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A Blended Learning Environment in Chemistry for Promoting Conceptual Comprehension: A Journey to Target Students' Misconceptions

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Abstract: Blended learning has become a new form of learning and teaching in science education. Researchers have indicated that the blended learning could create more meaningful in learning, support deep-level understanding, and contribute to better learning achievement in the exam. The present article presents a blended learning environment, combination of computer-based interactive lecture demonstration (CBILD) and web-based inquiry science environment (WISE), for chemistry learning of state of matter and phase change. To create the blended environment, 50 twelve-graders were recruited in an investigation of prior knowledge by challenging their epistemological and ontological belief of the chemistry concepts. As such, a series of two-tier conceptual items were administered and then the students' unscientific conceptions about state of matter and phase change were extracted as an account. The finding showed that they hold various patterns of misconceptions covering the effects of pressure and temperature on arrangement of particle and phase change, and shape of molecule during phase change. Moreover, all of them have no scientific conception that plasma is a state of matter. Many misconceptions seem to due to the fact that they could not realize interaction between observable and unobservable level of chemical phenomena because of its complexity and abstraction. To make chemistry more accessible and meaningful for student learning, CBILD learning process was design in emphasizing macro-level representation and WISE was design to support sub-micro-level and symbolic representations in chemistry as face-to-face and on-line learning experience respectively. The learning process of blended learning environment was illustrated and described in a sequence for implementing in chemistry classroom. This could be an implication for researchers and teachers how to create blended learning environment which could improve teaching and learning strategy into a new form for science classroom, and it might enhance the change of student's misconceptions and their mental model development in science.

Keywords: Blended learning, interactive lecture demonstration**,** web-based learning, microcomputer-based laboratory, chemistry education

1. Introduction

Chemistry is a fundamental science which is abstract and complex by its nature. Due with its nature, students lack of transfer what they learned, e.g. concepts, to real-world problems and everyday life, and they give no meaning to what they have learned (Gilbert et al., 2002; Gilbert, 2006).Although, the chemistry learning activities attempted to link the subject matter with how the world works, the students still have numerous learning difficulties and misconceptions on the subject. Moreover, they merely link their own existing ideas to the new concepts leading to fragmented and fractured understanding (Gilbert and Boulter, 2000). Such misconceptions, especially on the topic state of matter and phase change, are due to the fact that the students could not distinguish between macroscopic and sub-microscopic explanations. The students have also difficulty linking observable phenomena to molecular level interaction (Chang and Linn, 2013). As such, many studies suggested that the molecular visualizations could help students integrate observable, molecular, and symbolic aspects of chemical change (Russell and Kozma, 2005).

With the benefit of computers and technology in science education community, the contemporary technology-based approach has been used to enhance students' conceptual understanding (Vreman-de Olde et al., 2013; Srisawasdi and Kroothkeaw, 2014). Moreover, the inquiry-based learning strategy supported by Information and Communication Technology (ICT) has known as an effective pedagogical approach in science learning. ICT can also enable new ways of education to deliver knowledge directly from teachers to students and the learning can take place anywhere and anytime. Recently, there are many computer-supported inquiry-based science learning environments such as WISE, Co-Lab, Inquiry Island, and nQuire (Sun et al., 2013). The instructions that teachers implement have been changed by conducting the new learning paradigm and innovative educational tools. Active learning and knowledge sharing have been replacing traditional teacher-centered lectures, due to their ability to integrate ICT into the curriculum and their emphasis on meaningful learning (Yen and Lee, 2011).

Blended (hybrid, mixed-mode) learning is referred as learning combination of the classical teaching in classroom (face-to-face learning) and teaching assisted by contemporary technologies. Thorn (2003) described blended learning as a way of meeting the challenges of tailoring learning and development to the needs of individuals by integrating the innovative and technological advances in online learning environment. Moreover, Yapici and Akbayin (2012) revealed that the students who participated in blended learning model could achieve learning outcomes in biology course than those who participated in the traditional teaching method significantly. In additions, they also have positive attitude toward science if the learning environment had incorporated by internet access (Yapici and Akbayin, 2012). As such, the blended learning could be used to overcome the difficulties of practical science.

