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Investigating the Impact of Smartphone-based Guided Inquiry Laboratory on Middle School Students' Science Learning Performance

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Abstract: Currently, smartphones play an important role in the field of STEM-related education. The use of smartphones and mobile devices has changed the way of learning in and about science with the support of mobile applications. This paper presents a development of hands-on guided inquiry laboratory lessons in physical science with the support of smartphone, as instructional intervention, and presents also the impact of smartphone-based laboratory lessons on middle school students' learning performance in science, regarding scientific understanding and explanation. In this study, forty-four 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 guided inquiry laboratory on solution for six weeks. The results indicated that the instructional intervention could promote Thai middle school students' better scientific understanding of and positively induce their ability to explain solution phenomena scientifically. This revealed that it is a challenge to use smartphone-based hands-on guided inquiry laboratory environment as a modern 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 science teaching for young generation.

Keywords: Smartphone, guided inquiry, simulation, scientific understanding, scientific explanation

1. Introduction

For the past decades, science educators and researchers have attempted to develop science laboratory learning for promoting students' understanding in the connection of the subject matter with how the world works. With the advancement of mobile technology, mobile devices, such as smartphone and tablet, has been recognized as effective teaching tools. Recently, smartphone is recognized as modern, powerful, and convenient laboratory tool which potentially encourages laboratory learning for students in school science level (Premthaisong & Srisawasdi, 2016). The use of smartphones in laboratory makes the science learning in context of laboratory more interesting and challenging, and this kind of learning setting may stimulate effective scientific learning for students. Furthermore, 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. 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; (b) employing inexpensive applications (commonly called apps) for specific purpose of instruction; and (c) creating smart objects by using two-dimensional barcode labels.

In context of Thailand's science education, implementation of the mobile digital technology as a pedagogical tool to support inquiry-based learning in science was still limited (Srisawasdi, 2014, 2015). Currently, researchers, developers, and educators in our nation are paying attention to utilize smartphone technology into traditional science class for reforming the learning of science. With the support of smartphone technology, smartphone-based science laboratory makes the science learning in context of laboratory more interesting and challenging, and this kind of learning setting may stimulate effective scientific learning for students (Premthaisong, Pondee, & Srisawasdi, 2017). To promote the quality of science education, the purpose of this study was to evaluate middle school students' scientific understanding and their quality of scientific explanation after receiving smartphone-based hands-on inquiry laboratory lessons in physical science learning of solution.

2. Literature Review

In recent years, digital technologies have important role in education. Researchers, educators, and science teachers have paid much attention on how to use and apply the digital technologies, e.g. mobile devices and smartphones, as instructional tools in inquiry-based science learning in school science (Srisawasdi, 2014). To promote digital native students' learning performance in science, inquiry-based learning with the enactment of digital technology offers new opportunities to facilitate the ability to store and manipulate large quantities of information, the ability to present and permit interaction with information in a variety of visual and audio formats, the ability to perform complex computations, the support for communication and expression, and the ability to respond rapidly and individually to them.

The advancement of mobile devices, e.g. tablet PC, and smartphones brings about change to the way to deliver science laboratory learning (Srisawasdi, 2018). In term of teaching and learning, mobile devices (or m-devices) are recognized as an emerging technology instructional tool with the potential to facilitate teaching and learning strategies that exploit individual learners' context (Jeng & Chen, 2010). Nowadays, smartphones can be applied as integral part of science laboratory and it is becoming popular in the field of science and technology education (Chang, 2012). These mobile devices have many valuable capabilities that have tremendous potential for use in science education (de Morais et al., 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. Smartphone-based Inquiry Laboratory on Solution

The advancement of personal, portable, and wirelessly networked technologies leads us into a new phase in the evolution of technology-enhanced learning. Currently, smartphones are clearly ubiquitous in the hand of students. In this study, the researchers design smartphone-based guided-inquiry laboratory lesson to address student-centered science inquiry learning with guidance. With the use of the smartphone as an inquiry tool to conduct physical science learning activity, each student controls their own learning by manipulating their own smartphone and then interacts with computer simulation. 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 computer simulation on smartphone-based laboratory environments in physical science learning of factors affecting solubility used in this study.

