Liu, C.-C. et al. (Eds.) (2014). Proceedings of the 22nd International Conference on Computers in Education. Japan: Asia-Pacific Society for Computers in Education

Development of Digital Game-based Biology Learning Experience on Cell Cycle through DSLM Instructional Approach

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Abstract: Digital games were several used as instructional tool in science education in several countries. Using games could increase students' motivation and interest to learn in regular class. The purposes of this study were to design and develop digital game-based learning by inquiry regarding biology of cell cycle based on dual-situated learning model (DSLM) approach, and evaluate effectiveness of the digital game-based learning on improvement of students' conceptual understanding of cell cycle. In this paper, the researchers report results of an investigation of students' existing ideas on biological concepts about cell cycle. 36 twelfth-grade students were recruited into the investigation by undertaking a series of open-ended conceptual questions covering five main concepts i.e. cell cycle, interphase, mitosis, meiosis and cytokinesis. The results indicated that they hold different patterns of alternative- and misconceptions about cell cycle, and some had no conception on the concepts. Then, these findings on specific mental set students lack were used to particularly design dual-situated learning events for the cell cycle concepts. Purposively, a digital game was created by the researchers in order to use for eliminating or decreasing students' alternative- and misconceptions about cell cycle. Besides, the digital game was designing to use as inquiry-based tool to support constructing scientific understanding on the concepts and it is illustrated in this paper. An implication of this paper is to provide pedagogical guidance for developing digital game-based biology learning environment with regarding effective strategy for science learning, open-inquiry learning process.

Keywords: digital game, open inquiry, dual-situated learning model (DSLM), biology education, cell cycle

1. Introduction

In recent years, there are several studies with purpose to promote students' scientific conceptual understanding and conceptual change in biology education. Several researchers developed instructional models and teaching techniques for enhancing the leaning of biological concepts such as cellular respiration (Songer and Mintzes, 2006), genetics (Termtachatipongsa, 2014; Opfer and Siegler, 2004). The results from previous studies reported that students often hold alternative conceptions about cell cycle, especially interphase, mitotic and meiotic cell division, and cytokinesis, due to its abstraction and invisible by nature (Termtachatipongsa, 2014). Also, researcher mentioned that teaching method used in biology class might be a major factor which causes students alternative- and misconceptions (Obaidat and Malkawi, 2009). Moreover, lack of prior knowledge and appropriate ideas could affect ineffective conceptual learning in science (Obaidat and Malkawi, 2009; She, 2004). As such, to promote students' scientific understanding and conceptual development in science, several researchers have attempted to develop instructional materials and models for teaching and learning of science concepts. The dual-situated learning model (DSLM) was proposed by She (2004) and it is one of the instructional models which considers students' alternative conceptions to be a very important consideration in process of learning, and many researchers reported successful on the use of DSLM for enhancing students' conceptual understanding in science (Lee and She 2010; Liao and She 2009; She and Liao 2010; Srisawasdi and Kroothkeaw, 2014; Srisawasdi and Sornkhatha, 2014). However, no study has utilized digital game into this learning model.

In recent years, several researchers have paid attention to a new research trend that focused on using digital game for teaching biological concepts and other science concepts. With technological features, development of interactive computer-based learning materials for science teaching and learning provide opportunities to help student understand the concepts better by visualizing abstract science concepts into concrete experience to change students' alternative conceptions to scientific conceptual understanding (Srisawasdi, Kerdcharoen, and Suits, 2008; Suits and Srisawasdi, 2013). Moreover, teaching-learning process by using computer technology such as digital game could be a novel pedagogy to promote meaningful learning and students' motivation better than traditional teaching-learning process. Therefore, with the abovementioned reasons, importance of using digital game cooperated with DSLM for conceptual change in science learning, the researchers interested to develop digital game-based inquiry learning in biological concepts about cell cycle through DSLM approach for facilitating students' scientific conceptual understanding and cognitive process of conceptual change.

