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A Flipped Inquiry-based Learning with Mobility to Improving Students' Learning Performance in Science: A Comparative Study

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Abstract: The present study examines the differential impact of studying in an innovative learning approach, flipped inquiry-based learning with mobility (FILM) setting, as compared to a hands-on inquiry-based learning (HIL), and traditional learning (TL) setting on science learning performance regarding scientific conceptual understanding. Participants were eleventh-grade students (N = 79), enrolled in physics course in a public secondary school in northeastern region of Thailand. They were divided into the three groups and randomly assigned according to one of the three experimental conditions (TL n = 25, HIL n = 23, FILM n = 31). The results showed that conceptual learning performance on liquid pressure was superior in the FILM group as compared to other learning settings (*Cohens' d* = 3.35), HIL (*Cohens' d* = 0.64) and TL (*Cohens' d* = 0.99). Students in the HIL setting had a higher conceptual learning performance as compared to the TL setting. This finding suggest that the FILM setting could be a promising way of enhancing high school students' learning performance in science.

Keywords: Flipped classroom, inquiry, mobile learning, science education

1. Introduction

The Flipped classroom model was introduced by the high school chemistry teachers Jonathan Bergmann and Aron Sams in 2007 (Tucker, 2012). The principle of this instructional methodology is based on "directs instruction and lecture is not an effective teaching tool in the group learning space, but is effective when delivered to individual" (Sams and Bergmann, 2013). This approach allows students to learn at their own, having more flexibility to distribute their studying time and putting on them more responsibility in the learning process (O'Flaherty and Phillips, 2015). Thus, in the flipped classroom model, students are asked to view a recorded video prior to attending class and the class time is used to engage in student-centered learning activities like inquiry and problem solving, fostering the students to be more interactive during class time (Moraros et al., 2015). Another feature of the flipped classroom is that the video and interactive lesson are always available to students, they could reinforce their learning by re-watching the materials provided by the teacher the number of time they need. Moreover, flipped classroom could be integrating into many subject areas, i.e. general science (Gonzalez-Gomez et al.,2016); mathematics (Lai and Hwang, 2016); ICT teaching (Kostaris et al., 2017). Especially in science classroom with flipped learning, students have positive perceptions and engagement toward this methodology (Chaipidech and Srisawasdi, 2016).

In science learning environment, inquiry teaching approach has been widely used for support students to develop scientific concepts and knowledge. Moreover, the students were asked to observe and purpose explanations or answers from evidences gained by the experiment (National Research Council, 1996). Inquiry learning is procedure that focused on upcoming cognitive domain of students (Hofstein and Lunetta, 2004; Srisawasdi and Kroothkeaw, 2014). Thus, inquiry learning invests more opportunities for the learners to achieve an intensive understanding in the concepts (Vlassi and Karaliota, 2013).

For many years, to support the construction of conceptual understanding in science, numerous educators aimed to develop the instruction and teaching materials for physics concepts. For example, they indicated that the simulation-based inquiry learning could support conceptual understanding and the process of conceptual change in science learning. (Lazonder and Ehrenhard, 2014; Olympiou and Zacharia, 2012; Suits and Srisawasdi, 2013; Zacharia, Olympiou, and Papaevripidou, 2008).In this study, high school students were recruited to investigate the effects of instruction with flipped inquiry-based learning with mobile technology pedagogy by using computer simulation as a learning tools on conceptual understanding of the liquid pressure. The research question was addressed: Do the students who learn with flipped inquiry-based learning with mobility (FILM) improve conceptual understanding of liquid pressure than those who learn with hands-on inquiry-based learning (HIL), and traditional learning (TL)?

2. Literature Review

2.1. Previous Findings on Flipped Classroom

A more recent pedagogical approach known as “flipped classroom” or “flipped learning” which allow teachers more time to guide the learning activities and promote student’s learning. In addition, it moves the learning contents taught by teachers’ direct instruction to the time before class in order to increase the chances for students’ interaction. Several teachers have used some methods to flip the class, for example, offering video clips as supplemental materials and letting students learn outside the class. Nevertheless, more requirements need to be met to achieve flipped learning (Hwang, Lai, and Wang, 2015). In fact, ‘‘flipped learning’’ is closely definition of the ‘‘flipped classroom.’’ In this research, the two terminologies are not strictly distinguished. There are many adopting the concept of the flipped classroom. For example, Gonzalez-Gomez et al. (2016) examined performance and perceptions of students in general science classroom along with flipped classroom and result showed that students who leaned with flipped classroom have higher performing, positive perception than other and increased individualized learning.

Moreover, Hwang et al. (2015) have indicated some of the reasons why flipped learning has been adopted by so many educators.