With the importance of enhancing students' conceptual understanding in science concepts and considering benefits of blended learning environment as aformentioned, the researchers aim to develop an effective blended learning environment for chemistry learning of state of matter and phase change regarding students' specific misconceptions. As such, investigation of the misconceptions before designing of science learning environment could be a strategic way for research and development in science and technology education.

2. Blended Learning Environment

Lecture demonstration method is usually an integral part of a university education. This method helps students to visualize the material through students' understanding of the subject. Zimrot and Ashkenazi (2007) indicated that interactive lecture demonstrations (ILD) could be used to make more accessible of scientific conceptual understanding because of potential source of anomalous data that can trigger cognitive process of conceptual change. Moreover, ILDs are fun to do and provide concrete examples of abstract concepts. Nevertheless, using only the traditional approach to education, where the transfer of knowledge is achieved mostly by lecturing, has a number of shortcomings, because the students are not motivated enough to acquire knowledge actively (Hoic-Bozic, Mornar and Boticki, 2009; Burnham, 2001). To cope with this issue, the computer-based interactive lecture demonstration (CBILD) could be a novel of instruction to encouraging students learning and is one component of blended learning environment in this study.

Moreover, to enhance knowledge integration, the use of computer visualizations in inquiry activities can enhance students' conceptual understanding of molecular level interactions. web-based inquiry science environment (WISE), which is one of web-based learning environment and is one component of blended learning environment in this study, was developed based on the knowledge integration perspective that help students develop a more cohesive, coherent, and thoughtful account of scientific phenomena (Linn et al, 2003). WISE is a powerful, research-based online platform for designing, developing, and implementing science inquiry activities. Unique features and benefits of WISE consists library of free, assessments aligned with instruction, interactive visualizations and simulations, embedded prompts for reflection and collaboration, instructional support for diverse learners, teacher feedback and guidance tools, powerful authoring and customization tools library of free, and classroom-tested projects.

Therefore, in this study, the blended learning environment refers to a combination of computer-based interactive lecture demonstration (CBILD) and web-based inquiry science environment (WISE). In this blended learning environment, the learning sequence to facilitate the construction of conceptual understanding and induce the change of misconceptions on the topic state of matter and phase change has been designed and presented in this paper.

3. The Exploration of Students' Misconceptions

In this study, the researchers conducted an exploration to identify students' common misconceptions on chemistry topic of state of matter and phase change. The findings of the exploration provided us as a basis in order to design and create the blended learning environment by combining CBILD and WISE as a novel learning experience for chemistry learning.

3.1 Participants

To explore misconceptions on the topic, fifty twelve-grade students, age ranging from 17 to 18 years in a local public school at the Northeastern region of Thailand were recruited in to the study. They already completed a regular chemistry class and they were taught about the state of matter and phase change before participated in this study.

3.2 Research Instrument and Data Analysis

As aforementioned, 20-item two-tier conceptual test targeting chemistry concepts of state of matter and phase change was used to investigate students' common misconceptions. The conceptual test was adapted from a published research instrument, Particulate Nature of Matter (ParNoMa) (Bridle and Yezierski, 2011). Some of the two-tier conceptual items were constructed by the researchers, and the questions were developed specifically for the concept of phase change of gas to plasma concepts. This topic was chosen after an extensive literature review, which reported that there was no study about student's conceptual understanding in plasma state of matter before. The two-tier conceptual item contains a first tier of multiple choices associated with the main question and a second tier of open-ended reasoning. The two-tier conceptual test was reviewed by three experts for identifying construct and communication validity. The respondents were asked to complete the test within 60 minutes. In this study, the researchers have analyzed and interpreted the respondents' answers into four categories of conception: scientific conception (SC), incomplete conception (IC), misconception (MC), and no conception (NC). The misconceptions identified by this study were used in the development of blended learning environment for chemistry learning of state of matter and phase change.

