International Journal of Science Educators and Teachers
2015, Volume 1, Number 1
pp. 60 - 73

Scientific Inquiry as a Means to Develop Teachers' and Supervisors' Scientific Literacy

Luecha Ladachart

Office of the Basic Education Commission
Seventh Floor, OBEC Building 3, 319 Wangchankasem, Ratchadamnuennok Rd., Dusit, Bangkok, 10300, Thailand. Tel: +662885770. Fax: +662885770. Email: ladachart@gmail.com

Chokchai Yuenyong

Faculty of Education, KhonKaen University
Mittapap Rd., Nai-Muang, Muang Dsitrict, KhonKaen, 40002, Thailand.
Email: ychok@kku.ac.th

Abstract

This research report presents results of implementing 6 scientific inquiry learning activities with overall 120 science teachers and supervisors in northern region of Thailand. This research aimed at (1) comparing the science teachers' scientific literacy before and after the implementation, (2) comparing the supervisors' scientific literacy before and after the implementation, and (3) comparing the science teachers' and the supervisors' scientific literacy. A pre-experimental design was employed in order to address the research objectives. Data were collected using pre- and post tests on scientific literacy. Each test consists of 26 four-choice questions. These data were analyzed using t-test. Research results revealed that (1) the science teachers got an average scientific literacy score before the implementation higher than that of the after one with significance at .05, that (2) the supervisors got an average scientific literacy score before the implementation higher than that of the after one with significance at .05, and that (3) the science teachers got an average scientific literacy score higher than that of the supervisors with a significance at .05.

*Keywords:*Teaching and Learning Science, Science Teachers and Supervisors,Scientific Inquiry, Scientific Literacy

1. Introduction

Many countries around the world (Bingle & Gaskell, 1994; Hurd, 1998; Kolsto, 2001; Laugksch, 2000; Organisation for Economic Co-operation and Development [OECD], 2013; Yuenyong & Narjaikaew, 2009) have set scientific literacy as a main goal of science education for their citizen**.** Although scientific literacy defies a precise definition, it usually implies "*a broad and functional understanding of science for general education purposes*" (DeBoer, 2000: 594). More specifically, it is "*the ability to understand scientific processes and to engage meaningfully with scientific information available in daily life*" (Fives, Huebner, Birnbaum, & Nicolich, 2014: 550). It is believed that scientific literacy "*requires not just knowledge of the concepts and theories of science but also knowledge of the common procedures and practices associated with scientific enquiry and how these enable science to advance*" [OECD, 2013: 3 – 4].

As a main goal of science education, some attributes of scientifically literate persons have been identified (Hurd, 1998). For example, OECD (2013) suggests three competencies, which include (1) explaining phenomena scientifically, (2) evaluating and designing scientific inquiry, and (3) interpreting data and evidence scientifically. Fives *et al*., (2014) propose six aspects, which include (1) understanding the role of science as it helps understand natural phenomena, (2) ability to use scientific thinking in designing and conducting scientific inquiry, (3) understanding how science and society interact, (4) ability to critique scientific findings in mass media, (5) ability to use mathematics in science, and (6) motivation to engage in and learn about science. According to these, the ability to understand, design, and conduct scientific inquiry becomes part, if not central, of scientific literacy.

As such, many countries agree that inquiry-based instruction is a key approach to achieving the goal of scientific literacy (Abd-El-Khalick, Boujaoude, Duschl, Lederman, Mamlok-Naaman, Hofstein, Niaz, Treagust, & Tuan, 2004; Bureau of Academic Affairs and Educational Standards, 2010). As inquiry-based approach "*mirror(s) … the way scientists themselves did their work*" (DeBoer, 2000: 587), it can prepare young citizen to be knowledgeable enough to interpret functions of science in human affairs (Hurd, 1998), to deal with controversial socioscientific issues (Kolsto, 2001), and also to be sympathetic to the work of scientists as well (DeBoer, 2000). As a consequence, a number of science educators worldwide have devoted their effort to develop and promote inquiry-based instruction (Supasorn, 2011; Anderson, 2002; Minner, Levy, & Century, 2010).

