Technology-enhanced Chemistry Learning and Students' Perceptions: A Comparison of Microcomputer-based Laboratory and Web-based Inquiry Science Environment

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Abstract: With current advancement of information and communication technology, researchers have indicated the necessity and challenges of developing effective instructional strategies by the use of technological tools to promote chemistry learning in school science. Consequently, the researchers has developed two kinds of technology-enhanced chemistry learning environment regarding rate of reaction concepts: MBL-based guided-inquiry learning, as face-to-face instruction; web-based inquiry science environment (WISE), as online instruction. The purpose of this study was to investigate effects of both learning environment on students' perceptions. The participants were tenth graders; they are assigned randomly into two groups for interacting with different learning environment, MBL (N= 37) and WISE (N= 34). To assess students' perceptions in the different groups, pre- and post-questionnaires were used. The results of the study (N = 71) show that there was statistically significant difference between pre - and post-questionnaire for both groups. No significant difference was found between the MBL and WISE groups in terms of students' perceptions. The result suggested that both technology-enhanced learning environment progressed students' perceptions of learning and the progression was not indifferent. This finding highlight the benefits of face-to-face MBL and WISE to promote students' perceptions of learning.

Keywords: MBL, WISE, chemistry learning, perception, rate of reaction

1. Introduction

To advance the practice of science education, technologies have become commonplace because of their potential of bringing about change in ways of teaching and learning (Srisawasdi, 2012). For this reason, in research and development of the student learning process in science, the effective use of technology in the classroom teaching process has become a common place in science-based education. In the community of science educator and educational researcher, it has been widely established that contemporary science learning environments should foster inquiry-based experiences and investigations. These inquiry-based scientific practices should take place in the laboratory in order to interact directly with naturally occurring phenomena (Srisawasdi, 2014; Pyatt & Sims, 2011). In recent years, many researchers have applied microcomputer-based laboratory into inquiry-based science education for teaching and learning (Friedler et al., 1990; Gunhaart & Srisawasdi, 2012; Liao & She, 2009; She & Liao, 2009) that can promote authenticity and application of scientific process and practice and facilitate concrete-to-abstract conceptualization of real-world phenomena (Pyatt & Sims, 2011). Likewise, Web-based Inquiry Science Environment (WISE) is an open-source digital learning platform that supports student inquiry in classrooms for support students visualization and understand in sub-microscopic levels (Chiu, Jennifer & Linn, 2011). Researchers reported that students could be provided effective learning experience of science and student can link the idea of three levels of chemistry representation (i.e. macroscropic, sub-microscropic, and symbolic) (Chang & Linn, 2013). As abovementioned, both science learning environments were recognized as effective technological tool for inquiry-based learning process, and there is a plenty of challenge to think about how to use them in science teaching and learning pedagogically.

Accordingly, the aim of this study was to investigate students’ perceptions delivered in face-to-face MBL and online-mediated WISE. Specifically, the following questions were answered:

(1) Do the students engaged in face-to-face MBL and online-mediated WISE learning environment perform significantly better by students’ perceptions?

(2) Is there a difference between students' perceptions between face-to-face MBL and online-mediated WISE learning environment?

Following the questions, it is hypothesized that both face-to-face MBL and online-mediated WISE will lead greater students' perception after their participations, and there are no different on students' perceptions on experience with both learning environments.

2. Literature review

2.1 Microcomputer- based Laboratory (MBL)

Recently, In teaching and learning about of science-based education, computer technology has been widely used for modeling scientific knowledge structures or learning patterns, developing more in-depth and integrated understanding of concepts and process, enhancing the development of scientific skills, visualizing complex and dynamic scientific phenomena, promoting collaborative network in the community of learning for the construction of knowledge, and sharing of data, support access to a variety of information, support collecting various types of scientific data, test underlying theories through diagnostic or tutorial strategies, and enhance characteristics of inquiry as the way scientists work (Srisawasdi, 2014). In recent years, the reviewing of empirical evidence it is clear that microcomputer can improve the learning process of students in science education. Moreover, many researchers have applied microcomputer-based learning to inquiry-based science education for teaching and learning (Friedler et al., 1990; Gunhaart & Srisawasdi, 2012; Liao & She, 2009; She & Liao, 2009). The result of researchers shown that microcomputer-based inquiry learning can support student to learn science efficiency and make student can observe phenomena and understand in macroscopic level of representation.