3.3 Results of Students' Misconceptions on State of Matter and Phase change

The two main topics in this study were state of matter and phase change. These topics consist of many fundamental concepts in chemistry. The concepts were: (i) effect of pressure on the arrangement of particle; (ii) particle movement; and (iii) physical properties of matter, i.e. solid, liquid and gas, and plasma, a new-defined state of matter. After the survey, the researchers found that students hold various patterns of misconceptions in the first topics. In this paper, the researchers reported only students' misconceptions on the effect of pressure on arrangement of particle that most students illustrated especially with many misconceptions. In the second topic, most of students' misconceptions were in place with chemistry phenomena of bubble formed during boiling, phase change of gas to plasma, shape of molecule and the phase change, and the relationship between temperature and phase change. Table 1 displays percentage of students' misconceptions on state of matter and phase change.

Table 1: Students' misconceptions about state of matter and phase change.

Topic	Concept	Specific types of misconception (MC)	Frequency (%)
State of matter	Effect of pressure on particle arrangement	When pressure of carbon dioxide decreased: ▪ No effect on space and size of its molecules ▪ Decreasing of molecule attachment and getting smaller in size ▪ More diffusion of substances ▪ Increasing of space among molecules and getting larger in size ▪ Increasing of numbers of molecule ▪ Decreasing of space among molecules but no effect on size of molecule	 12 8 2 20 12 24
		Total	78
Phase Change	Bubbles formed during boiling	The bubbles were produced because: ▪ Making change by heat	 20
		The bubbles come from: ▪ Air ▪ Decomposing of water into hydrogen atoms and oxygen atoms ▪ Liquid pressure	 8 22 2
		Total	52
	Phase change of gas to plasma	When gas reach to high temperature around 10,000 Celsius: ▪ Decomposing into hydrogen molecules and oxygen molecules ▪ Decomposing into H^+ *and* OH^- ▪ Decomposing to the end of nothing ▪ Nothing happened	 36 14 14 14
		Total	78
	Shape of molecule and phase change	The condensation causes: ▪ Larger size of water molecule ▪ Larger size of water molecule because of its combination	 13 12
		The freezing causes: ▪ Larger size of water molecule because of its combination	 17
		The melting causes: ▪ Larger size of water molecule because of its expansion	4
		Total	46
	The relationship between temperature and phase change	When ice was heated: ▪ Changing to be water and stream state respectively	66
		Total	66

4. Discussion

This pilot study reports students' misconceptions on state of matter and phase change and the design of blended learning environment combining CBILD with WISE based on the findings of students' misconceptions. The result showed some patterns of students' misconceptions about state of matter and phase change. This could be discussed that students hold with various misconceptions in the same content, it shows difference of understanding although they were provided in the same learning context in classroom. Many misconceptions are due to the fact that students do not distinguish between macroscopic and submicroscopic explanations and students have also difficulty linking observable phenomena to molecular level interaction (Chang and Linn, 2013). Almost all students could not explain in term of molecular level, some can answer correctly in multiple choice part of two-tier test but cannot give a reason of their answer or give it by not corresponding. Most chemistry courses require improving students' understanding by adding scientific concepts; however, students often add concepts without integrating them with their other related concepts, which leads to fragmented and fractured understanding (Gilbert and Boulter, 2000). Hence, the researchers can conclude that knowledge integration affects conceptual understanding.

To enhance scientific conceptual understanding the instructor needs to provide instruction for supporting the knowledge integration. The blended combination of CBILD and WISE was designed to address students' misconceptions by supporting knowledge integration and conceptual understanding to make science accessible.

5. The Design of Blended Learning Environment to Address Students' Misconceptions about State of Matter and Phase Change

The blended learning was considered learning environment to address students' misconceptions about state of matter and phase change. Face-to face learning takes place in the conventional science classroom using the computer-based demonstration provided by teacher in front of classroom via projector. The computer-based demonstration may be science experiment or video presentation that dependent on the content and accessible learning materials. For example, the experiment of plasma cannot be demonstrated or performed its experiment in classroom because it is very harmful and instrument also rare in laboratory. During learning period, students took one hour for CBILD in conventional classroom and then two hours for WISE in computer room. Teacher provided student CBILD strategy to make science accessible by empirical evident that is observable phenomena and lead them to distinguish macroscopic explanation. Student were further conducted to investigate unobservable phenomena in the molecular level by using molecular visualization supporting sub-microscopic explanation related to macroscopic and symbolic explanation. When they gain knowledge by related concepts, they will can link three explanations together and result in knowledge integration that becomes conceptual understanding, as shown in Figure 1.