Inquiry-based instruction has a foundation on the idea that science is both knowledge and processes for constructing that knowledge, which are inseparatable (Ketsing & Roadrangka, 2011). Thus, students should learn science in ways "*that emphasize integration between knowledge and processes*" (Bureau of Academic Affairs and Educational Standards, 2010: 1), which are similar to processes by which scientists construct scientific knowledge (Ketsing & Roadrangka, 2011)**.** This idea is consistent with a constructivist theory of learning in that learning science will meaningfully occur when students have hands-on and mind-on experiences in order for them to answer scientific questions that they want to know (Bybee, Taylor, Gardner, Scotter, Powell, Westbrook, & Landes, 2006)**.** In doing so, students should reflect on their prior understanding in light of evidences gained from their first-hand experiences in order to change their understanding to be more intelligible and fruitful (Posner, Strike, Hewson, & Gertzog, 1982)**.**

However, during a transitional period of reforming science education in Thailand (Dahsah & Faikhamta, 2008), inquiry-based instruction is not common in Thai science classrooms (Promprasit, Yutakom, & Jantrarothai, 2008; Ladachart & Roadrangka, 2008; Bongkotphet, Roadrangka, & Panacharoensaward, 2009). Many teachers lack of knowledge and understanding about inquiry-based instruction (Musikul, 2007). A number of them are confused between "inquiry-based instruction" and "information searching" (Bongkotphet & Roadrangka, 2010), which translation of the term "inquiry" into Thai is misleading. This confusion could influence them to understand that inquiry-based instruction is:

> *"assigning students to search for some information … from many sources such as books, news, web (internet) … collect them together. Then, there are presentations in front of the classroom (or) group reports … (After that) the teacher will teach as amendment of what the students have searched" (Liangkrilas & Yutakom, 2010**:** 29).*

Moreover, some Thai teachers partially understand that inquiry-based instruction is hands-on activities. Thus, although they use hands-on activities, those activities require students to strictly follow pre-determined steps without a true understanding about those steps (Ketsing & Roadrangka, 2010)**.** Pongsophon (2009: 89) has noted this after observing one teacher's science classroom.

> *"Often, students did experiments without goals. The teacher did not inform them why to do those experiments. There were no explanations about the experiments. The students neither were asked to formulate questions nor have opportunities to think of ways to answer those questions. In other words, they did not get experiences as real scientists did. They just got results (as presented in the textbook and as expected by the teacher). The teacher satisfied. The students also satisfied. But they did not even know what they learned."*

As a consequence, most Thai students have poor understanding in science (National Institute of Educational Testing Service [NIETS], 2012). They also lack of scientific process skills (Chaiyen, Bunsawansong, & Yutakom, 2007; Nakthong, Anuntasethakul, & Yutakom, 2007). Moreover, a number of students do not understand nature of science (Ladachart, Suttakun, & Faikhamta, 2013). Mahalee & Faikhamta (2010) found that 71% of 110 seventh grade students do not understand or partially understand about ways by which scientists acquire scientific knowledge. Chamrat, Yutakom, & Chaiso (2009) also found that about 53% of 135 tenth grade students partially understand about scientific methods. These students share a similar understanding that a fixed-steps experiment is either the only scientific method or the best way to acquire scientific knowledge.

The situation about inquiry-based instruction, as described above, has not happened only in Thailand (Abd-El-Khalick *et al*., 2004) **.**For instance, Chinn & Malhotra (2002) analyzed a number of science learning activities, as appeared in textbooks and in research articles, which resulted in that those learning activities mainly consist of (1) simple experiments with one independent variable and one dependent variable, (2) simple observations with descriptions of what and how to be observed beforehand, and (3) simple demonstrations with emphasis on directly presenting or confirming scientific concepts. These kinds of learning activities, Chinn & Malhotra (2002) argued, rarely provide students to do authentic scientific inquiry—they just ask the students to follow recipe procedures, which are similar to what Bloome, Puro, & Theidorou (1989) called "procedural display" without learning anything about those procedures.

