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A Comparative Study of Students' Perceptions and Engagements toward Smartphone-based Inquiry Laboratory on Solution Concentration

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Abstract: Currently, mobile technology plays important role in education and the instructional practice of science education has been changed by the advancement of mobile learning and apps. This article presents a combination of physical and virtual smartphone-based experimentation in guided-inquiry chemistry learning of concentration of solution. In this pilot study, 95 eleventh-grade students in northeastern region of Thailand were recruited to participate in a series of inquiry laboratory and they were divided into three groups for receiving different setting of learning environment. They were administered 21-items perception and 20-items engagement questionnaires after interacting with the assigned learning environment. The results revealed that gender difference has a significant effect on students' perceptions, but there was no effect of gender difference on their learning engagement regarding the smartphone-based inquiry laboratory learning module. This implied that it is possible to use smartphone-based inquiry laboratory to facilitate chemistry learning of solution concentration for high school students.

Keywords: Mobile learning, blended laboratory, guided inquiry, chemistry education, high school

1. Introduction

Chemistry is a branch of science that deals with matter, properties, structure and change of matter, and the main field of investigation of chemistry involves atoms, ions, molecules, the interactions occuring at atomic and molecular levels. For secondary and thertiary education, topics in chemistry learning include abstract atomic level or complicated symbolic representations, and students have to face with difficulty in chemistry education. Research on students' chemistry learning has consistently indicated that students have great difficulty understanding chemistry concepts and they often hold alternative conceptions on chemical phenomena (Suits and Srisawasdi, 2013). In chemistry, concentration of solutions is a complex chemical concepts refered to the amount of substance dissolved in a certain volume of the solution, and it is one of the most conceptually difficult subjects on the school curriculum (Childs and Sheehan, 2009).

One of the important topics in school chemistry is concentration of solutions and an effective learning environment addressing the abstract and complicated nature of the concentration concepts is chemistry laboratories. Laboratories in chemistry education are considered to have potential as a crucial medium not only for improving science process skills, but also for improving conceptual understanding by making abstract subjects to be more concrete and visual (Karatas, 2015; Laredo, 2013). In addition, researchers has also pointed out that laboratory activities may positively affect students' attitudes and interests toward chemistry (Cooper and Kerns, 2006; Karataş et al., 2015).

Recently, smartphones can serve as powerful and convenient laboratory tools on a mobile platform, which potentially encourages chemistry learning for students. The smartphones are actually a portable and powerful computer that can be very valuable in chemistry laboratories. To enhance chemistry education, three major ways to use smart phones are giving access to the wealth of material on the World Wide Web (WWW), employing inexpensive applications (commonly called apps) for specific purpose of instruction, and creating smart objects by using two-dimensional barcode labels (Williams and Pence, 2011). By the way, Hwang and Chang (2011) suggested that integration of mobile devices into learning environment can encourag 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 compararison of students' perceptions and engagement toward smartphone-based inquiry laboratory in chemistry education. Accordingly, the purpose of this study was to compare high school students' perceptions and engagement between traditional chemistry laboratory, smartphone-based hands-on laboratory, and smartphone-based virtual laboratory.

2. Literature Review

Digital Technology in Thailand Science Education

In recent years, researchers, educators, and teachers have become increasingly interested in digital technology in education. Digital technologies have been recognized as effective teaching tools in inquiry-based science learning (Srisawasdi, 2014). In context of Thailand, implementation of digital technologies as a pedagogical tool to support inquiry-based learning in science was still limited, terms of curriculum coverage and alignment in national science curriculum (Srisawasdi, 2015). One of an effective digital technologies implemented in Thailand science education is computer simulation, which features the learning of science by visualizing things at a molecular level and may directly link unobservable processes to symbolic equations and observable phenomena. This kind of digital learning technology is an alternative of curriculum in which content is broken up into discrete pieces or learning objects, ranging from a small chunk of instruction to a series of resources. These simulations are used as pedagogical tools to promote active learning in science and also enhance students' development of conceptual learning in science. In Thailand, computer simulations (e.g. Yenka, PhET) have been used to encourage inquiry-based science learning by visualizing scientific phenomena and examining them in their everyday experiences. However, the use of both visualized digital technology still remains rare in Thai science course.

