Hayashi, Y., et al. (Eds.) (2017). Workshop Proceedings of the 25th International Conference on Computers in Education. New Zealand: Asia-Pacific Society for Computers in Education

Developing Smartphone-based Hands-on Inquiry Laboratory: Results on Students' Affective Channels of Chemistry Learning

Banjong PRASONGSAP [a], Niwat SRISAWASDI [b,c*]
[a]*Science Education Program, Faculty of Education, Khon Kaen University, Thailand*
[b]*Division of Science, Mathematics, and Technology Education, Faculty of Education, Khon Kaen University, Thailand*
[c]*Institute of Learning and Teaching Innovation, Khon Kean University, Thailand*
*niwsri@kku.ac.th

Abstract: Currently, mobile devices such as smartphones plays an important role in the field of science education. The advancement of mobile technology has changed the way of learning in and about science using mobile application on smartphones. This paper illustrates a development of hands-on inquiry laboratory lessons in chemistry with the support of smartphone, and presents also the results on middle school students' perceptions and attitudes in chemistry learning with smartphone-based laboratory. 43 middle school students in a public secondary school located northeastern region of Thailand voluntarily participate in this study, and they were assigned to interact with a series of smartphone-based hands-on inquiry laboratory in chemistry of solution lesson for two weeks. After the participation, they were administered 21-items and 20-items perception and engagement questionnaire, respectively. The preliminary results showed that they expressed positive perceptions towards the learning experience of smartphone-based laboratory, and impressed with the laboratory lessons. In addition, they expressed positive attitudes to the technology-enhanced chemistry learning with smartphone-based laboratory. This revealed that it is a challenge to use smartphone-based hands-on inquiry laboratory learning in chemistry as a pedagogy for new generation learners who have digital skills to perform science learning in 21st century education era. The main implication of this study is the rethinking of pedagogy used for modern and up-to-date teaching of solution for promoting favorable motivation to learn chemistry.

Keywords: Mobile learning, hands-on laboratory, inquiry-based learning, perception, attitude

1. Background

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). For the past decades, science educators and researchers have attempted to develop chemistry laboratory learning for promoting students' understanding in the connection of the subject matter with how the world works. However, many researchers found that students still have numerous learning difficulties and they hold various misconceptions about chemistry (Nantakaew and Srisawasdi, 2014; Niroj and Srisawasdi, 2014). To eliminate this problematic issue, mobile digital technology has been recognized as effective teaching tools in inquiry-based learning in science (Srisawasdi, 2014). In context of Thailand, implementation of the mobile digital technology as a pedagogical tool to support inquiry-based learning in science was still limited (Srisawasdi, 2015). With the advancement of mobile technology, one of an effective mobile digital technology, however, that researchers, developers, and educators in worldwide are paying attention to utilize it into traditional chemistry class for reforming the chemistry education is smartphone technology.

Recently, mobile devices, such as smartphone and tablet PC, are recognized as modern, powerful, and convenient laboratory tool which potentially encourages chemistry laboratory learning for students in school science level (Premthaisong and Srisawasdi, 2016). The use of smartphones in chemistry laboratory makes the chemistry learning in context of laboratory more interesting and challenging, and this kind of learning setting may stimulate effective scientific learning for students. By the way, Hwang and Chang (2011) suggested that integration of mobile devices into learning environment can encourage students' learning interest and motivation. Moreover, Hwang, Wu, and Ke (2011) reported that the use of an interactive concept map with mobile learning can promote learning attitude and achievement for students. To the best of our knowledge, there is no study involving a comparison of students' perceptions and engagement toward smartphone-based inquiry laboratory in chemistry education. Moreover, Williams and Pence (2011) additional suggested alternative ways to use smartphone for science learning as follows: (a) giving access to the wealth of material on the World Wide Web (WWW); (b) employing inexpensive applications (commonly called apps) for specific purpose of instruction; and (c) creating smart objects by using two-dimensional barcode labels. According to the abovementioned, the purpose of this study was to explore middle school students' perceptions and attitudes towards smartphone-based hands-on inquiry laboratory lessons in chemistry learning of solution.