Since Thailand has promoted inquiry-based instruction for many decades (Ketsing & Roadrangka, 2011) but authentic scientific inquiry is not common in science classrooms especially at basic education levels. Thus, the Office of the Basic Education Commission [OBEC], which is directly under, the Ministry of Education [MOE], initiated a project for introducing a set of learning activities for lower secondary students to develop their ability to do authentic scientific inquiry. In order to make those learning activities to be authentic, each learning activity highlights some important aspects of scientific inquiry such as designing scientific inquiries, doing scientific experiments, manipulating and analyzing scientific data, making scientific inferences and explanations, and engaging in scientific argumentation. These aspects are emphasized because ability to do scientific inquiry is an important component of scientifically literate persons (OECD, 2013).

This research report presents results of the implementation of six scientific inquiry learning activities with science teachers and supervisors in the northern region of Thailand. This research aimed at (1) comparing science teachers' scientific literacy before and after the implementation of the learning activities, (2) comparing supervisors' scientific literacy "before" and "after" the implementation of the learning activities, and (3) comparing science teachers' and supervisors' scientific literacy. As scientific inquiry is not common in Thailand and some Thai teachers and supervisors may be familiar with following (quite strictly) the 5E inquiry cycle (Bybee *et al*., 2006) with little emphases on its five essential features (i.e., engaging in scientific questions, giving priority on evidence, formulating explanations from evidence, connecting explanations to scientific knowledge, and communicating and justifying explanations), introducing these six learning activities becomes novel. Thus, the research results would provide insights to whether and how these learning activities promote the teachers' and supervisors' scientific literacy.

2. Scientific Inquiry Learning Activities

All learning activities in this project were developed in accordance to Chinn & Malhotra's (2002) suggestions that science learning activities should not be too simple and algorithmic, as appeared in common textbooks, but should contain some degree of complexity in order for students to authentically do science. As Kang, Thomson, & Windschitl (2014) suggested that a contexualized phenomenon has great impact on students' explanations and learning, each learning activity begins with a contextualized phenomenon from media, leading to some scientific question(s) in order for students to address the scientific question(s). This is because all scientific inquiries begin with, and are guided by, scientific questions whose answers are based empirical evidences (Lederman, Lederman, Bartos, Bartels, Meyer, & Schwartz, 2014).

Once a given scientific question is presented, students are challenged to think if and how that scientific question can be answered by doing (even some part of) scientific inquiry (e.g., designing scientific inquiries, doing scientific experiments, manipulating and analyzing scientific data, making scientific inferences and explanations, and engaging in scientific argumentation). In doing so, students are reminded to answer a scientific question using data and evidence. In some cases, students are required to use their mathematical knowledge and computational ability to analyze data and interpret evidence. Also in some cases, students can realize that some limitations, which include social ones, can influence scientific inquiry (e.g., limited social support to explore the moon in details) and vice versa (e.g., an exploratory result of CO_2 in the air can increase public concern about global warming). These are emphasized for students to understand the role of science, practice scientific thinking and doing, realize interaction between science and society, evaluate scientific information in media, and use mathematics in science.

The scientific inquiry learning activities in this project include 6 activities, namely (1) Global Warming, (2) Finch Puzzle, (3) Origin of the Moon, (4), Tides, (5) Sink and Float, and (6) Volume Missing. All the learning activities are developed in accordance to indicators and core content standards described in the National Science Curriculum Standards (Bureau of Academic Affairs and Educational Standards, 2010). Each learning activity is developed to reflect nature of scientific inquiry (Lederman et al., 2014) with a view of practical possibility for typical teachers in common classrooms. The development of the learning activities follows a suggestion by Hodson (1988: 35) that:

> *"It is naïve to believe that any one kind of laboratory work [learning activity] can meet a wide variety of learning goals. Laboratory experiences, like all learning experiences, must be designed with a specific goal in view. It is naïve, also, to assume that laboratory work in science education corresponds directly with the experimental phase in scientific research."*

Moreover, four of these six learning activities are based on real scientists' works or contexts. Summary of each learning activity is presented as follows.