Recently, the use of smartphone in science laboratory is becoming popular in the filed of educational technology. From a science education perspective, there have been interests in developing curricula that specifically consider the affordances of these mobile technologies. To support the improvement of science-based education through inquiry-based investigation, a number of international high schools in Thailand and public schools for gifted and talented students in science and mathematics employ mobile devices or apps to support students' practical work in the science laboratory. These devices have many valuable capabilities that have tremendous potential for use in science education (de Morais et al., 2016). Furthermore, A number of Thai educators and science teachers are driving change in Thailand science education research and practices by promoting digital technologies, such as mobile device and app., as appropriate inquiry tools to bring about benefits to investigative and inquiry learning environments for both science-based and integrated STEM education (Srisawadi, 2015).

Affordance of Physical and Virtual Laboratory in Science Instruction

Recently, computer-based technology has become commonplace in the science education as an integrate of the science classroom and laboratory experimentation. de Jong et al. (2013) concluded that students are able to take advantage of computer-transformed representations to interact with and investigate how the real world works by using the tools, techniques of data collection, models, and science theory in physical laboratory or in virtual laboratory. Both physical and virtual laboratory concern numerous overlapping applications. Olympiou and Zacharia (2012) concluded that physical laboratory can present experience of students that involve the manipulation of the actual items of an experiment, and only virtual laboratory can provide students with opportunities to manipulate the conceptual objects involved in an experiment and may be used to visualize things at a molecular level and may directly link unobservable processes to symbolic equations and observable phenomena.

Furthermore, many researchers found that advantage about both physical and virtual laboratory tcan provide high levels of interaction and learner engagement. The National Research Council (2006) stated that using both physical and virtual laboratory can achieve similar educational objectives, such as exploring the nature of science, enhancing conceptual development, developing scientific inquiry skills, and cultivating interest and motivation in science.

3. The Smartphone-based Inquiry Laboratory on Solution Concentration

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 hands of students. In this study, the researchers design our mobilized chemistry lesson to be student-centered, inquiry-based and personalized in nature. With the use of the smartphone as an inquiry tool to conduct chemistry laboratory learning activity, each student controls their own learning and investigation of concentration of solutions based on their own mobile devices. To create student-centered, inquiry-based learning activities with smartphone, the researchers model a guided-inquiry learning process and foster students' self-directed inquiry by initial teacher's facilitation of their inquiry-based learning. Figure 1 displays the smartphone-based laboratory environments used in this study.

Figure 1. An illustration of smartphone-based laboratory environments of solution concentration in chemistry: physical (hands-on) mobile laboratory (Left) and virtual (computerized visualization) mobile laboraotory (Right)

For the smartphone-based inquiry laboratory on solution concentration in this study, the use of smartphones coupled with data collection and analysis via Google applications, such as google spreadsheet, can make sophisticated lab experiments more feasible, especially for teachers with limited budgets. After completing the experiment with a mobile laboratory, students were assigned to interact with interactive spreadsheet, called excelet, for visualizing the relationship between varaibles. The excelet shows a relative graph that demonstrates relationships between H-value and concentration of measured solution. Moreover, the excelet shows chemistry equation of decomposition which represents symbolic levels, and it can changes a variable in the form of slide bar. For example, when students move the input slider bar, the experimental result will changs immediately. Consequently, excelets are an effective tool that incorporates easy-to-change variables so as to quickly illustrate their impacts on output. Figure 2 illustrates the excelet of the concentration of solution.

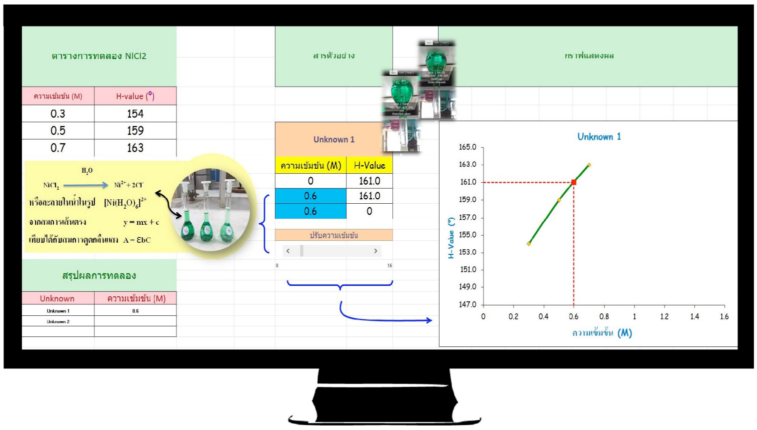

Figure 2. An Illustration of the excelet sheet for solution concentration laboratory

4. Methods

In this study, the researchers conducted a preliminary investigation to examine effect of smartphone-based inquiry laboratory on high school students' perceptions toward the laboratory on chemistry topic of solution concentration and their learning engegaments. The findings of this investigation provided us as a basis in order to redesign and develop a blended smartphone-based inquiry laboratory by combining mobile physical and virtual laboratory into guided-inquiry learning process as a novel learning experience for chemistry teaching and learning.