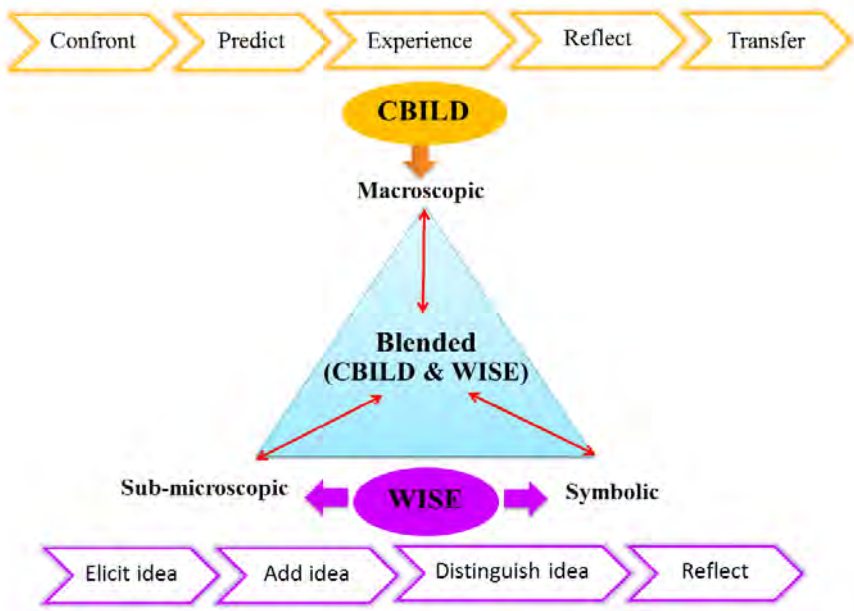


Figure 1. Features of blended learning environment to facilitate students' conceptual understanding in chemistry.

5.1 An Example of CBILD on the Relationship between Temperature and Phase Change

In this part, the researchers would like to present emerging the new technology into science classroom to make science to support students' conceptual understanding and meaningful learning about scientific content from empirical evident. The Vernier Software and Technology is conducted to demonstration of experiment, us sensors such as temperature probe to detect temperature during phase change process of water, and also use a gas pressure sensor to measure vapor pressure of liquid for study the effects of temperature and type of liquid on vapor pressure of liquid. These sensors can connect with computer supported by LabQuest Mini and Logger *Pro* software to acquire real time collection and analysis data, and directly display the result by giving a real-time graph. The researchers use interactive lecture demonstration (ILD) strategy to provide instruction. They help students to visualize the material that is being discussed in class and are frequently described by students as an important component of their understanding of the subject. In this method, the students are asked to predict the outcome of a demonstration and write down their prediction and explanation, and therefore commit to an explicit model. Peer discussion follows, with the students discussing their predictions in small groups– again, they have to address their existing models explicitly (see Table 2).

Table 2: An example of learning process in CBILD classroom.

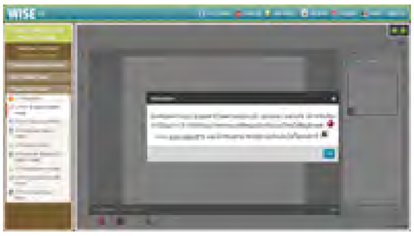
Components	Description of learning process	Examples of learning activity
1. Confront	● Teacher engages student by thinking and giving examples about phase change phenomena in daily life and then provides questions about relationship between temperature and phase change.	
2. Predict	● Teacher conducts students to predict how does temperature change if ice is heated and become water and finally to vapor, respectively, and then water become ice after cooling.	
3. Experience	● Teacher demonstrates change of temperature during phase change by using the Vernier Software and Technology to real time data collection and analysis.	
4. Reflect	● Teacher allows students to compare the results of experiment and their previous prediction and engages them to discuss on the confront phenomena ● Teacher induces student into formative assessment question or statement related the phase change phenomena.	