2.2 Web-based Inquiry Science Environment (WISE)

WISE is the multimedia learning, in which the teachers can insert the lessons into web-based learning environment in order to aid and follow the learning results from students. WISE has four steps following Knowledge Integration (KI) framework (Chiu, Jennifer, & Linn, 2011): (i) eliciting ideas is to emphasize the native knowledge of the students; (ii) adding ideas is to add the new knowledge to the students; (iii) distinguishing ideas is to promote critical thinking of the students; and (iv) sorting out ideas is to rearrange the ideas of the students. In an addition, researcher reported impact of the WISE that students can link the idea of three levels of chemistry knowledge (i.e. sub-microscropic, macroscropic, and symbolic (Chang & Linn, 2013).

3. Method

3.1 *Participants*

The participants in this study were tenth-grade students (16-17 years old) in the Northeastern region of Thailand. The selection of samples performed randomly. They were divided into two groups which received different learning environment: WISE (N=34) and MBL (N=37) groups. Both groups were assigned to learn a chemistry lesson on rate of reaction. For online-mediated WISE class, the students were enabled to learning by self-regulated learning process with the WISE, which was designed the rate of reaction lesson followed KI framework. In contrast, the students in face-to-face MBL class were engaged into guided-inquiry learning process with the support of MBL tools. However, two technology-based learning environments were equivalent in term of chemistry concepts on rate of reaction. The students had not had any formal education on rate of reaction before the study took place. Figure 1 illustrated information about participants and learning environment.

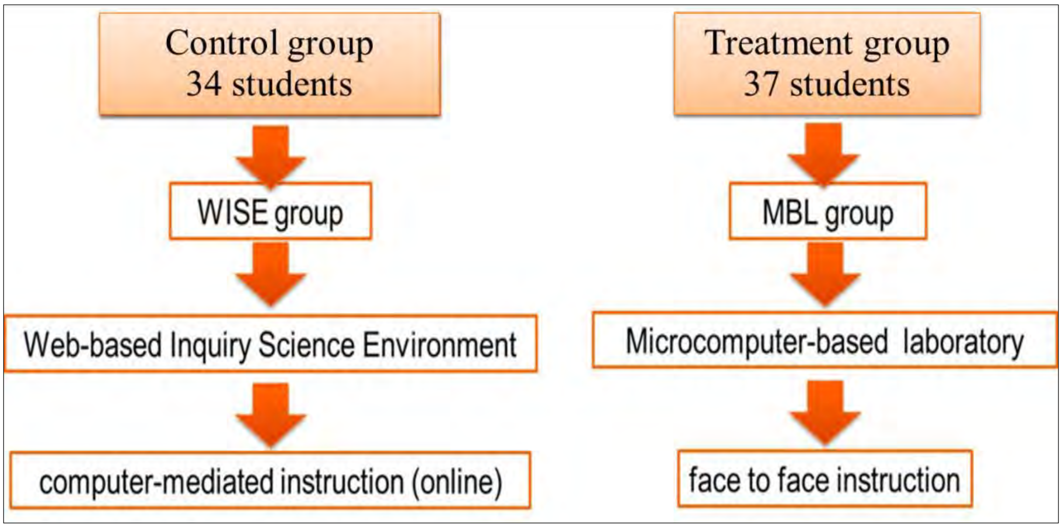


Figure 1. Diagram of participants and learning environment

3.2 *Learning Environments*

3.2.1 *Face-to-face MBL*

To engage student into face-to-face MBL, this study employed microcomputer-based laboratory (MBL) by Vernier and software technology. Vernier mini-LabQuest is a digital interface used to collect sensor data and then transfer data into Logger Pro software building graph and analysis application. For this study, students were provided opportunity to conduct an investigation of effects of reaction rate using carbon dioxide gas sensor. Figure 2 displays an example of hands-on MBL for guided-inquiry learning process in chemistry class.