2. Literature review

2.1 Dual-situated Learning Model (DSLM)

Dual-situated learning model (DSLM) (Lee and She 2010; Liao and She 2009; She and Liao 2010). is one of instructional model that considered prior knowledge, alternative conceptions of students and use these data for generating instructional tools for helping students to have correct science concepts through process of conceptual change. The DSLM comprised of six major stages: (1) examining the attributes of the science concept to provide information in which essential mental sets are needed to construct a scientific view of the concepts; (2) probing students' misconception on the concept; (3) analyzing for mental sets in which the students lack to pinpoint which and how many particular mental sets students lack for restructuring the science concepts based upon the first pair of DSLM theory; (4) designing dual-situated learning events including the ideas of second and third duals of DSLM; (5) instructing with dual-situated learning events to provide students an opportunity to make predictions and provide explanations before and after the event, and to further explain why they changed their conceptions or retained their original conceptions and (6) instructing with challenging situated learning event to provide an opportunity for the students to apply the mental sets they have acquired to a new situation, ensuring that successful conceptual change to occur (She and Liao 2010).

According to several previous studies, DSLM had been used in learning of physics and chemistry, and the results showed that students had meaningful learning in science concept through process of conceptual change (Srisawasdi and Kroothkeaw, 2014; Srisawasdi and Sornkhatha, 2014) However, there was no study on application of DSLM in biology class before.

2.2 Games-based Learning in Science

A game is a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome" (Salen and Zimmerman, 2004). General characteristics of game are fun and challenge (e.g. leader board). Effective educational computer game should have five characteristics: (i) built on learning principle; (ii) provide personalized learning opportunities; (iii) provide more engagement for learner; (iv) teach 21th century skills; and (v) provide an environment for authentic and relevant assessment (McClarty et al., 2012).

Currently, digital game or computer game plays common role to provide fun and relax because the game can challenges the player to a digital control of the game on their own. As a result, educators are interesting into how to use the game to facilitate and enhance teaching and learning in subject matters. Kumar (2000) suggested utilization of computer games as instructional tools to stimulate intrinsic motivational factors that encourages curiosity and creates the impression to the students by self-controlled learning. In additions, there were several researches showed that digital games can promote students' learning and their positive attitudes (Sung and Hwang, 2013), support development of critical thinking (Squire, 2006), and creativity (Annetta, Cheng, and Holmes, 2010). Compared to traditional class, digital game can increase motivation that make students interested to learning better than the traditional (Bergin and Reilly, 2005; U.S. Department of Education, 2010). Moreover, learning with digital games promote collaborative process for learning (Gee, 2005; Sung and Hwang, 2013; Wu, Chiou, Kao, Hu, and Huang, 2012).

3. Methods

3.1 Participants

The participants in this study were 36 twelfth-grade students, age ranging from 17 to 18 years old in a public school in Northeast of Thailand. They are attending a biology course for basic education level and they study in special science program for gifted students. Based on background knowledge of twelfth grade students were learned contents about cell cycle before, in tenth grade.

3.2 Instrument

The instrument in this study is ten open-ended conceptual question items regarding five major concepts about biology of cell cycle, i.e. cell cycle, interphase, mitosis, meiosis and cytokinesis. Before employ the instrument to elicit students' understanding of these concepts, it was processed construct and communication validity by four independent experts, including two biologists and two biology teachers, and two of ten items were revised following the experts suggestions.

3.3 Procedures and Data Analysis

All students took 60 minutes to complete the series of open-ended conceptual question items. Following this, content analysis was the primary method for analysis of students' written responses to the open-ended question items, represented their conceptual understanding about biology of cell cycle. The researchers began with repeatedly read the students' written responses and then development of a general conceptual understanding category. The researchers have analyzed, interpreted, and classified their responses into five categories i.e. scientific conception (SC), incomplete scientific conception (IC), alternative conception (AC), misconception (MC), and no conception (NC). Then the researchers have designed a series of dual-situated learning events for facilitating mechanism of change and revise of their alternative and misconceptions of cell cycle into scientific conception. The dual-situated learning events were emphasizing into the design of a digital game of cell cycle.

4. Results and Discussion

Based on the five categories (SC, IC, AC, MC and NC) interpreted students' unscientific conceptions, the percentages of quantity of a combination between students' alternative- and misconceptions and their no conceptions on the interphase concept was displayed in Figure 1.