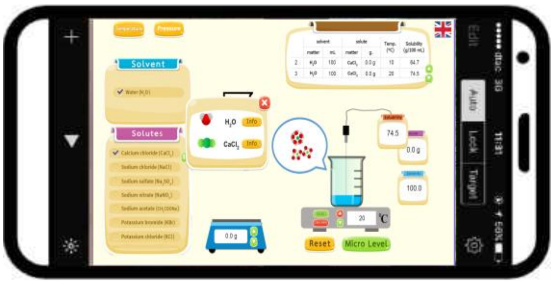

Figure 1. An illustration of computer-simulated laboratory on smartphone

For the smartphone-based guided-inquiry laboratory learning, students have been assigned to install a mobile app called *Istyle Science Note*, which is available for both iOS and android, developed by Niwat Srisawasdi and Komkat Meuansechai for implementing in KKU Smart Learning Academy project. The *Istyle Science Note* app has been particularly designed to enhance inquiry-based learning in science in order to promote students' scientific explanation performance. Figure 2 illustrates smartphone screens of the mobile application and its components regarding students' scientific explanation.

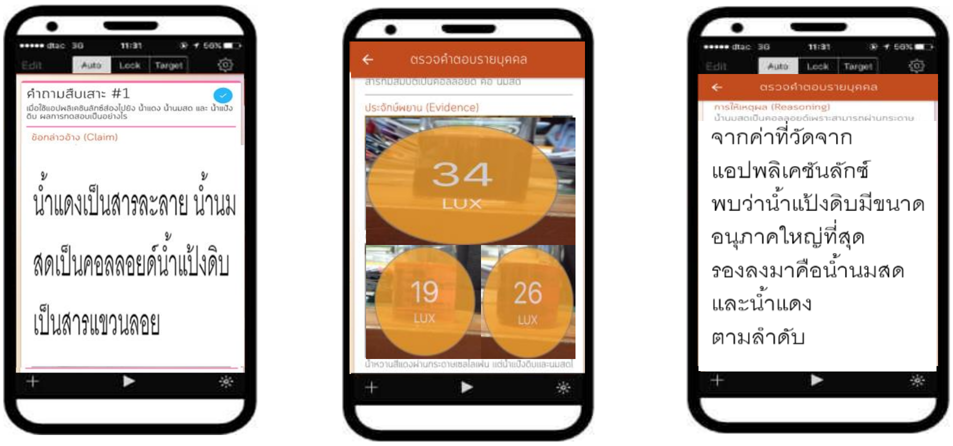

Figure 2 Illustrative examples of the mobile app. screens emphasizing scientific explanation: student's claim before hands-on experiment (left), an evidence collected from the experiment (middle), a reasoning concluded by student (right)

4. Context of the Study

4.1 Research Design

In this study, the researchers conducted a pre-experimental research to examine impact of smartphone-based guided inquiry laboratory on middle school students' scientific conceptual understanding and their scientific explanation ability. A pretest-posttest research design was selected to to study the impact of the proposed instructional intervention regarding the students' science learning performance as abovementioned.

4.2 Study Participants

A total of 44 student-respondents in their sevventh grade, age ranging from 11 to 13 years in a local public school at the northeastern region of Thailand participated in this study. They were attending a physical science course for basic education level. All of them have satisfactory skills on basic computer and information and communication technology, but they have no experience yet using smartphone in science learning. In an addition, they have never experienced having guided-inquiry learning process with the support of mobile technology in any formal class. This implied that they are heterogeneous before interacting with the pre-experimental study.

4.3 Instrument and Measures

The research instrument for measuring students' scientific understanding on solution was a 12 two-tier conceptual test focused on six specific-domain science concepts as follows: (i) solution colloid suspension; (ii) electrical conductivity of solution; (iii) solution preparation; (iv); factors affecting solubility; (v) acid-base solution; and (vi) acid-base solution in everyday life. The perfect score of the conceptual test was 36 points. Another, the *Istyle Science Note* mobile app. has been used to collect data for exploring students' scientific explanation performance regarding the three components, i.e. claim, evidence and reasoning. The students were assigned to use the mobile app. in all six science lessons during their inquiry-based learning activities.

4.4 Data Collection and Analysis

In this study, all students took 30 min to complete the 12 two-tier conceptual items as pretest. Then, the students received 20-minute orientation of the learning steps of the smartphone-based guided inquiry laboratory on chemical solution by the first researcher. Then, students were exposed to interact independently in a small group with smartphone laboratory environment. All the students received the learning setting of smartphone-based guided inquiry laboratory on chemical solution for six 100-minute class periods. In addition, they were assigned to investigate the phenomena related chemical solution by using the *iStyle Science Note* app. along the class periods. As such, their performances of scientific explanation were recorded into the mobile app. automatically. Figure 3 illustrates students' learning interaction with the smartphone-based guided inquiry laboratory in this study.