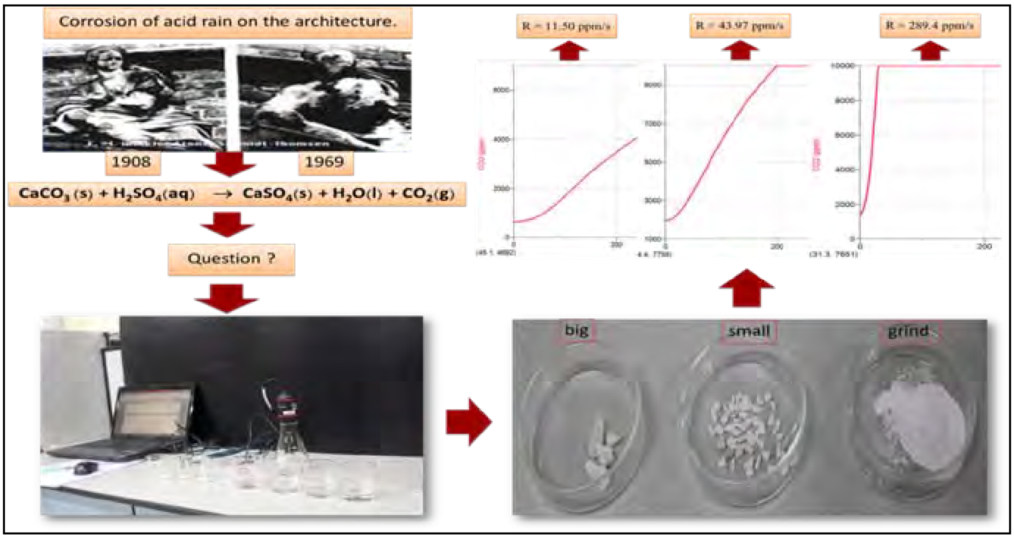


Figure 2. Example of hands-on guided-inquiry MBL on the effects of rate of reaction

As mentioned, guided-inquiry learning process was used to promote student's chemistry learning of rate of reaction. The simulation-based open inquiry with dual-situated learning model (Srisawasdi and Kroothkeaw, 2014; Srisawasdi and Sornkhatha, 2014) was applied for the face-to-face MBL learning process in a manner of guided inquiry. Table 1 displayed an example of the learning process on rate of reaction concept.

Table 1: The six-stage guided-inquiry learning process for face-to-face MBL environment

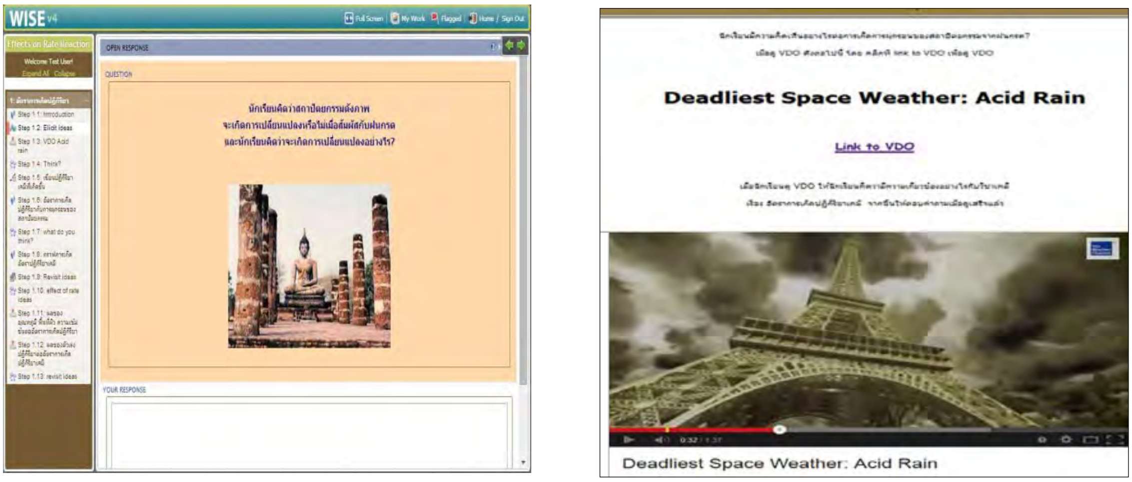
Stage	Learning process
Pre-lab	
Open-ended inquiry question	Teacher provides an open-ended inquiry question: ‘‘How about rate of reaction if difference surface areas of sculpture react with acid rain is concentrated static?’’
Scientific background/ information	Teacher induces collaborative discussion toward the definitions and pictorial diagram of acid rain reaction ;surface area ;CO_2 gas
Lab practice	
Procedure/design	Teacher introduces the overall procedure of the laboratory, explains how to perform a predetermined experiment step-by-step, and guides how to record necessary data. Then, student conducted the experiment about acid rain (H_2SO_4) with sculpture ($CaCO_3$) interaction for collecting the experimental data from carbon dioxide gas when they change surface area of $CaCO_3$.
Data and result analysis	After the interacting with laboratory, students make a decision to analyze obtained experimental data from their own design and interpret it into results.
Post-Lab	
Result communication	Students have to select the way to present, communicate, and discuss the meaning of data and experimental results to others, for an example, writing experimental question, experimental design, results, and discussion on a newsprint paper and then present to the class.
Conclusion	Students have to collaboratively make a relationship between each group results and then draw it into a conclusion as the best answer to the provided inquiry question. For an example, teacher induces each group make a conclusive answer by using an integration of their own and other results.