(1) The multimedia technology is provided by teacher let students learn without time or space limitations. Students are taught to collect information before class and are expected to be active learners responsible for their own learning.

(2) the interaction between students with teaching videos allows them to prepare themselves and to have thoughtful prior knowledge before class, and lets those students who miss classes catch up.

(3) With enough prior knowledge, students have more time to conduct higher level activities and questions. teachers can further provide individualized consulting and would better understand the learning status of their students.

(4) In-class activity could increase teacher and student’s interaction. An active atmosphere can improve students’ learning motivation and, through peer pressure, the learning effects would increase.

2.2. Simulation-based Inquiry Learning in Science

The appropriate learning tools which considered for effective conceptual change are Simulation-based learning environments in science learning. It can allow learners to observe and understand abstract and complex concepts. In addition, the capability of computer simulations is closely related to the pedagogy through which they are employed (Srisawasdi and Panjaburee, 2015). For science educators, teaching and learning through scientific inquiry is recognized as an instructional practice.

The Inquiry-based learning with simulations is an encouraging area for teaching to promote learners' interaction with the physical and social world in order to develop scientific understanding, explanation, and communication among science ideas. Many educators have found that simulation-based inquiry learning works as an improving process by producing change in the alternative conceptions held by learners (Srisawasdi and Kroothkeaw, 2014; Zacharia, 2007), and promoting more qualitative knowledge than formalized knowledge (Suits and Srisawasdi, 2013), offering students more time to experience on its conceptual aspects. (Zachaia et al.,2008), and promoting positive perception of science learning (Buyai and Srisawasdi, 2014; Pinatuwong and Srisawasdi, 2014).

2.3. Mobile Technology-enhanced Learning

Over the years, a number of studies about mobile technology have been increased. Many mobile devices were used in class or out class for enhance students' learning in science (e.g. iPads, smart phones, tablets, and PDAs) and their effect related to cognitive and affective goals in different settings. For example, the students used mobile devices at the school classroom, outdoors, and museums (e.g. Chu et al., 2010; Klopfer et al., 2012).

Most of the findings of these studies pointed the added mobile learning is promoting students' affective (e.g. interest, attitudes) and cognitive domain (conceptual understanding). In terms of promoting students' understanding, the findings from of these studies showed that the use of mobile devices could enhance students' conceptual understanding and learning achievement in science (e.g. Chu et al., 2010; Zacharia, Lazaridou, and Avraamidou, 2016). In addition, Looi et al. (2009) also mentioned the fact that mobile learning offers a student-centered learning environment that aims at enhancing personalized and self-directed learning. These positive outcomes could be attributed to different affordances of the mobile devices (e.g. individuality, connectivity, context sensitivity, mobility, immediacy, content provision, collaboration, gaming, and rapid data collection) (Zacharia et al., 2016).

3. Research Methodology

3.1. Participants

The participants of this research were eleventh-grade students of a public secondary school in northeastern region of Thailand. Seventy-nine students from three classes participated in the experiment. Two of the classes were designated as the experimental group A and experimental group B, and the third one was designated as the control group, respectively. The study has not recruited students on a random basis but had to use existing classes. Three classes were selected by a regular science teacher in the school.

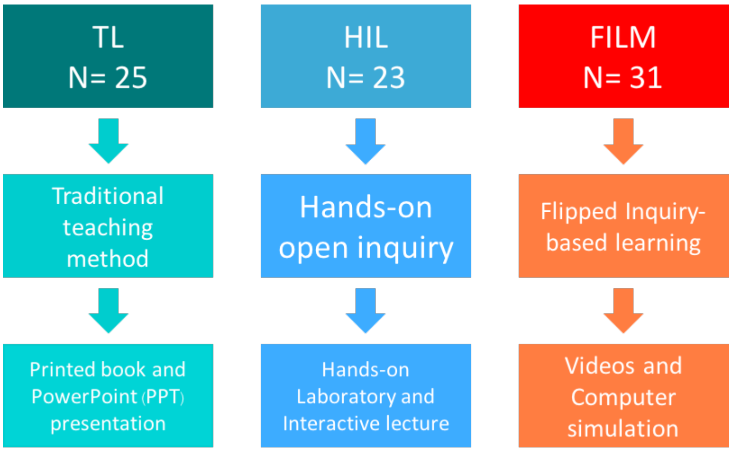

Figure 1. Diagram of participants and learning environment

3.2. *Research Instruments*

The tools for measurement in this study included a *"Liquid Pressure"* conceptual test. This conceptual test consisted of five open-ended conceptual questions that focused on four main science concepts consisting of the following: (i) liquid pressure-depth; (ii) liquid pressure-type of liquid; (iii) liquid pressure-shape of container; and (iv); liquid pressure-gravity, with a perfect score of 10 points. The conceptual test was adapted from Buyai and Srisawasdi (2014).

