Teaching How Light can be Refracted Using Simulation-based Inquiry with a Dual-Situated Learning Model

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Abstract

Although light is an everyday phenomenon that we constantly observe, numerous research studies have reported that students display learning difficulties and hold unscientific conceptions about light waves. This paper presents the effects of using a simulation-based inquiry teaching method with a dual-situated learning model (DSLM) on Grade 10 students' conceptual understanding of light refraction. The results showed that their conceptual scores for pre-test, post-test and a retention test were significantly different and they gained a better conceptual understanding after attending the simulation class. The findings suggest that this method could be used to help students learn science concepts in a more meaningful and understandable way.

Keywords: DSLM, open inquiry, computer simulation, conceptual change

1. Introduction

In science learning, there are many scientific activities which cannot be conducted using real laboratory experiments in a classroom setting, because they are either impossible to conduct, too dangerous, too complex or take too long. In contrast, where there is limited classroom time, computer simulation plays an important role in the science classroom, providing students the opportunity to study different kinds of scientific phenomena in a variety of circumstances with several presentation methods, for example: pictures, graphs, vectors, etc. (Jimoyiannis & Komis, 2001; La Velle, McFarlane & Brawn, 2003). Moreover, students can manipulate the variables, recreate scenarios, receive immediate feedback and observe the effects to construct their own scientific conclusions with the aid of computer simulation (de Jong, 2006; Jimoyiannis & Komis, 2001; Sutherland, 2004). Computer simulation, therefore, serves as an educational tool for science learning activities (Hennessy, Deaney & Ruthven, 2006), especially in activity-based scientific inquiry and in conceptual development in science.

The concept of light refraction is a basic and yet important one in physics education. Students need to acquire this scientific concept properly in order to understand advanced concepts in the future. Possible misconceptions about light refraction, therefore, must be identified and removed (Aydin, Keles & Hasiloglu, 2012). Computer simulation might provide students’ the opportunity to visualize the refraction of light when it passes from a fast medium to a slow medium, bending the light rays toward the boundary between the two media, in order to confront their
alternative conceptions of light refraction. However, computer simulation alone was not enough to promote students' understanding and conceptual change (Srisawasdi, 2012); this needed to be incorporated with an instructional model. Therefore, in this study, a method of simulation-based inquiry learning using a dual-situated learning model (DSLM) was developed for science learning. This study aims to investigate students' development in conceptual change after learning from the method and to examine the retention of students' conceptual understanding.

2. Theoretical framework

In the past decade, researchers have proposed a variety of theories regarding conceptual change in the teaching and learning process, implying that conceptual change has been a major research area in science education (Duit & Treagust, 2003). Misconceptions need to be identified and removed from students' understanding. In 2003, Sinatra and Pintrich indicated that conceptual change can be a process of intentional learning incorporating aspects of "goal-directed" and "under learner’s control" methods (Sinatra & Pintrich, 2003). The students must have clear goals and intrinsic motivation in order to successfully learn during the conceptual change process. Thus, motivation and encouragement need to be considered during the teaching and learning process for conceptual change.

The Dual-Situated Learning Model (DSLM) is one of the teaching and learning models which promote student conceptual development when alternative conceptions exist (She, 2003, 2004). DSLM includes six stages: 1) examining the attributes of the scientific concept; 2) probing students’ alternative scientific conceptions; 3) analysing which mind-sets the students lack; 4) designing dual-situated learning events; 5) instructing with these dual-situated learning events and 6) instructing with challenging-situated learning events (She & Liao, 2010).

3. Methodology

3.1. Participants

Forty Grade 11 secondary-school students aged between 17 and 18 were recruited from a local public school in the Northeast region of Thailand to participate in this study. All of them have satisfactory basic computer, information and communication technology skills but they have not had any experience of using computer simulation in physics learning before. Based on DSLM instructional procedures, these students were asked to learn three designed learning events for light refraction phenomena: definition of 'refraction of light' (C1); refraction of light when passing through the same medium (C2); the angle incident increase or decrease when rays pass through different media (C3).