2. Mobile Learning in Science Education

In science education, research on technological design, pedagogical development, and implementation and evaluation of mobile devices enabled learning has been accumulating evidence of student learning process in the context of mobile learning (Sun and Looi, 2016). Mobile technologies promise new and exciting opportunities for both teachers and learners in a climate of distributed, ubiquitous, informal learning supported by mobile devices and wireless communication. For informal science learning, mobile technologies have been successfully used for science learning process during field trips, science museums, and interactive science centeres, where they enable the learners to gather scientific data for later analysis in the classroom (Vavoula et al., 2005). In term of formal science learning, mobile technologies use in science laboratory is gaining in popularity in both cutting-edge scientific research and technology-enhanced science learning. Many examples of mobile technologies supporting formal science learning demonstrate mobile devices acting as data logging tools that allow learners to collect data from laboratory settings. In this context, students can collect textual, pictorial, or numerical data by using built-in software on most mobile devices as data logger. In addition, there are also various add-on sensors available that allow mobile devices to be used as probes to collect information from the environment. With mobile technology, the science learning environment can be mobile and moves with the students to the field site, to the laboratory and beyond (Martin and Ertzberger, 2013; Zydney and Warner, 2016). As such, the researchers and educators have recognized the importance of mobile learning in science for various instructional contexts, e.g. curriculum design and implementing, effective pedagogy, and assessment of learning supported by mobile technology.

3. An Example of Smartphone-based Hands-on Inquiry Laboratory in Chemistry

In this study, the researchers design our smartphone-based chemistry laboratory lesson to address student-centered science inquiry learning with guidance. With the use of the smartphone as an inquiry tool to conduct chemistry laboratory learning activity, each student controls their own learning by manipulate a smartphone and then investigate chemical substances, i.e. solutions, suspensions, and colloids, based on their own mobile devices. To create student-centered approach, inquiry-based laboratory learning with smartphone, the researchers employ a guided-inquiry learning process and foster students' self-directed inquiry facilitated by teacher's supports. Figure 1 illustrates the smartphone-based laboratory environments in chemistry learning of solutions, suspensions, and colloids used in this study.

Figure 1. An illustration of a smartphone-based laboratory environment for enhancing chemistry learning of solutions, suspensions, and colloids.

For the smartphone-based inquiry laboratory setting in chemistry learning of solutions, suspensions, and colloids, students installed and used a mobile application for measuring light intensity of any solutions. Then, the mobile app. reports the measured intensity of light, as seen in Figure 1. After, they were assigned to collect and record data using Google spreadsheet. The use of spreadsheet application is making chemistry laboratory experiments more feasible, especially for teachers with limited budgets. After completing the experiment with smartphone-based laboratory, students were assigned to interact with interactive spreadsheet, called Excelet, for visualizing the relationship between variables. To illustrate the relationship between target variables, a chart shows the relative graphs that the relationship between light intensity and type of chemical substance, i.e. solutions, suspensions, and colloids, will be presented on smartphone screen. Figure 2 shows illustrative smartphone screens of using a mobile application measured light intensity in various solutions.

Figure 2. Illustrations of smartphone screen in measuring the intensity of light passing through solutions, suspensions, and colloids, a comparison graph

4. Methods

In this study, the researchers conducted a preliminary investigation to examine effect of smartphone-based inquiry laboratory on middle school students' perceptions and attitudes toward the laboratory. The findings of this investigation provided us as a basis to re-design and develop a blended smartphone-based inquiry laboratory by combining mobile hands-on physical and virtual simulation-based laboratory into guided-inquiry learning process as a novel learning experience for chemistry teaching and learning.

4.1. Participants

The participant of this study included 43 of seventh-grade students, aged between 11 - 13 years old, in a local public middle school located at northeastern region of Thailand.

4.2. Research Instruments

This study used two instruments for evaluating the middle school students' perceptions and attitudes toward smartphone-based inquiry laboratory lessons. The perception questionnaire consisted of 21 5-points rating scale items (Peng et al., 2009) that focused on two perceptual constructs consisting; (i) learning experience (12 items) and (ii) overall impression (9 items), with a perfect score of 60 and 45 points, respectively. Another, the attitude questionnaire consisted of 20 5-points rating scale items (Barkatsas, Kasimatis and Gialamas, 2009) that focused on five constructs consisting; scientific confidence (SC), attitude to learning science with technology (ST), confidence with technology (TC), affective engagement (AE), and behavioral engagement (BE), which each dimension has four items. To develop a Thai version of the questionnaires, the original English version was translated identically in Thai language, and then translated back into English again. For each item, respondents were assigned to rate how much the respondent agree with into five scales, ranging from 1-strongly disagree to 5-strongly agree. Validity and reliability had established the instrument.

4.3. Data Collection and Analysis

In this study, students were exposed to interact independently with the assigned laboratory environment for 30-40 minutes. Figure 3 illustrates students' learning interaction with the smartphone-based inquiry laboratory on chemical solutions. After completing the experiment, they were asked to complete both perception and attitude questionnaires for 10-20 minutes.