3.3. *Data Collection and Data Analysis*

Figure 2 illustrates the procedure of the implementation of the learning activities. Before the learning activity, the students took the pre-test of conceptual understanding. Then, they were provided four activities (i.e. (i) liquid pressure-depth; (ii) liquid pressure-type of liquid; (iii) liquid pressure-shape of container; and (iv); liquid pressure-gravity). After completing all of learning activity, the students were administered the conceptual test again as the post-test.

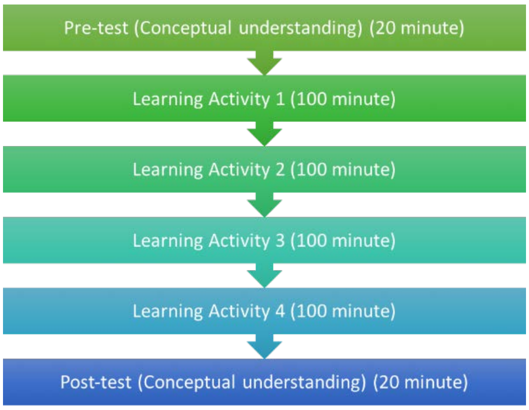

Figure 2. Diagram of experimental design in this study

The statistical data techniques selected for analyzing were the Wilcoxon Signed-rank sum test for paired data (a nonparametric equivalent of pair-sample t-test) was used to compare learning gains for all groups. To answering the research questions, the one-way analysis of covariance (ANCOVA) was used to compare the scores of the three groups in terms of conceptual understanding among the experimental and control groups

3.4. *Learning Materials and Activity*

3.4.1. *Traditional Teaching Method by Lecture-based Instruction for CG*

Students assigned to regular teaching method (n = 25) interacted liquid pressure lectures and assignments in a normal classroom. The lecture-based instruction was organized in four lectures (2x50 minutes) and 25 were usually following the lectures which were given as doublets every week. Lectures consume the vast bulk of actual class time, and each lecture is accompanied by a set of PPT slides. The slides have been designed to provide students with full notes of lessons and project in class concerning general principles for effectively using PowerPoint. Such principles include using text sparingly on slides (i.e. bullet points made up of only key words or brief phrases), making slides visual, ensuring that any slide visuals are integrated with the verbal lecture message, avoiding non-relevant sounds and animations, etc. In addition, the lectures and learning assignments in this class were aligned with series of formative assessment task in every lesson.

3.4.2. Hands-on Open Inquiry Learning and Interactive Lecture for EG#A

Students assigned to hands-on open inquiry learning and interactive lecture (n = 23) solved liquid pressure assignments in a normal classroom, with manipulative laboratory equipment and materials that included plastic bottles, beakers, cylinders, plastic tube, glass tube, water, salt water, alcohol, and a manometer.

3.4.3. Flipped Inquiry-based Learning Approach with Mobile Technology for EG#B

In the flipped classroom with the support of mobile technology, students were assigned to take responsible for their own learning with a series of video-based lecture material via YouTube, that are studied prior attend the face-to-face lab section. The video provided the content of open-ended driving questions and scientific background and terms or describing related theory as same as the other groups in 6-9 minutes.

For each lab section, students received additional instructional support (i.e. apparatus set up and diagram illustration of the learning process) via PPT slides, and then they take control of their own learning pace, and be responsible for their own learning process with simulation on mobile devices, both tablet and mobile phone.

4. Results and Discussions

4.1. Scientific Conceptual Understanding of Liquid Pressure Phenomena

To examine the influence of three different learning strategies on high school students' understanding of liquid pressure. The one-way ANCOVA were used to test the main effect for the experimental groups and the control group, controlling the effect of prior conception. The result of the ANCOVA analysis displayed in Table 1. In addition, this study analyzed the differences between pre-test and post-test, using Wilcoxon Signed-rank test. Table 2 reports the result of the Wilcoxon Signed-rank test analysis.

Table 1: The ANCOVA results of post-test score for three groups of students.