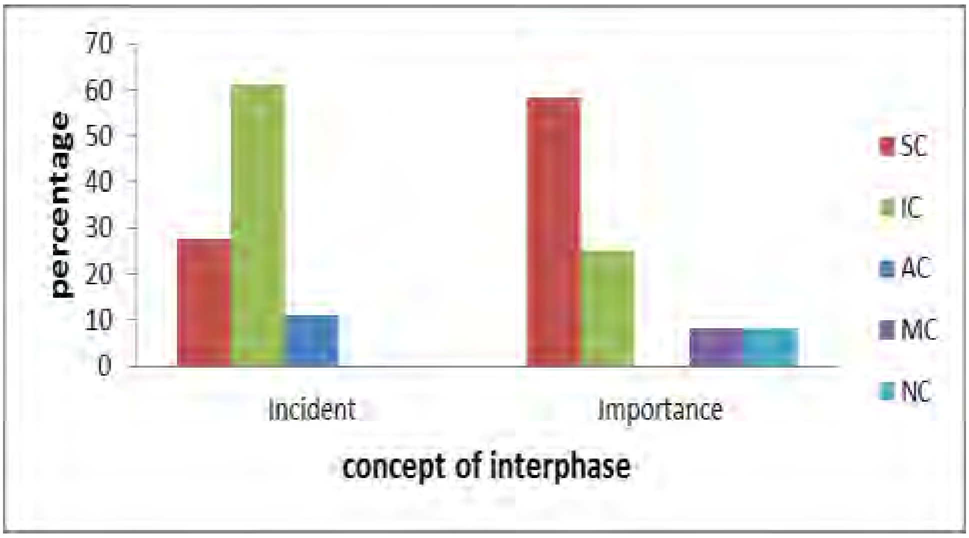

Figure 1. Distribution of students' alternative conceptions on interphase concept

According to Figure 1, the percentages for combination of alternative- and misconceptions for incident of interphase and importance of interphase were 11.1% and 8.3%, respectively. The percentages of no conception for incident of interphase and importance of interphase were 0% and 8.3% respectively. The result of students' alternative-, mis-, no conceptions on meiosis concept was illustrated in Figure 2.

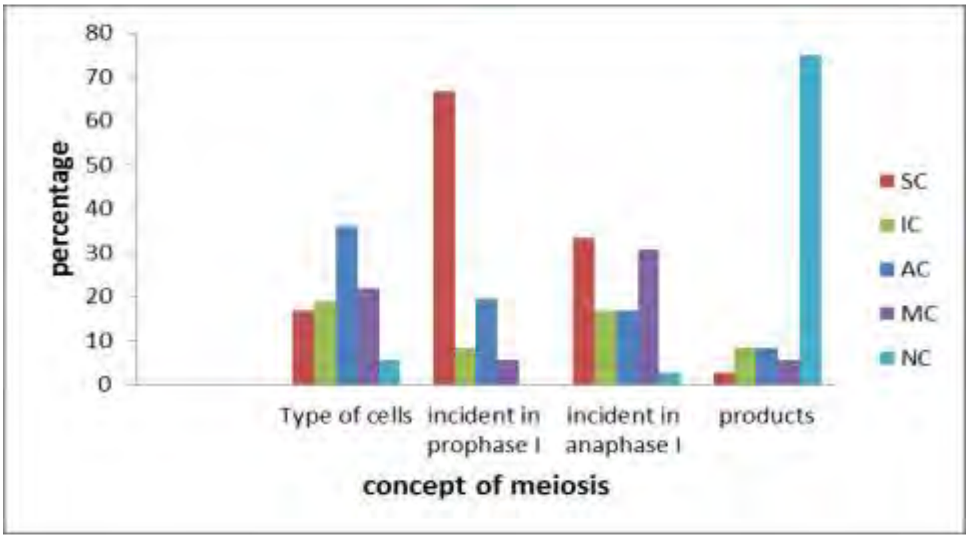

Figure 2. Distribution of conceptual understanding on meiosis concept.

As seen in Figure 2, the highest percentages for combination of alternative- and misconceptions on the concept of meiosis were (i) type of cells and properties of organism, (ii) important incident in anaphase I, (iii) important incident in prophase I, and (iv) products, and there were 58%, 47.3%, 25%, and 13.9% respectively. The percentage of no conception was highest on the products concept (75%), and there was none of the students who had no conception on the important incident in prophase I. This means the researchers should focus to design learning event for the process of conceptual change for this sub-concept, but it need to be ground the students' conceptual understanding in the learning events for another three meiosis sub-concepts. In the next, Figure 3, the results of students' conceptions of process and products within mitosis concept were presented.