The Global Warming Activity corresponds to the National Science Curriculum Standards at seventh grade level, which describes that *"(students) search for information, analyze, and explain natural and human factors that affect change in the Earth's temperature …"* (Bureau of Academic Affairs and Educational Standards, 2010: 79). This activity emphasizes that students should have opportunities to *"design a scientific experiment by themselves as well as evaluate and criticize that of others"* (Bureau of Academic Affairs and Educational Standards, 2014: i). The activity begins with a video about a longitudinal study of an amount of CO_2 in the atmosphere, which tends to be increasing. This is mostly consistent with an increasing tendency of the average of the Earth's temperature. However, there is some part of this study's result showing that, in some years, even though CO_2 increases, the Earth's average temperature does not increase. Following this situation, students are asked to design an experiment in order to answer a scientific question that *"when exposed to sun light, can a more concentration of CO_2 in the air make the temperature of the air increase more rapidly?"* (Bureau of Academic Affairs and Educational Standards, 2014: 8). Next, the students have to present their experiment design to their classmates in order for them to evaluate and criticize that of others in positive and constructive ways. This activity is consistent with what Chinn & Malhotra (2002: 211) called "Verbal Design of Research," which helps the students understand how to design a fair experiment. Next, the students implement their experiment and discuss about its results. With facilitation by the teacher, the students will understand that CO_2 (and other greenhouse gases) can absorb infrared radiation in the atmosphere, making its temperature increase more rapidly when compared to the air without CO_2.

The Finch Puzzle Activity corresponds to the National Science Curriculum Standards at ninth grade level, which expects students to understand that environmental changes (e.g., deforestation and using chemical substances in agriculture) *"are a cause of the loss of biological diversity"* (Bureau of Academic Affairs and Educational Standards, 2010: 27). This activity emphasizes that students should have opportunities to *"make scientific inferences as well as construct a scientific explanation based on evidences"* (Bureau of Academic Affairs and Educational Standards, 2014: i). The activity begins with a situation of drought in a Galapagos island, which caused death of a large number of finches (Boag & Grant, 1981). Following this situation, students are asked to consider nine evidences in order to make inferences and construct an explanation addressing a scientific question that *"does and how drought affect the loss of genetic diversity in the finch population?"* (Bureau of Academic Affairs and Educational Standards, 2014: 29). This activity is adapted from an activity called BGuILE by the Northwestern University (2013), which fosters students to use empirical evidences to construct an explanation that drought can affect an amount of food (i.e., seed) and its physical properties (i.e., size and shell's hardness), which determine what kinds of finches to survive. Since some finches with some physical characteristic (i.e. bigger and stronger beaker) have more advantageous to survive than others, the genetic diversity in the finch population decreases. Next, the students are asked to use this explanation to explain how other environmental changes (e.g., deforestation and using chemical substances in agriculture) can affect the loss of biological diversity of other plants and animals in their local community.

The activity namely Origin of the Moon corresponds to the National Science Curriculum Standards at ninth grade level, which describes that students understand that *"the Sun, the Earth, and the Moon are a system governed by gravity"* and *"gravity between the Earth and the Moon makes the Moon orbit around the Earth … gravity* *between the Sun and its planets makes the planets orbit around the Sun …"* (Bureau of Academic Affairs and Educational Standards, 2010: 89). This activity emphasizes that students should have opportunities to *"persuade and argue in scientific discourses in order to infer for the best explanation based on available evidences and scientific knowledge"* (Bureau of Academic Affairs and Educational Standards, 2014: i). The activity begins with a longstanding scientific issue about how the moon originated. This is followed by four possible theories, which consist of (1) Fission Theory, (2) Capture Theory, (3) Nebular Theory, and (4) Giant Collision Theory. After considering these theories, students have to select which theory they agree most. Then, students work in groups according to their theory selection. Next, they have to consider and use seven evidences to persuade and argue with other groups. After listening to all student groups' arguments, each student has to evaluate whether and how each theory is supported, and which theory should be most accepted. Like real astronomers' vote about Pluto's status (Britt, 2006), all students have to vote which theory they agree most. With facilitation by the teacher, the students discuss about the vote result until they see that the Giant Collision Theory is supported by most of the available evidences in light of scientific knowledge. This activity is consistent with what Chinn & Malhotra (2002: 210) called "Evidence Evaluation," which helps the students to evaluate consistency between theoretical ideas and empirical evidences. Furthermore, the students are asked to consider what aspect all four theories share. In doing this, they can see that these theories explain the origin of the moon based on gravitational force. Next, the students work on a computer simulation called PhET (University of Colorado, 2013) to explore how gravitational force works.