Figure 3. An illustration of students' interaction with smartphone-based inquiry laboratory by conducting in small groups

Figure 4 shows the procedure of the study. Before the interaction with the smartphone-based inquiry laboratory learning in chemistry, teacher provided an introduction of chemical solution concepts and the procedure of the smartphone-based inquiry laboratory. After participating with the laboratory learning activity, all students were administered and took both questionnaires

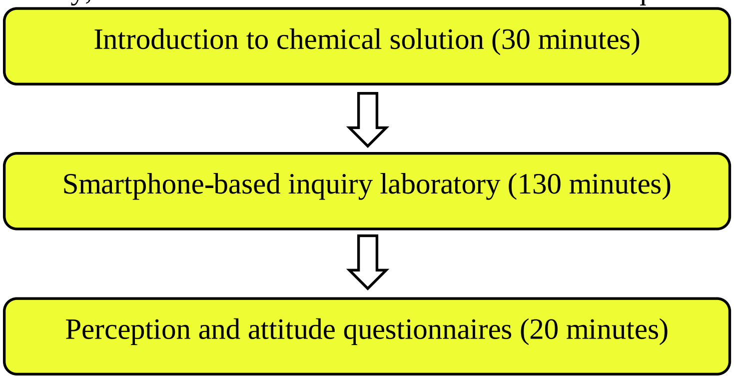

Figure 4. A diagram of the experimental procedure of this study

5. The Preliminary Results

5.1. Students' Perceptions with Smartphone-based Inquiry Laboratory Lessons

The result from the perception questionnaire covering two subscales, including learning experiences and overall impressions, shows that they perceived positively on the learning experiences (75.51%) and overall impressions (73%) of the smartphone-based inquiry laboratory lessons. Figure 5 represents percentage of the middle school students' perceptions toward the laboratory lessons.

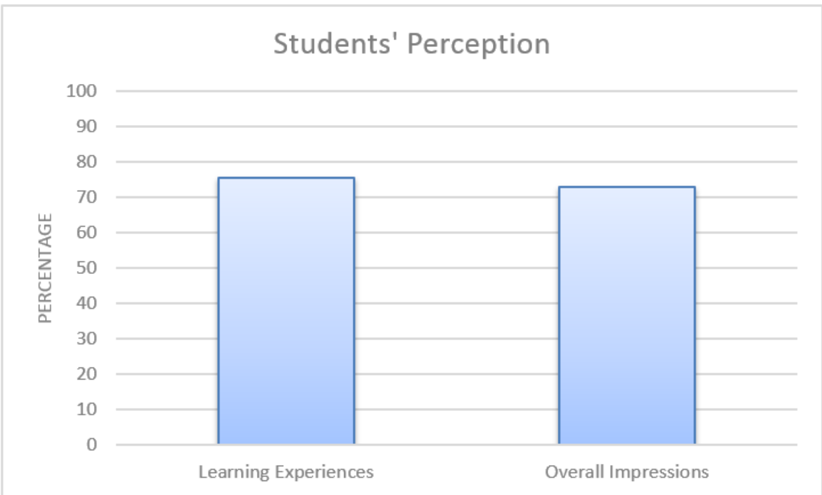

Figure 5. Percentages of the middle school students' perceptions

As seen in Figure 5, it shows that the middle school students perceived the learning experiences of smartphone-based inquiry laboratory in a high level, greater than 70%, and also expressed their impression in overall in a high level, greater than 70%, regarding the percentage of their perception scores.

5.2. Students' Attitudes toward Smartphone-based Inquiry Laboratory Lessons

To explore middle school students' attitudes toward the smartphone-based inquiry laboratory lessons, the attitudes questionnaire covering five subscales, i.e. scientific confidence (SC), attitude to learning science with technology (ST), confidence with technology (TC), affective engagement (AE), and behavioral engagement (BE) has been administered to the students, and the result shows a different level of their attitudes on each subscale. The highest score was relied on AE (88.64%), ST (85.91%), BE (85.34%), SC (83.18%), and TC (78.86%), respectively, as illustrates in Figure 6.