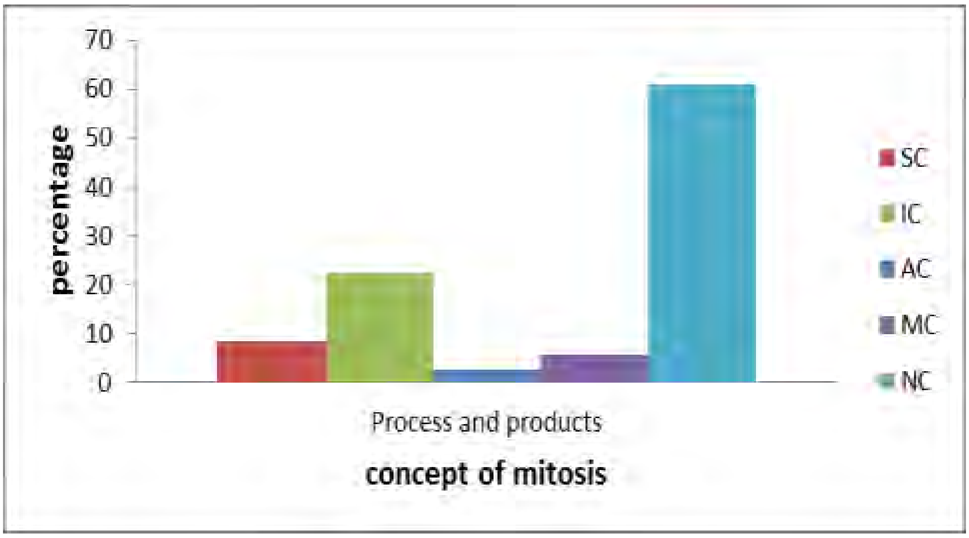

Figure 3. Distribution of conceptual understanding on concept of mitosis.

As show in Figure 3, there was a small number of the students who hold alternative- and misconceptions on process and products sub-concept (8.4%). However, more than a half of them showed no conception on the concept (61%). This means there need help for facilitating construction of conceptual understanding regarding the concept of process and products., The result of students' alternative-, mis-, no conceptions on cytokinesis concept was depicted in Figure 4.

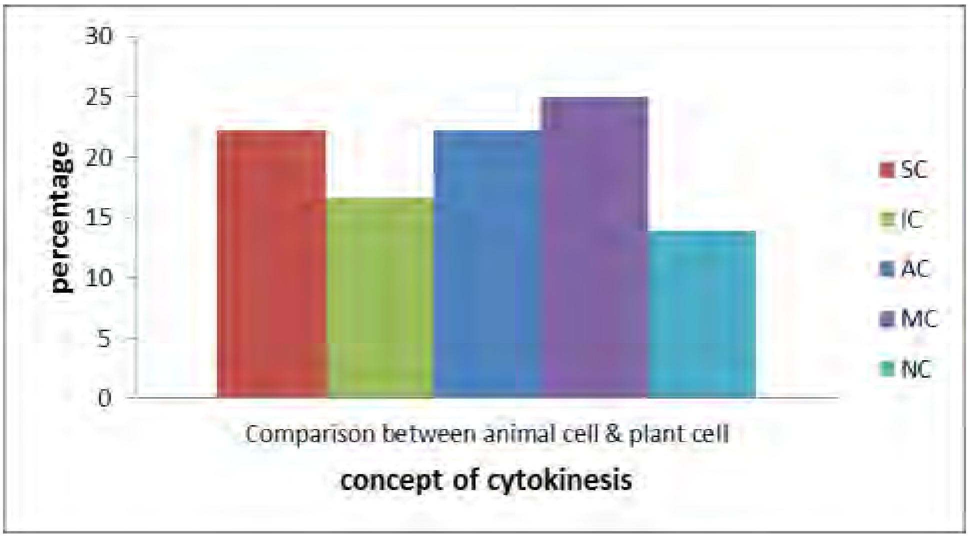

Figure 4. Distribution of conceptual understanding on cytokinesis concept.

Figure 4 shows the percentage for combination of alternative- and misconceptions for comparison between animal and plant cell was about the half of them (47.2%), and for no conception was 13.9%. This revealed that this concept need a couple for student learning, both grounding scientific concept and changing unscientific concept. For the main concept of cell cycle, Figure 5 displayed students' conceptions on the sub-concept of important of cell cycle and types of cell.