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 effects of rate of reaction 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. Information about scientific process and procedures were given to guide them performing experimentation with MBL tools. During experimenting with the MBL, instructor came to probe them with a series of formative assessment question. When they finished the experiment, all group has to communicate findings among groups by creating a chart of results and explaining findings. Finally, instructor induces students into a forum for drawing a conclusion based on evidence and collaborative explaining the result of hypotheses testing. Figure 3 displays an example of students’ interaction in the context of hands-on guided-inquiry MBL.

Figure 3. An illustrative example of classroom learning activity through face-to-face microcomputer-based laboratory with guided-inquiry process.

3.2.2 *Online-mediated WISE*

WISE curriculum materials is an online-mediated environment which features powerful, interactive scientific visualizations to illustrate unobservable phenomena such as chemical reactions at the atomic level, large-scale phenomena such as climate change, and phenomena that happen quickly such as collisions. The online environment logs student interactions and responses to embedded assessments. WISE offers teachers grading and classroom management tools to monitor student progress, provide feedback to students, and personalize instruction. In this study, the researchers created a chemistry learning unit on rate of reaction on WISE system by emphasizing the interplay between macro-, sub-micro-, and symbolic representations of chemistry. The learning unit was constructed following Knowledge Integration (KI) framework. Figure 4 displays screen interface of WISE system for the chemistry learning unit of rate of reaction.



(A) Elicit Ideas: asking students what happen in this picture? for eliciting their existing knowledge of the students

(B) Add idea: giving student necessary information for adding new related knowledge to existing ideas

(C) Distinguishing idea: using of simulation and animation to promote students' scientific thinking and reasoning

(D) Sorting out idea: Asking students a question, "What factors affect the weathering of architecture from acid rain?" to rearrange conceptual ideas

Figure 4. An illustrative examples of screen interface of the chemistry learning unit of rate of reaction in online-mediated WISE following KI framework, from (A) to (D)

In this learning process, student will collaborative work together in small groups of two or three members. The teacher gave project ID to students in order to access the WISE and then facilitate students' group learning in the class and monitor progression of learning process during their participations. Finally, instructor induces students into a forum for drawing a conclusion based on evidence and collaborative explaining the rate of reaction phenomena. Figure 5 displays an example of students' interaction in the context of online-mediated WISE.

Figure 5. An illustrative example of classroom learning activity through online-mediated WISE.

3.3 Instruments

A 16-item Likert-scale questionnaire was developed to use in this study for examining students' perceived ease of use (3 items), perceived usefulness (3 items),and perceived satisfaction (3 items), obtained from Barzilai & Blau (2014), while an instrument by Cheng (2014) was used to measure perceived learning (4 items), and enjoyment (3 items). To develop a Thai version of the questionnaire, the original English version was translated identically in Thai language. Two experts were recruited to identify communication validity of the items. 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. The instrument had been established validity and reliability. Table 2 displayed sample items of the questionnaire used in this study and its reliability.