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

Finally, a 30-minute posttest was applied after the smartphone laboratories were completed. For the posttest, the same two-tier conceptual question items were administered to the students again for investigating conceptual status of their scientific understanding of chemical solution. The obtained data has been analyzed by using descriptive statistics, i.e. arithmetic mean, standard deviation, frequency, percentage and paired t-test. The paired t-test was used to examine the difference in scientific understanding scores both overall and individual science concept, before and after the instructional intervention.

5. Results

In order to explore the impact of smartphone-based guided inquiry laboratory on the students' scientific understanding of chemical solution phenomena, Table 1 presents the results of statistical comparative analysis for students' pretest and posttest using paired t-test.

Table 1
Descriptive statistics and paired t-test results to compare students' scientific understanding in overall

Test	N	Total	Mean	S.D.	t-score	*p*
Pretest	44	36	16.57	2.07	310.028	.000*
Posttest	44	36	32.85	1.92		

*significant difference at .05 ($p<0.05$)

The results indicated that the posttest mean scores (Mean = 32.85, S.D. = 1.92) was significantly higher (t_{43} = 310.028, p = .000, $p < .05$) than the pretest mean scores (Mean = 16.57, S.D. = 2.07). In addition, it revealed that the students made substantial gains in their scientific understanding of chemical solution from pretest to posttest.

To be more precise, the pretest and posttest of each concept for all six scientific concepts about solution has been analyzed using paired t-test. The t-test was used to compare both test scores in order to investigate the particular influence of smartphone integrated into guided-inquiry laboratory learning. Table 2 presents the comparative results of individual scientific concept.

Table 2

Descriptive statistics and paired t-test results to compare students' scientific understanding for each concept

Code	**Concept**	**Pretest**		**Posttest**		**t-score**	***p***
		Mean	S.D.	Mean	S.D.		
C1	Solution colloid suspension	3.36	0.99	5.41	0.54	12.854	.000*
C2	Electrical conductivity of solution	3.00	0.78	5.45	0.90	17.116	.000*
C3	Solution preparation	3.11	0.69	5.64	0.53	22.892	.000*
C4	Factors affecting solubility	2.43	0.62	5.43	0.70	23.068	.000*
C5	Acid-base solution	2.18	0.50	5.20	0.67	25.314	.000*
C6	Acid-based solution in everyday life	2.48	0.66	5.57	0.55	26.553	.000*

Table 2 showed the t-test scores that indicated the difference on students' conceptual learning achievement in the smartphone-based guided-inquiry laboratory learning. For the solution colloid suspension concept (C1), the mean score results of C1 implied that students were more able (Mean = 5.41, SD = 0.54) to learn as compared to the pretest (Mean = 3.36, SD = 0.99). The t-test results further indicate a significant difference between the pretest and posttest for C1 (t = 12.854, p = .000, $p < .05$). For the concept of electrical conductivity of solution (C2), the mean score results of C2 implied that students were more able (Mean = 5.45, SD = 0.90) to understand as compared to the pretest (Mean = 3.00, SD = 0.78). The t-test results further indicate a significant difference between the pretest and posttest for C2 (t = 17.116, p = .000, $p < .05$). For the concept of solution preparation (C3), the posttest score (Mean = 5.64, S.D. = 0.53) was higher than the pretest (Mean = 3.11, S.D. = 0.69) that the result implied significantly better understanding of this concept (t = 22.892, p = .000, $p < .05$) as compared to the initial status of understanding. For the concept of Factors affecting solubility (C4), the mean score results of C4 implied that students developed better understanding (Mean = 5.43, SD = 0.70), as compared to the pretest (Mean = 2.43, SD = 0.62). The t-test results further indicate a significant difference between the pretest and posttest for C4 (t = 23.068, p = .000, $p < .05$). For the concept of acid-base solution (C5), the posttest score (Mean = 5.20, S.D. = 0.67) was higher than the pretest (Mean = 2.18, S.D. = 0.50) that the result implied significantly better understanding of this concept (t = 25.314, p = .000, $p < .05$) as compared to the initial status of understanding. For the acid-based solution in everyday life of the last concept (C6), the mean score results of C6 implied that students developed better understanding (Mean = 5.57, SD = 0.55), as compared to the pretest (Mean = 2.48, SD = 0.66), at the end of their learning. The t-test results further indicate a significant difference between the pretest and posttest for C4 (t = 26.553, p = .000, $p < .05$).