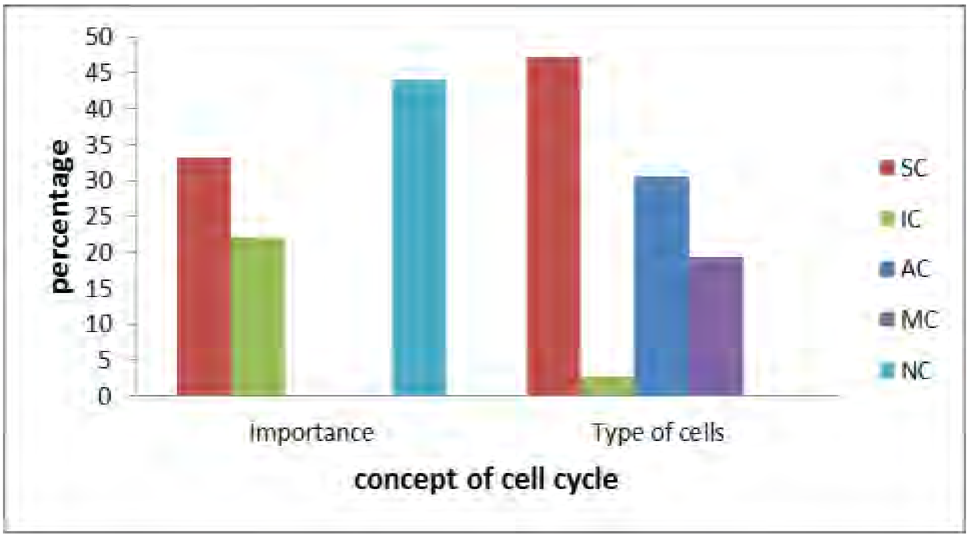

Figure 5. Distribution of conceptual understanding on the cell cycle concept.

In Figure 5, none of students' unscientific conceptions on importance of cell cycle were found and only 22.2% of them showed incomplete conceptions in this sub-concept. This means most of them were able to comprehend the sub-concept from the regular class. Nevertheless, a half of them (50%) hold unscientific conceptions on type of cells sub-concept, and there was 44% who had no conception about the concept.

The findings of this study consistent with the previous finding that many students hold alternative conceptions in mitotic and meiotic division (Ozcan, Yildirim, and Ozgur, 2012). Moreover, the results also confirm to a research carried out by Lewis and Robinson (2000) that high school students hold unscientific understanding, and encounter learning difficulty and they cannot understood on biological concepts of DNA, gene, chromosome, mitotic and meiotic division.

According to the DSLM approach the researcher used, Table 1 shown examples of students' alternative conceptions in cell cycle concepts and the design of learning events to address and facilitate conceptual change. Moreover, the next section illustrates the design of digital game-based inquiry learning in biology of cell cycle.

Table 1: Designing dual-situated learning events regarded students' alternative conceptions on cell cycle.

Concept	Sub-concept (item)	Example of students' alternative conceptions	Design of learning event to address the alternative conceptions
Interphase	Incident of Interphase (1)	DNA synthesis occurs in G_1 phase.	Comparison of necessary compounds for biological process occurred in G_1, S, and G_2 stage (Learning Event#1)
	Importance of Interphase (2)	-	-
Meiosis	Type of cells & properties of organism (3)	Meiosis occurs in reproductive organs, for example, testes and ovaries.	Comparison between the origin of somatic cell and reproductive cell (spermatogenesis and oogenesis) (Learning Event#2)
	Important incident in prophase I (5)	Crossing over occurs in prophase II of meiosis process.	Identification of key characteristics of "crossing over" (Learning Event#3)
	Important incident in anaphase I (6)	Segregation of homologous chromosomes occurs in telophase I.	Comparisons among meiosis I, meiosis II, and mitosis (Learning Event#4)
	products (7)	Segregation of homologous chromosomes occurs in anaphase II.	

Mitosis	Process and products (4)	When mitosis completed, there is followed by meiosis.	
Cytokinesis	Comparison between animal cell and plant cell (8)	Similarly, both plant and animal cell have process of mitotic karyokinesis.	Comparison between cytokinesis of plant cell and animal cell (Learning Event#5)
Cell cycle	Importance of Cell cycle (9)	-	
	Type of cells (10)	There may be fix over.	Comparison of different types of cell (Learning Event#6)

4. The Design of Digital Games about Cell Cycle

According to the stage 4 of DSLM, learning events associated students' unscientific conceptions on cell cycle has been design and presented in the previous section (See Table 1). To develop the digital games which facilitate process of conceptual change, the researchers employed the designed learning events as a basis to create a prototype of "The Cell Cycle Game". This game consists of two parts; game playing and visualization. Figure 6 illustrates interaction part of game playing in the cell cycle game, and Figure 7 displays visual representation about cell division, both mitosis and meiosis.