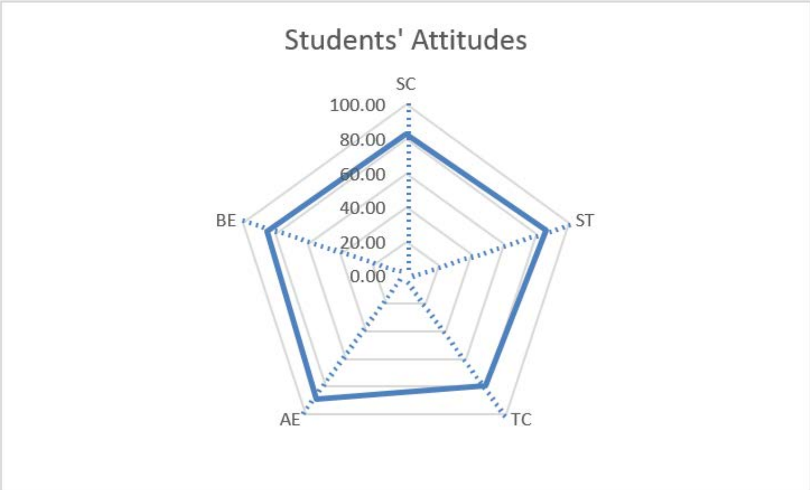

Figure 6. Percentages of the middle school students' attitudes

As seen in Figure 6, it illustrates the symmetry of the middle school students' attitudes toward the smartphone-based inquiry laboratory lessons. The graph indicated that their attitudes nearly fit to a high level, approximately 80%, regarding SC, ST, TC, AE, and BE percentage scores.

5.3. Students' Interviews for Evaluating Their Perceptions and Attitudes

To qualitatively explore the middle school students' perceptions and attitudes toward the smartphone-based inquiry laboratory lessons, the researchers conducted individual interviews with seven volunteer students. The result reveals that they have favorable perceptions and attitudes toward the laboratory lessons. Some evidences could be illustrated as follows:

Student A and F (Males):

> *"Doing science experiment with the use of smartphone is very fun and easier than conventional laboratory work. This kind of laboratory activity made me feel enjoy and challenge. The most important thing is that it is very convenient to do science experiment because I and my friends can work together and every member of the group has assigned their roles, e.g. picturing, experimenting with both conventional lab and smartphone lab. In addition, we can conduct and repeat the experiment many times."*

Student B (Female):

> *"I love to use smartphone in chemistry experiment because it is not difficult to me. I use the smartphone every day in my living and I can use mobile app. very well. In the laboratory, I and my friends shared responsibility for our lab assignment."*

Student C and D (Females):

"With the use of smartphone in science laboratory, we can precisely measure quantity of things in the laboratory. It is very interesting experiment in science. We can see and obtain the number of light intensity without any estimation or guess when we use the mobile app. scanning solutions, fresh milk, and raw starch."

Student E (Male):

"Basically, I love to play digital game on smartphone for every day. When teacher assigned us to use smartphone in the science class, it is very cool, especially for doing science laboratory. It is very easy for me to do the laboratory with smartphone, and it made me more interesting on science lesson."

Student G (Female):

"When we employed smartphone as a tool for doing science laboratory, it is very challenge that what we will get from the mobile application, and I really want to know how would my smartphone help me in science learning. Finally, I found that it is a quick way to do science, e.g. measuring light intensity and acid-based solutions. In this laboratory, we can clearly see the experimental results and can make sense what happen. I also tell this learning experience to my friends in other class and they said to me they would like to learn science by this way."

According to the interview transcription above, both female and male middle school students trend to have positive perceptions and attitudes to the smartphone-based inquiry laboratory lessons.

6. Discussion and Conclusion

This study reported a preliminary investigation of smartphone-based inquiry laboratory lessons on middle school students' perceptions and attitudes toward the laboratory learning. The findings show that they expressed positive perceptions towards the learning experience of smartphone-based laboratory, and impressed with the laboratory lessons. In addition, they expressed positive attitudes to the technology-enhanced chemistry learning with smartphone-based laboratory. This finding is consistent with Permthaisong and Srisawasdi (2016) and Chaipidech and Srisawasdi (2016) that students expressed favorable perceptions and engagements on science laboratory learning experiences with the support of mobile devices such as smartphones. This revealed that it is a challenge to use smartphone-based hands-on inquiry laboratory learning in chemistry as a pedagogy for new generation learners who have digital skills to perform science learning in 21st century education era.

Acknowledgements

This research was financially supported in partial by Graduate School, Khon Kaen University, Thailand, and KKU Smart Learning Academy project. This contribution was partially supported by Science Education Program, Faculty of Education, Khon Kaen University. The authors would like to express sincere thanks to school principal, science teachers, and middle school students in the school for their kind cooperation and participation in this study.