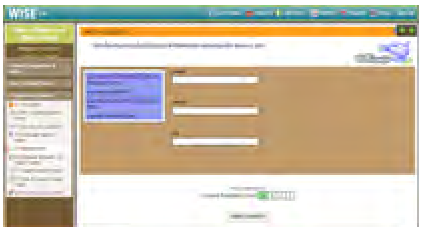
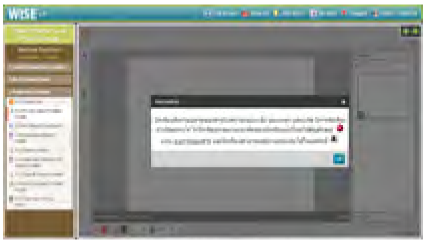
5. Transfer	• Teacher encourages student to explain another physical phenomenon based on the phase change concept.	

5.2 An Example of WISE on State of Matter

Students will use the visualization, resources from The Concord Consortium, PhET, Molecular Workbench and so on, as part of the WISE to explore unobservable scientific phenomena. The inquiry activity helps students to connect new concept to their existing concept. The knowledge integration pattern was implemented in synthesize of WISE. This pattern involves four main learning processes. (i) Eliciting student concept, consistent with the values of predictions; (ii) adding new concept, essential case or new scientific concepts; (iii) supporting students to distinguish among the new and existing concept by constructing arguments and using scientific evidence; and (iv) fostering reflection and self-monitoring to help students consolidate their understanding. Table 3 shows an example of inquiry activity based on knowledge integration (KI) processes. The researchers will assess students' conceptual understanding and knowledge integration by analyzing their answers the prompting questions embedded in WISE activity before and after investigation.

Table 3: Embedded prompts/assessment capturing the knowledge integration processes.

KI processes	Description and Examples of activity	Illustrations of WISE screenshot
1. Eliciting ideas	Using prompting questions to probe prior knowledge and existing ideas Example: • Could you draw the model of arrangement of particle in each state, liquid solid and gas? • Explain why did you draw the previous model.	
2. Adding new ideas	Providing necessary information to help students make sense of the topic and connect to existing ideas Example: • The picture below represents the arrangement of particle in solid, liquid and gas state of matters, you can move the cursor anywhere inside the picture to see the difference of particle movement. • For this part, you can control the molecular visualization to explore the structure of a solid, liquid and gas at the molecular level.	

3. Distinguishing ideas	Encouraging students to distinguish among ideas and realizing how existing ideas relate to, conflict with, or extend these new ideas Example: ● By the evident from previous page, recall the structure of a solid, liquid and gas at the molecular level in the model you investigated, Could you match the motion of particle with solid, liquid or gas?	
4. Sorting out ideas	Encouraging students to sort out and refine their knowledge based on these evaluations Example: ● Recall the previous questions. After your investigation, could you draw the model of arrangement of particle in each state, liquid solid and gas? And explain why did you draw the previous model.	

6. Conclusion and Future work

The blended learning environment designed based on misconceptions of state of matter and phase change finding in this pilot study will be used in eleventh-grade students to evaluate the effectiveness of the proposed approach. In further study, the combination of CBILD and WISE will be used to enhance eleventh-grade students' conceptual understanding, knowledge integration of the state of matter and phase change, and also scientific motivation. The simultaneous mixed methods strategy of non–equivalent control group design and phenomenological research design will be carried out. The participants will be separated into two group, control and experiment group. Only ILD will be implemented in a control group, on the other hand, ILD combined with WISE will be implemented in an experiment group. Student's knowledge integration will be addressed during learning through WISE, which is designed based on knowledge integration framework, by taking the questions before and after using WISE within class period. To compare difference the outcome between two groups, pre-test, post-test and embedded questions in WISE will be analyzed and interpreted to answer the research question; does blended learning combining CBILD and WISE effect eleventh-grade students' conceptual understanding, knowledge integration about state of matter and phase change, and scientific motivation differently from using only CBILD?.

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