Table 2: Sample items of the Likert-scale questionnaire measured students' perceptions

Dimension	Sample items		α
	WISE	MBL	
Perceived ease of use	▪ It is easy for me to learn how to use WISE. ▪ I can easily accomplish what I need to do in WISE.	▪ It is easy for me to learn how to use MBL. ▪ I can easily accomplish what I need to do in MBL.	0.737
Perceived usefulness	▪ WISE can help me learn more effectively. ▪ WISE can improve my course performance.	▪ MBL can help me learn more effectively. ▪ MBL can improve my course performance.	0.842
Perceived satisfaction	▪ I feel comfortable to use WISE. ▪ I enjoy the experience of using WISE.	▪ I feel comfortable to use MBL. ▪ I enjoy the experience of using MBL.	0.774
Perceived learning	▪ I learned a lot from the WISE. ▪ The WISE added to my knowledge.	▪ I learned a lot from the MBL. ▪ The MBL added to my knowledge.	0.803
Enjoyment	▪ I enjoyed the WISE. ▪ Interacting the MBL was pleasant.	▪ I enjoyed the MBL. ▪ Interacting the MBL was pleasant.	0.754

3.4 Data Collection and Analysis

Students were investigated perceptions by the 5-point Likert-scale questionnaire before giving face-to-face MBL and online-mediated WISE intervention for 10 minutes. Both learning environments, students participated to interact with them for 60 minutes. After the instruction, students were administered by the same questionnaire again as post-test. The statistical data techniques selected for analyzing students' perceptions was repeated-measures MANOVA in SPSS 21.0.

4. Results and Discussion

The results for the repeated-measures MANOVA indicated no significant main effect for group (Wilks' lambda=0.878, $F(5, 65) = 1.798$, $p=0.126$, partial $\eta^2 = 0.122$). There was no significant difference on students' perceptions between face-to-face MBL and online-mediated WISE groups. The univariate results on two group revealed none of the five subscales on perception reached a statistical significance between both groups. That is, both face-to-face MBL and online-mediated WISE group performed indifferently with regard to perceived ease of use, perceived usefulness, perceived learning, perceived satisfaction, and enjoyment. Also, there was no significant interaction effect between group and time (Wilks' lambda=0.934, $F(5, 65)=0.923$, $p=0.472$, partial $\eta^2 = 0.066$). This means that both face-to-face MBL and online-mediated WISE has similar effects on students' perceptions. However, there was a significant main effect for time (Wilks' lambda=0.567, $F(5, 65)=9.940$, $p<0.001$, partial $\eta^2 = 0.433$). This suggests that, on average, students' perceptions have changed over the learning environments. Univariate analyses of variances (ANOVA) on each subscale were conducted as follow-up tests to the one-way MANOVA. The results of the univariate test for face-to-face MBL and online-mediated WISE groups are summarized in Table 3.

Table 3: The students' subscale means of perceptions by group and time and univariate MANOVA by time

Subscale	MBL		WISE		F	Sig.	η^2
	Pre-test	Post-test	Pre-test	Post-test			

Perceived ease of use	8.38(1.97)	11.19(1.71)	9.71(1.95)	11.35(1.97)	43.741	0.000	0.388
Perceived usefulness	8.87(2.64)	11.54(2.00)	9.97(2.36)	11.62(1.84)	34.515	0.000	0.333
Perceived learning	11.35(3.13)	15.00(2.43)	13.47(3.06)	15.15(2.41)	31.124	0.000	0.311
Perceived satisfaction	11.14(3.13)	14.84(2.27)	13.09(3.06)	15.47(2.43)	42.716	0.000	0.382
Enjoyment	8.30(2.52)	10.87(2.11)	9.94(2.53)	11.32(1.89)	25.807	0.000	0.272

As can be seen in Table 3, The univariate MANOVA on the five subscale scores of perceptions were significant differences across time, from pre-test to post-test. The univariate results revealed a significant effect on perceived ease of use ($F_{1,69}$ = 43.741, p < 0.01, partial η^2 = 0.388), perceived usefulness ($F_{1,69}$ = 34.515, p < 0.01, partial η^2 < 0.333), perceived learning ($F_{1,69}$ = 31.124, p < 0.01, partial η^2 = 0.311), perceived satisfaction ($F_{1,69}$ = 42.716, p < 0.01, partial η^2 = 0.382), and enjoyment ($F_{1,69}$ = 25.807, p < 0.01, partial η^2 = 0.272). According to aforementioned results, the overall result suggested that the increase of students' perceptions regarding perceived ease of use, perceived usefulness, perceived learning, perceived satisfaction, and enjoyment from the pre-test to post-test was homogeneous both face-to-face MBL and online-mediated WISE group. This result consistent with findings that students perceived online learning environment easy to use, to learn, and to accomplish what need to be done (Barzilai & Blau, 2014). In an addition, it confirm with previous studies (Voogt, Tilya and van den Akker, 2009) that students were satisfied with hands-on MBL experience for getting more investigative and open-ended learning, and user friendly.