To explore middle school students' scientific explanation performance towards the smartphone-based inquiry laboratory lessons, the result showed that their scientific explanation performance with the proposed science learning experience reached a high level, gaining the mean score over 80 percentage. Figure 4 illustrates scientific explanation performance of the study.

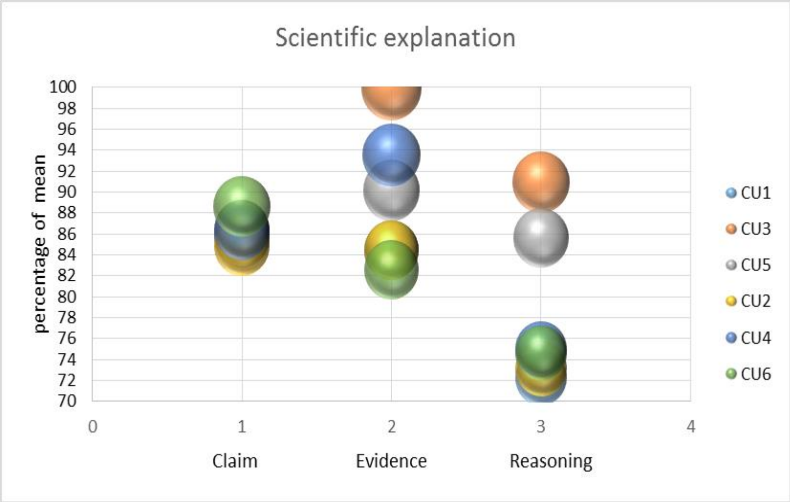

Figure 4. Percentages of the middle school students' scientific explanation performance

In order to gain better understanding of the influence of smartphone integrated into guided-inquiry laboratory learning, we have conducted a semi-structured informal interview with some of students. According to the individual interview, some of interview data reflected their cognitive gaining with the intervention. Some evidences of their attitudes 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 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 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 my smartphone would 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."*

6. Conclusions

This study reported an impact of smartphone-based inquiry laboratory on middle school students' scientific understanding and their scientific explanation performance. The finding showed that the significant different in students' scientific understanding was detected between pretest and posttest after their participating with smartphone-based laboratory. In addition, they expressed positive scientific explanation performance to the technology-enhanced physical science learning with smartphone-based laboratory. This revealed that it is a challenge to use smartphone-based hands-on inquiry laboratory learning in physical science class as a pedagogy for new generation learners who have digital skills to perform science learning in 21st century education era.

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References

Chang, H.-Y. (2016). How to augment the learning impact of computer simulations? The designs and effects of interactivity and scaffolding. *Interactive Learning Environments*. doi:10.1080/10494820.2016.1250222

De Morais, C. L. M., Silva, S. R. B., Vieira, D. S., & Lima, K. M. G. (2006). 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

Gilbert, J. K. (2006). On the nature of 'context' in chemical education. *International Journal of Science Education*, *28*(9), 957-976.

Gilbert, J., de Jong, O., Justi, R., Treagust, D. & Van Driel, J. (2002). Research and development for the future of chemical education. In J. Gilbert et al., (Eds.). *Chemical Education: Towards Research-based Practice* (pp.391-408). Dordrecht/Boston: Kluwer Academic Publishers.

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.

Jang, S. J., & Chen, K.-C. (2010). From PCK to TPACK: Developing a transformative model for pre-service science teachers. Journal of Science Education and Technology, 19(6), 553-564.

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.

Permthaisong, S., Pondee, P., & Srisawasdi, N. (2017). Development of smartphone-based inquiry laboratory lessons in chemistry learning of solution and concentration: An evidence-based practice. In *Proceedings of the 6th IIAI International Congress on Advanced Applied Informatics*, International Institute of Applied Informatics, July 9 – 13, 2017, Hamamatsu, Japan.

Srisawasdi, N. (2012). Student teachers' perceptions of computerized laboratory practice for science teaching: A comparative analysis. *Procedia - Social and Behavioral Sciences, 46*, 4031-4038.

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.

Srisawasdi, N. (2018). Transforming Chemistry Class with Technology-enhanced Active Inquiry Learning for the Digital Native Generation. In C. Cox & W. Schatzberg (Eds.) *International Perspectives on Chemistry Education Research and Practice (pp. 221-233).* ACS Symposium Series 1142, American Chemical Society: Washington, DC.

Srisawasdi, N., & Nantakaew, N. (2014). Investigating correlation between attitude toward chemistry and motivation within educational digital game-like learning. *In Proceeding of the 22nd International Conference on Computers in Education*. Asia-Pacific Society for Computers in Education, Japan.

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