Participants

The participant of this experiment included 95 of 11th grade students, aged between 16-17 years old, attending three intact classes in a local public high school at northeastern region of Thailand. Two classes were assigned to the experimental groups (EG#1 = 30 and EG#2 = 31) and the other was the control group (CG = 34). The differences between the two experimental groups were the mobile learning tool to be utilized (physical or virtual lab). To be precise, the learning activity for the EG#1 was virtual (computerized visualization) mobile laboratory learning and the EG#2 was physical (hands-on) mobile laboratory learning. For the control group, they were taught with the traditional laboratory (hands-on laboratory without mobile app.) instruction.

Research Instruments

This research used two instruments for evaluating students' perceptions toward smartphone-based inquiry laboratory and their learning engagements. 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 engagement 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 dimensions 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 scale, ranging from 1-strongly disagree to 5-strongly agree. Validity and reliability had established the instrument.

Data Collection and Analysis

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

Figure 3. An illustration of students' interaction with smartphone-based inquiry laboratory: working with virtual (Left) and physical (Right) mobile inquiry laboratory

Figure 4 shows the procedure of the experiment on this study. Before the interaction with the mobile laboratory of concentration, teacher provided an introduction of solution concentration concepts and the procedure of the mobile laboratory. After participating with the laboratory learning activity, all students were administered and took both questionnaires

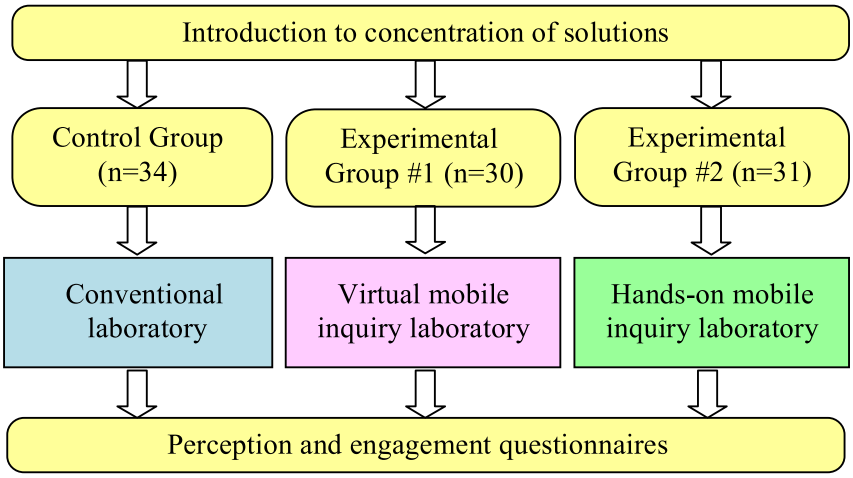

Figure 4. A diagram of the experimental procedure of this study

To compare the obtained data, the statistical data techniques for analyzing students' perceptions and engagements were performed by one-way MANOVA in IBM SPSS 20.0 for comparing the effect of the laboratory interventions (tradional/hands-on, physical mobile, and virtual mobile laboratory).

5. Results

5.1 Effect of the Three Different Laboratory Interventions on Students' Perceptions

The one-way MANOVA were conducted to determine the effect of the three types of laboratory delivery methods on the two dependent variables, i.e. learning experience and overall impression. As reported in Table1, the MANOVA indicated a significant main effect for gender (Wilks' lambda=.852, $F(4,88)=7.665$, $p=.001$, partial $\eta^2=.148$), but there was no significant main effect for intervention (Wilks' lambda=.918, $F(4,88)=1.933$, $p=.107$, partial $\eta^2=.042$). However, there was a significant difference for its interaction effect (Wilks' lambda=.884, $F(4,88)=2.805$, $p=.027$, partial $\eta^2=.060$). The result in Table 1 suggested that both genders had almost non-equal perceptions to learn with smartphone-based laboratory after participating with the laboratory learning.