The Tides Activity corresponds to the National Science Curriculum Standards at ninth grade level, which expects students to understand that *"gravity that the Moon and the Sun acts on the earth causes ocean tides, which affects environmental and living things on the Earth"* (Bureau of Academic Affairs and Educational Standards, 2010: 89). This activity provides the students opportunity to *"manipulate and analyze a set of complex data in order to make meanings inherent in those data"* (Bureau of Academic Affairs and Educational Standards, 2014: i). The activity begins with a video showing ocean tides. Next, the students are asked what happens in the video. Once the students answer ocean tides, which sea level goes up and down as time goes on, they are asked a few questions *"how often sea level goes at its crest and go down at its trough during one day?"* and *"what factors cause ocean tides to happen?"* (Bureau of Academic Affairs and Educational Standards, 2014: 86). In order to answer these two questions, the students have to analyze real scientific data collected by the Hydrographic Department, Royal Thai Navy (2014) using a hand-written graph. This analysis reveals the fact that ocean sea level goes up at its crest two times a day and also goes down at its trough two times a day. Next, students have to conjecture possible factors causing tides, which include wind, storm, rain, sunlight, air pressure, humidity, the Moon, and the Sun. In a discussion about these factors, the students are asked why a traditional Thai song (Loi Kar Tong) says that once a full moon especially on 12th month according to Thai traditional calendar (about November) comes, water logging also occurs. The students are stimulated to think whether or not tides and moon phases are related with some reason and, if yes, what is an evidence supporting such a relation. In order to answer these two questions, the students have to analyze two sets of data—one is a set of data about tides and the other is a set of data about moon phases—that occur at the same period of time. In doing so, the students can use a computer data processing program (i.e., MS Excel). This activity is consistent with what Chinn & Malhotra (2002: 209 – 210) called "Data Analysis," which helps the students to use their creativity in order to manipulate and analyze complex data. The analysis of these data reveals that both phenomena (i.e., tides and moon phases) are related because they cyclically change with a same period of time. This cyclic change is evidence possibly leading to a conclusion that tides and moon phases are related with some particular reason. Since a scientific explanation of tides is complicated, for example why the earth has two bulges (Viiri, 2000), it is presented in a lecture format with a computer simulation (Ruzhitskaya & Montfrooij, 2011).

The activity namely Sink and Float corresponds to the National Science Curriculum Standards at ninth grade level, which expects students to *"do experiment and explain (why an object sinks or floats) using a buoyancy force acting on the object"* (Bureau of Academic Affairs and Educational Standards, 2010: 58). This activity provides the students opportunity to "*do experiment using a computer simulation*" (Bureau of Academic Affairs and Educational Standards, 2014: i). It is also designed to prepare the students to be familiar with experiments using a computer simulation since the Programme for International Student Assessment (PISA) in 2015 will be implemented in a computer format (OECD, 2013). The activity begins by putting some objects into water and asking the students to predict which ones will either sink or float. Next, the students are asked to propose possible factors that determine whether each object will sink or float. These possible factors include mass, volume, and material (among others). Then, the students do an experiment using a computer simulation called PhET (University of Colorado, 2013) to test their idea of each possible factor. Once the students understand that mass, volume, and material all involve sinking or floating of the objects, they are asked to do an experiment whether these factors are related. The results of this experiment, with a reading about density, can lead the students to understanding a concept of density. Then, the students are asked to do experiments to investigate (1) whether an object's density is a factor determining that it will sink or float in water and (2) whether liquid's density is a factor determining that any object with sink or float in that liquid. The experiments with discussion led by the teachers will result in understanding that relative density between an object and liquid determine whether that object will sink or float in the liquid. This series of experiments is designed according to the learning progression about sinking and floating proposed by Corcoran, Mosher, & Rogat (2009: 69). Next, a concept of buoyancy force and weight is introduced. After that, the students do one experiment to investigate whether and how buoyancy force acting on an object and the object's weight determine whether the object will sink or float. This activity is consistent with what Chinn & Malhotra (2002: 207 – 209) called "Computer-Simulated Experimentation," which allows the students to learn about doing experiment such as proposing hypotheses, defining different variables, varying independent variable's value, recording dependent variable, controlling extraneous variables, analyzing data, and making conclusions.

