitative explain cognitive process of conceptual change during students' learning action, taxonomy of conceptual change (Dykstra, Boyle & Monarch, 1992) was placed on a template to analyze the change of the students' conceptual understanding, within their exiting conceptual framework. The taxonomy included (1) Differentiation (D) - wherein new concepts emerge from existing, more general concepts; (2) Class extension (CE) - wherein existing concepts considered different are found to be cases of one subsuming concept; and (3) Reconceptualization (R) - wherein a significant change in the nature of and relationship between concepts occurs. The students' discourse protocols were transcribed and reviewed and their conceptual framework were described on the template. Through comparison of the templates, the students' cognitive processes of conceptual change were identified.

4. Results

4.1 *Characteristics of Conceptual Change*

The percentage of the average quantity of type of conceptual change from pre-test to post-test, and post-test to retention-test are presented in Figure 2.

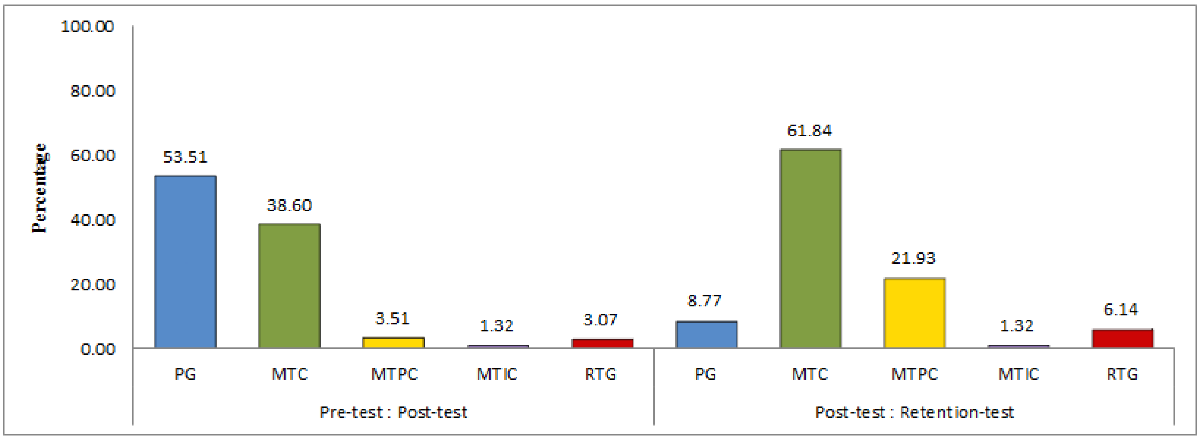


Figure 2. Distribution of conceptual change on sound wave phenomena among pre-test, post-test, and retention-test

As seen in Figure 2, there is the average percentage of change for students' understanding of sound wave from post-test to retention-test, and post-test to retention-test. For the transition of pre-test and post-test, the result shows that the average percentage of Progress (PG) (53.51%) and Maintain-correct (MTC) (38.60%) were the main category of conceptual change for students' conceptual understanding in sound wave. This indicates a potential of SimIn-DSLM teaching method that most of students' conception (92.11%) have had acceptable scientific conception after interacting with the SimIn-DSLM. Nevertheless, there was, after the interacting, 4.83% of their conceptions still be alternative (unscientific) conception on sound wave and 3.07% of their conceptions had been retrogressed their own scientific conception into alternative conception. The result in considering to the transition of post-test and retention-test shows that 70.61% (8.77% of PG and 61.84% of MTC) of their conceptions have been reserved permanently in the status of acceptable scientific conception even two months after the last interaction with the SimIn-DSLM class. However, there was a number of students' conception that the change of their conception was not sustained (18.42%). Unfortunately, about 3.07% of their conception has been completely transformed into alternative conception in two months after the SimIn-DSLM class.

4.2 Cognitive Mechanism of Conceptual Change

Using Dykstra, Boyle and Monarch (1992)'s framework of conceptual change process, the following discourse is an example of student' conceptual mechanism of change during interacting with the SimIn-DSLM class. The following discourse protocol was identified by the Differentiation.

[1] Student B: For our experiment, we are comparing speed of sound in -10 degree Celsius and -30 degree Celsius. Which one is going faster?
[2] Student C: At -10 degree Celsius is faster.
[3] Student A: No. The sound is going faster at -30 degree Celsius. Isn't it?
[4] Student B: We should consider the experimental result that there showed its velocity. The speed of sound at -10 and -30 degree Celsius were 325 and 349 m/s respectively.
[5] Student A: Is the greater number indicated faster move?
[6] Student C: Umm… So, the sound movement at -30 degree Celsius should be listened firstly.

An example of this discourse protocol is demonstrated the cognitive process of Reconceptualization for conceptual change occurred in Student C. Initially, the Student C held an alternative conception that the speed of sound wave in a lower temperature environment is faster than higher temperature as seen in line 2. During their inquiry learning process with sound wave simulations, Student A has discussed and shared a scientific conception of speed of sound wave as illustrated in line 3. Moreover, Student B posed a critical suggestion in order to consider the speed of sound wave in the experimental data obtained from the simulation as seen in line 4. After and then the Student A could get some more scientific details of the reflection phenomenon. Finally, the Student C has totally changed his alternative conceptions about the speed of sound phenomenon into scientific conception as evidence showed in line 6.

5. Conclusion

This present study results reveal that incorporation of learning by simulation-based inquiry into the DSLM, called Simulation-based Inquiry with Dual-situated Learning Model (SimIn-DSLM), has potential on the development of students' conceptual understanding in science through the mechanical process of conceptual change on the physics of sound wave because this learning environment provide students opportunity to visualize the sound wave phenomenon resulting in help them change scientific views of property of sound wave and speed of sound wave concepts. Moreover, the change of their conception was a deep process of repairing students' alternative conceptions into scientific conception, called radical conceptual change. This implies that students can more quickly and efficiently recall correct scientific conceptions in order to conceptualize more advanced science concept once their conceptual change is successful. The result of this study came from only one school. Before using or generalizing, it should be tried on a large number of students with different backgrounds. This further demonstrates that the DSLM can be effective in fostering students' radical conceptual change in simulation-based inquiry learning environment as well as in web-based learning environment or in the classroom.

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