Table 1: Descriptive statistics, means and standard deviations for students' perceptions of traditional, virtual mobile, and physical mobile laboratory by gender

Perceptual constructs	Male			Female			Overall
	Traditional	Virtual	Physical	Traditional	Virtual	Physical	
Experience	49.67 (6.16)	53.10 (6.12)	56.79 (2.83)	48.12 (5.82)	51.20 (4.55)	47.35 (5.34)	50.58 (5.97)
Impression	38.11 (4.17)	38.90 (3.81)	41.43 (2.90)	37.04 (4.69)	38.70 (4.33)	36.88 (4.03)	38.31 (4.30)

The finding from this result indicated that students' perceptions toward smartphone-based inquiry laboratory in chemistry depended on their gender. It implied that the gender difference had an influence on their perceptions. Moreover, it was found that males expressed more positive perception toward the smartphone laboratory environment compared to female.

3.2.2 Effect of the Three Different Laboratory Interventions on Students' Engagements

In order to investigate effect of students' learning engagements for the two experimental groups (virtual and physical mobile laboratory environment), Table 2 shows descriptive statistics, means, and standadard deviations on scientific confidence (SC), attitude to learning science with technology (ST), confidence with technology (TC), affective engagement (AE), and behavioral engagement (BE) dimension. The results of the one-way MANOVA indicated that there was no significant main effect for both gender (Wilks' lambda=.844, $F(2,56)=1.956$, $p=.100$, partial $\eta^2=.156$) and intervention (Wilks' lambda=.945, $F(2,56)=0.623$, $p=.683$, partial $\eta^2=.055$). Furthermore, there was also no significant difference for its interaction effect (Wilks' lambda=.935, $F(2,56)=0.740$, $p=.597$, partial $\eta^2=.065$).

Table 2: Descriptive statistics, means and standard deviations for students' learning engagement of traditional, virtual mobile, and physical mobile laboratory by gender

Engagement characteristic	Male		Female		Overall
	Virtual	Physical	Virtual	Physical	
Scientific confidence (SC)	17.70 (2.06)	18.00 (2.48)	17.40 (2.01)	15.53 (3.06)	17.07 (2.59)
Attitude to learning science with technology (ST)	18.40 (1.71)	18.07 (2.46)	17.90 (1.92)	16.76 (2.59)	17.70 (2.25)
Confidence with Technology (TC)	18.00 (1.49)	18.00 (2.39)	16.90 (2.53)	15.29 (3.18)	16.89 (2.74)

Engagement characteristic	Male		Female		Overall
	Virtual	Physical	Virtual	Physical	
Affective Engagement (AE)	18.30 (2.21)	17.79 (2.04)	18.00 (1.65)	16.65 (2.85)	17.62 (2.25)
Behavioral Engagement (BE)	18.60 (1.65)	17.71 (2.27)	17.35 (2.52)	15.94 (3.19)	17.25 (2.66)

According to the aforementioned results, the overall results suggested that the learning engagement of female and male students regarding scientific confidence, attitude to learning science with technology, confidence with technology, affective engagement, and behavioral engagement was homogeneous after participating in the three different laboratory interventions. This means there was no effect of gender difference on students' learning engagement based on the smartphone-based inquiry laboratory learning. This implied that both females and males can learn chemistry laboratory with smartphone-based inquiry laboratory environment.

6. Conclusions and Future Study

This study reported an impact of smartphone-based inquiry laboratory on high school students' perceptions toward the mobile laboratory and learning engagements. The finding showed that significant difference in students' perception was detected between females and males after their participating with different laboratory intervention, i.e. traditional lab, virtual smartphone-based lab, and physical smartphone-based lab. As such, the results suggested that gender disparity was found on their perceptions. However, the finding indicated that gender difference had no impact on students' learning engagements on the use of smartphone-based inquiry laboratory for solution concentration. According to the preliminary findings, the researchers will design an appropriate pedagogy regarding gender to promote high school students' learning performance in the next study. The three chemistry knowledge representations, including macroscopic, sub-microscopic and symbolic, will be used to create an emerging pedagogy for smartphone-based inquiry laboratory environment for chemistry teaching and learning.

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