Figure 6. Example illustration of "The Cell Cycle Game": (A) a screen for selecting a car represented a type of cell; (B) a screen for controlling the car (a type of cell) and collecting nutritive essence for cell development.

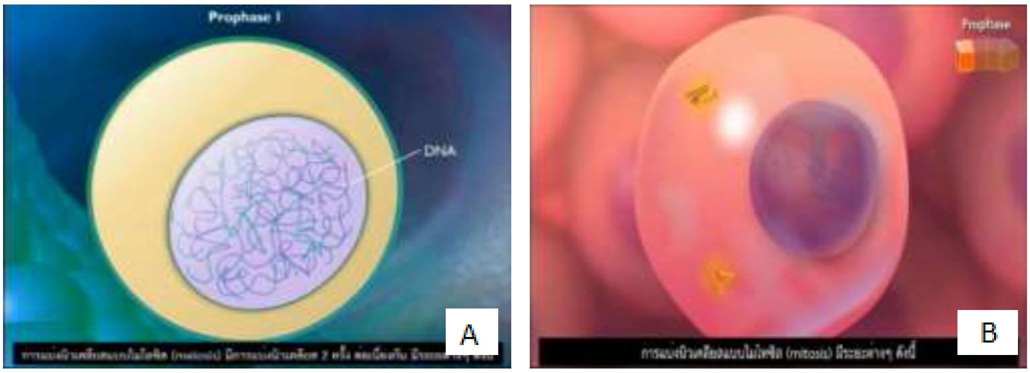

Figure 7. Example illustration of visualization, embedding in the game: (A) a screen representing mitosis process of cell division; (B) a screen representing meiosis process of cell division.

5. A Proposed Learning Process of Digital Game-based Open Inquiry with Dual- situated Learning Model on Cell Cycle

This section presents a proposed inquiry learning process using the cell cycle game. The simulation-based open inquiry with dual-situated learning model (Srisawasdi and Kroothkeaw, 2014;

Srisawasdi and Sornkhatha, 2014) was applied for the proposed learning process. Table 2 displayed an example of the learning process on cell cycle concept.

Table 2: Example of the design of learning process by game-based open inquiry with dual-situated learning model

The main stage	Components of the proposed learning process	Example of learning process
Pre-gaming	Open-ended inquiry question	Teacher provides an open-ended inquiry question: "How many DNA during the cell division?"
	Scientific background/ information	Teacher encourages collaborative discussion on basic information related the question by presenting a concept map of cell cycle.
Collaborative gaming	Procedure/design	Students are classified into small group to play game. Each group designs their own task, independent selecting a type of cell, to play game. 
	Data and result analysis	After the interacting with the game, students make a decision to analyze obtained playing game data e.g. scores and interpret it into a graphical representation. 
Post-gaming	Result communication	Students have to select the way to present, communicate, and discuss the meaning of data for whole class.
	Conclusion	Students have to collaboratively make a relationship between each group results and then show conclusion as the best answer to the provided question.

In this learning process, student will collaborative work together in small groups of three to five members. This pedagogy begins with an open-ended driving question targeted to alternative conceptions about cell cycle commonly found in students. To assist the process of hypothesis generation addressed the question, essential scientific backgrounds are provided to students. Then, students are required to perform generating testable hypotheses, designing an investigation with the cell cycle game. During playing the game, each group was assigned to access Google Drive spreadsheet, preparing by instructor, for recording scores and what they found into a predetermined table. In an addition, each group was assigned to analyze the recorded data by comparing individual score and also use Google Chat for discussing in the group. When they finished the game, all groups have to communicate findings among groups by creating a PowerPoint presentation via Google Drive presentation. Finally, instructor induces students into a forum for drawing a conclusion based on evidence and collaborative explaining the result of hypotheses testing.

Acknowledgements

This work was financially supported by the Institute for the Promotion of Teaching Science and Technology (IPST) and Graduate School, Khon Kaen University. The author would like to express gratefully acknowledge to Faculty of Education, Khon Kean University, for supporting this contribution.

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