5. Conclusion

The results revealed that there is no interaction effect on group (face-to-face MBL and online-mediated WISE) and time (pre- and post-test) regarded perceived ease of use, perceived usefulness, perceived learning, perceived satisfaction, and enjoyment. This means that the increasing of students' perceptions did not depend on different technology-enhanced learning environments e.g. face-to-face MBL and online-mediated WISE. This finding highlights the importance of the need for considering effective instructional design and environment to enhancing chemistry teaching and learning. For the chemistry class, both face-to-face MBL and online-mediated WISE group could be used to facilitate teaching and learning of chemical concepts and support emotional practice in chemistry education. For the next study, the authors have a plan to implement both learning environments for investigating whether if it would be more beneficial to combine WISE and MBL activities than to use them separately in teaching rate of reaction.

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References

Barzilai, S., & Blau, I. (2014). Scaffolding game-based learning: Impact on learning achievements, perceived learning, and game experiences. *Computers & Education*, *70*, 65-79.

Caspi, A., & Blau, I. (2011). Collaboration and psychological ownership: how does the tension between the two influence perceived learning?. *Social Psychology of Education*, *14*(2), 283-298.

Chang, H., & Linn, M. (2013). Scaffolding learning from molecular visualizations. *Journal of Research In Science Teaching*, *50*(7), 858-886.

Cheng, G. (2014). Exploring students' learning styles in relation to their acceptance and attitudes towards using Second Life in education: A case study in Hong Kong. *Computers & Education*, *70*, 105-115.

Drennan, J., Kennedy, J., & Pisarski, A. (2005). Factors affecting student attitudes toward flexible online learning in management education. *The Journal of Educational Research*, *98*(6), 331-338.

Friedler, Y., Nachmias, R., & Linn, M. (1990). Learning scientific reasoning skills in microcomputer-based laboratories. *Journal Of Research In Science Teaching*, *27*(2), 173-192.

Gunhaart, A., & Srisawasdi, N. (2012). Effect of integrated computer-based laboratory environment on students' physics conceptual learning of sound wave properties. *Procedia - Social and Behavioral Sciences, 46*, 5750-5755

Johnson, M., & Lawson, A. (1998). What are the relative effects of reasoning ability and prior knowledge on biology achievement in expository and inquiry classes?. *Journal of Research in Science Teaching*, *35*(1), 89-103.

Lawson, A.E. (1994). Science Teaching and the Development of Thinking. Belmont, California, United States: Wadsworth Pub Co.

Lawson, A.E.;1; (1995). *Science Teaching and Development of Reasoning. Belmont, CA: Wadsworth.*

Liao, Y., & She, H. (2009). Enhancing Eight Grade Students' Scientific Conceptual Change and Scientific Reasoning through a Web-based Learning Program. *Educational Technology & Society*, *12*(4), 228-240.

Linn, M., Layman, J., & Nachmias, R. (1987). Cognitive consequences of microcomputer-based laboratories: Graphing skills development. *Contemporary Educational Psychology*, *12*(3), 244-253.

Pyatt, K., & Sims, R. (2012). Virtual and physical experimentation in inquiry-based science labs: Attitudes, performance and access. *Journal of Science Education and Technology*, *21*(1), 133-147.

Srisawasdi, N., & Kroothkeaw, S. (2014). Supporting students' conceptual development of light refraction by simulation-based open inquiry with dual-situated learning model. *Journal of Computers in Education*, *1*(1), 49-79.

Srisawasdi, N. (2014). Developing Technological Pedagogical and Content Knowledge in Using Laboratory Environment: An Arrangement for Science Teacher Education program. *Research and Practice in Technology Enhanced Learning*, *9*,123-143.

Voogt, J., Tilya, F. & van den Akker, J. (2009). Science Teacher Learning of MBL-Supported Student-Centered Science Education in the Context of Secondary Education in Tanzania. Journal of Science Education and Technology, 18(5), 429-438.

Weld, J., Stier, M., & McNew-Birren, J. (2011). The Development of a Novel Measure of Scientific Reasoning Growth among College Freshmen: The Constructive Inquiry Science Reasoning Skills Test. *Journal of College Science Teaching*, *40*(4), 101-107.