References

Barkatsas, A. T., Kasimatis, K. & Gialamas, V.)2009(Learning secondary mathematics with technology: Exploring the complex interrelationship between students' attitudes, engagement, gender and achievement. *Computers & Education*, 52, 562-570.

Chaipidech, P., & Srisawasdi, N. (2016). Mobile technology-enhanced flipped learning for scientific inquiry laboratory: a comparison of students' perceptions and engagement. In *Proceedings of the 24th International Conference on Computers in Education (ICCE2016)*, Asia-Pacific Society for Computers in Education, November 28 – December 2, 2016, Mumbai, India.

Childs, P. E., & Sheehan, M.,)2009(. What's difficult about chemistry? An Irish perspective. *Chemistry Education Research and Practice*, 10, 204-218.

Cooper M. M. and Kerns T. S.,)2006(, Changing the laboratory: effects of a laboratory course on students'attitudes and perceptions. *Journal of Chemical Education*, 83)9(, 1356.

de Jong, T., Linn, M. C., & Zacharia, Z. C.)2013(. Physical and virtual laboratories in science and engineering education. *Science*, 340)6130(, 305-308.

de Morais, C. L. M., Silva, S. R. B., Vieira, D. S., & Lima, K. M. G.)2016(. Integrating a smartphone and molecular modeling for determining the binding constant and stoichiometry ratio of the Iron)II(- Phenanthroline complex: an activity for analytical and physical chemistry laboratories. *Journal of Chemical Education*. DOI: 10.1021/acs.jchemed.6b00112

Hwang, G.-J., & Chang, H.-F.)2011(. A formative assessment-based mobile learning approach to improving the learning attitudes and achievements of students. *Computers & Education*, 56, 1023-1031.

Hwang, G.-J., Wu, P.-H., & Ke, H. R.,)2011(. An interactive concept map approach to supporting mobile learning activities for natural science courses. *Computers & Education*, 57, 2272-2280.

Karata§, F. O.)2015(. Pre-service chemistry teachers' competencies in the laboratory: a cross-grade study in solution preparation. *Chemistry Education Research and Practice*, 17, 100-110.

Karata§, F. O. Co§tu B. and Cengiz C.,)2015(, Laboratory applications in chemistry teaching, in Ayas and Sozbilir M.)ed.(, *Chemistry Education*, Ankara: Pegem Akademi, pp. 57-92.

Laredo T.,)2013(, Changing the first-year chemistry laboratory manual to implement a problem-based approach that improves student engagement, Journal of Chemical Education, 90, 1151-1154.

National Research Council.)2006(. *America's lab report: Investigations in high school science.* Washington, DC: National Academy Press.

Olympiou, G., & Zacharia, Z. C.)2012(. Blending physical and virtual manipulatives: an effort to improve students' conceptual understanding through science laboratory experimentation. *Science Education*, 96)1(, 21-47.

Peng, H., Chuang, P.-Y., Hwang, G.-J., Chu, H.-C., Wu, T.-T., & Huang, S.-X.)2009(. Ubiquitous performance-support system as Mindtool: a case study of instructional decision making and learning assistant. *Educational Technology & Society*, 72)1(,107-120.

Srisawasdi, N.)2014(. Developing technological pedagogical content knowledge in using computerized science laboratory environment: An arrangement for science teacher education program. *Research and Practice in Technology Enhanced Learning*, 9)1(, 123-143.

Srisawasdi, N.)2015(. Motivating inquiry-based learning through combination of physical and virtual computer-based laboratory experiments in high school science. In M. J. Urban & D. A. Falvo)Eds.(*Improving K-l2 STEM Education Outcomes through Technological Integration*)pp. 108-134(. Hershey, PA: Information Science Reference.

Permthaisong, S., & Srisawasdi, N. (2016). A Comparative Study of Students' Perceptions and Engagements toward Smartphone-based Inquiry Laboratory on Solution Concentration. In *Proceedings of the 24th International Conference on Computers in Education (ICCE2016)*, Asia-Pacific Society for Computers in Education, November 28 – December 2, 2016, Mumbai, India.

Suits, J. P., & Srisawasdi, N.)2013(. Use of an interactive computer-simulated experiment to enhance students' mental models of hydrogen bonding phenomena. In J.P. Suits & M.J. Sanger)Eds.(*Pedagogic roles of animations and simulations in chemistry courses ACS Symposium Series 1142*, American Chemical Society: Washington, DC.

Williams, A. J., & Pence, H. E.)2011(. Smart phones, a powerful tool in the chemistry classroom. *Journal of Chemical Education*, 88, 683-686.