Group	N	Mean (S.D.)	Adjusted mean	Std. error	$F_{(2,67)}$	Post hoc test (Bonferroni)
(a) TL	25	3.76(1.88)	4.17	.42	19.658	(b) > (a)
(b) HIL	23	5.09(2.00)	4.62	.42		(c) > (a)*
(c) FILM	31	7.03(1.55)	7.19	.35		(c) > (b)*

$^{*}p$ = < .05

The result of ANCOVA indicated that there was a statistically significant difference ($F_{(2,67)}$ = 19.658, *p* = .000) between the experimental groups and the control group after intervention as shown in Table 6. After eliminating the influence of covariance (pre-test), the EG#A had an adjusted mean of 4.62 (SE = .42); the EG#B group had an adjusted mean of 7.19 (SE = .35), and the CG group had an adjusted mean of 4.17 (SE = .42) for the post-test measure of conceptual understanding. Students who participated in the FILM group outperformed others. In other words, after the instruction (flipped inquiry-based learning with mobile technology), the students in this experimental group had enhanced their conceptual understanding on liquid pressure phenomena.

To determine where the differences among the teaching methods were, Bonferroni's Post HOC Test in Table 6 was employed to test for significance. All tests were conducted using the adjusted means, controlling for any difference prior conceptual understanding. The EG#B group were compared to EG#A and CG groups revealing a mean difference of 2.571, p = .000, and of 3.025, p = .000, respectively. This evidence indicated that integration of flipped learning approach with mobile technology could better effect on enhancing students' scientific conception on liquid pressure phenomena. In addition, the comparison of the EG#A group with the CG group revealed a mean difference of .450 and level of significant of p = .826 that indicated that there was no significant difference between the two teaching methods of HIL and TL on liquid pressure phenomena.

Table 2: Statistical results on Wilcoxon Signed-rank test for the students' conceptual understanding of liquid pressure.

Group	Test	Mean	Mean Rank	S.D.	Posttest-Pretest	N	Z	Sig.	Cohen's d
TL	Pretest	2.20	32.06	1.19	Posttest<Pretest	4	-2.953	.003*	0.99
	Posttest	3.76	23.00	1.88	Posttest>Pretest	16			
					Posttest=Pretest	5			
					Total	25			
HIL	Pretest	3.91	55.67	1.70	Posttest<Pretest	3	-2.559	.011*	0.64
	Posttest	5.09	35.96	2.00	Posttest>Pretest	16			
					Posttest=Pretest	4			
					Total	23			
FILM	Pretest	2.39	34.77	1.20	Posttest<Pretest	0	-4.879	.000*	3.35
	Posttest	7.03	56.71	1.55	Posttest>Pretest	31			
					Posttest=Pretest	0			
					Total	31			

$^{*}p = < .05$

The analysis from Wilcoxon signed-rank test reveal students in traditional learning class (CG) have post-test greater than pre-test score (Z= -2.953, $p_{(pre-post)} < .05$). This evidence indicated that although students have a progression of conceptual understanding when learned with conventional method. For another groups, students who learned with flipped inquiry-based learning with mobility (FILM) and hands-on Inquiry-based learning (HIL), their post-test score showed increased significantly (Z = -4.879, $p_{(pre-post)}$)<.05), (Z = -2.559, $p_{(pre-post)}$<.05). However, students in FILM class were highest score when compared with others, as shown in Table 3. This indicated that when the flipped inquiry-based learning had been integrated with the computer-simulated visualization into the science learning of liquid pressure, there had been a significant impact on conceptual understanding. Therefore, this method has been shown to be superior to a more general flipped learning. Similar to previously studies regarding the students' performance reported that all assessment was significant difference found with students in the flipped class, when compared to a traditional group (Gonzalez-Gomez et al., 2016). Similar conclusions were found in an engineering course (Mason, Shuman, and Cook, 2013). In addition, Davies et al., (2013) determined what benefit flipped classroom might have for undergraduate students and investigated how technology can be used to enhance technology skills in this class. They found that the flipped classroom approach allowed students to learn course content by themselves, and to make better use of their time, improving their perception toward the class. In our study, the significant differences are observed between FILM, HIL, and TL. Especially students' performance was significantly higher when a flipped model integrated to inquiry-based learning with visualize simulation on mobile devices was followed. In most cases simulation conditions showed improving learning outcomes, Srisawasdi and Kroothkeaw (2014) mentioned that students' conceptual score for pre-test, post-test, and retention test were significantly different and they increased conceptual understanding after participated with simulation

class. However, the flipped approach integrated into simulation-based inquiry was also better than the regular approach for delivering this course.

5. Conclusion

This research aimed to explore students' learning performance in the flipped inquiry-based learning with mobility (FILM), comparing the results with hands-on inquiry-based learning (HIL) and traditional learning (TL). The study was conducted in a physics course, eleventh grade high school students in the northeastern region of Thailand. The students' performance was measured in terms of overall students' testing score. The result showed that better outcomes were achieved when the FILM was followed. In addition, an integration of flipped learning into inquiry-based learning with mobile technology and using simulation as learning tools can help students to comprehend conceptual understanding about liquid pressure both observable and unobservable level of phenomena.

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