3.2. Interactive PhET Simulation on Light Refraction

In order to facilitate the students' learning of light refraction concepts through the designed learning events mentioned previously, an interactive simulation from the Physics Education Technology (PhET) research group was used as a conceptual tool for students. It is clear that students’ commonly held alternative conceptions regarding the refraction of light are due to the invisibility of the amount of refraction involved and its nature, making it more difficult to construct concepts related to the refraction of light. Therefore, the refraction of light simulation was designed and developed around the common alternative conceptions held by students at all levels. It emphasizes providing students with visualizations of the refraction of light phenomenon to help them to develop a more scientific view of the concept. For example, one part of the refraction of light simulation allows students to interact with the simulation in order to understand the introduction of the concept of how and when light refracts when passing through the same medium and through different media, as shown in Figure 1.
3.3. Data collection

For investigating students’ conceptions in this study, a series of open-ended questions were asked of them before they attended the proposed classroom session. The method of simulation-based inquiry using DSLM was implemented during three lecture weeks (three hours each week). After that, the same questions were asked of the students again, to explore their conceptual understanding on exit and to investigate changes in their conceptual understanding after the intervention. Moreover, the students were asked the same questions again in order to examine their conceptual retention at two months after the post-test.

3.4. Data analysis

To investigate the impact of the intervention on the students’ conceptual learning of light refraction, both quantitative and qualitative analysis methods were conducted. For analysis of the students’ conceptual understanding, content analysis was primarily used for analysing their answers to the open-ended questions. Afterwards, a rubric scoring system was used to evaluate the conceptual quality of their understanding. The normal distribution of data was not met for the students’ conceptual understanding scores; thus, nonparametric statistics using a Friedman test and a Wilcoxon sign-ranked test were used to examine significant differences between their conceptual understanding scores. Another analysis used for measuring students’ conceptual change was the degree of qualitative change in their conceptual understanding between pre-test and post-test. This was measured and quantified into five categories based on She and Liao’s ideas, including: 1) Progress (PG); 2) Maintain-correct (MTC); 3) Maintain-partial correct (MTPC); 4) Maintain-incorrect (MTIC) and 5) Retrogression (RTG) (She & Liao, 2010).

4. Results and discussion

4.1. Students’ conceptual understanding scores

The results of statistical comparative analysis on the students’ pre-test, post-test and retention-test for their conceptual understanding of light refraction are shown in Table 1.


From Table 1, a significant difference is seen between the conceptual scores for pre-test and post-test implying that the students made great progress in their conceptual understanding of light refraction. Also, progression in their conceptual understanding was found due to a significant difference between pre-test and retention-test scores. This finding could be used to argue that the students’ understanding of the concept made progress throughout their learning with the intervention. The result is consistent with the research findings that show that students performed better with learning using computer simulation (Bell & Trundle, 2008). A possible explanation for why students made progress in their conceptual understanding between the pre-test and the post-test is that learning with the intervention could induce students into the process of conceptual change.

4.2. Students’ conceptual change category

The percentage of the quantity of conceptual change from pre-test to post-test is presented in Figure 2.

As seen in Figure 2 for pre-test to post-test changes, the percentage of the Progress (PG) category was higher than the other categories for all three concepts and the PG value of C2 was the highest. The percentage of PG ranges from 68.75% to 80.60%; the Maintain-correct category (MTC) ranges from 10.0% to 12.50% except none was found for C3 and the Retrogress category (RTG) was 12.50% for C3. The results for these three concepts demonstrated the change of the students’ existing conceptual knowledge because of the SimIn-DSLM. Most of the conceptual change occurred in the category of Progression (PG) demonstrating the more scientific views of the students’ conceptions. The argument corresponds with the claim that the students’ level of pre-knowledge affects their learning outcome from simulation (de Jong & van Joolingen, 1998; Winberg & Berg, 2007). Additionally, this finding is consistent with studies that show that the use of DSLM can improve students’ conceptual learning in science (She, 2003, 2004; Tang, She & Lee, 2005).

5. Conclusion

The results of this present study reveal that the incorporation of learning by simulation-based inquiry into DSLM has the potential to develop students’ conceptual understanding in science through the mechanical process of conceptual change. Moreover, the change in their conception was a deep process of repairing the students’
alternative conceptions into scientific conceptions. This implies that the intervention of simulation-based inquiry with DSLM can be effective in fostering radical conceptual change in students. The results from this study conclude that the simulation-based inquiry learning environment based on DSLM could be an alternative method for developing conceptual understanding of light refraction.

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