The Volume Missing Activity corresponds to the National Science Curriculum Standards at seventh grade level, which expects students to understand that *"when substances dissolve, their mass does not change but physical properties (e.g., their volume) can change"* (Bureau of Academic Affairs and Educational Standards, 2010: 48). This activity provides the students to learn that *"scientific experiments begin with scientific questions, which are followed by conjecturing about their answers. Then, scientists design experiments in order to test whether those answers are possible. If some answers are supported by evidence (i.e., experimental results), they gain more acceptance. But if not, they are ignored or even abandoned."* (Bureau of Academic Affairs and Educational Standards, 2014: i). The activity begins with a demonstration that mixing between 50 ml^3 of water and 50 ml^3 of alcohol before asking the students what the net volume of the mixed liquid is. As can be seen by the demonstration, the students know that the net volume of the mixed liquid is lesser than 100 ml^3 (about 97 ml^3). Then, the students are asked to explain why the mixed liquid has the net volume lesser than the sum of the original volume of each liquid. According to a prior survey, some students thought that water and/or alcohol disappear by evaporating into the air or by spilling out the containers while some students thought that water and alcohol do not disappear. Other causes (e.g., difference between water's and alcohol's density and/or dissolving between water and alcohol) make the net volume of the mixed liquid lesser than 100 ml^3. After proposing possible causes, the students have to design and conduct an experiment to verify their idea or falsify that of others. In doing so, scientific instruments such as beakers, cylinders, stirring rods, a digital balance, and some substances (including water and alcohol) are provided. By weighting the mixed liquid and comparing with the sum weights of water and of alcohol, the students know that even though the net volume of the mixed liquid decreases, weight (and also mass) of water and of alcohol stay constant—nothing disappears. This result leads the students to ignoring the liquid-disappear hypothesis, and focusing more on the dissolving hypothesis. In order to explain this volume-missing phenomenon, the students are presented with an analogy by pouring salt powder from a cylinder into another cylinder containing green beans (V. radiata). As the students measure and record weight and volume of salt powder and those of green beans before mixing both, the students know that, when compared to the sum of their original values, the net mass stays constant while the net volume decreases. As this analogy is similar to what happens when mixing water and alcohol, it can be a particulate model for the students to explain why the net volume of the mixed liquid lesser than 100 ml^3.This activity is consistent with what Chinn & Malhotra (2002: 206 – 207) called "Hands-On Inquiry," which allows the students to use scientific instruments to do experiments to verify and/or falsify ideas.

These learning activities were developed by collaboration among 4 science educators from universities, 2 science educators from a government institute, 2 science supervisors, and 31 science teachers around the countries. These participants worked together in 2 successive workshops during 14 – 18 May 2014 and 25 – 27 July 2014 respectively. In the first workshop, the participants selected appropriate content at the lower secondary levels according to the National Science Curriculum Standards (Bureau of Academic Affairs and Educational Standards, 2010), aspects of scientific inquiry (Lederman *et al*., 2014), and types of learning activities (Chinn & Malhotra,

2002) to be emphasized. They also crafted how each activity would flow. As a result, activity drafts and instructional materials were developed. In the second workshop, the participants reviewed their activity drafts and instructional materials in terms of content correction, activity flow continuity, and developmental ideas. Each activity was tried out by some of the teacher participants with their students in their classrooms. Feedbacks after trying the activities out were discussed online through a closed group on Facebook. According to this discussion, minor changes were made.

3. Research Methods

As the implementation of the learning activities in this project was launched in a traditional four-day workshop in order for teachers and supervisors, who were selected and assigned by their affiliation to attend the workshop, to learn and disseminate the learning activities to their peers in the local communities, it was unlikely for the researchers to assign a half of them to be an experimental group and another half of them to be a controlled group—all of them had to engage in the learning activities. It was also unlikely for the researchers to recruit another group of teachers and supervisors, who are as same as or even similar to the teachers and the supervisors, to be a controlled group because of limited budget. As a result, a true experimental design was not possible under these conditions. Thus, a pre-experimental design (Cohen, Manion, & Morrison, 2000: 212) seems to be appropriate for this research as it aimed at assessing the workshop participants' scientific literacy before and after engaging in the learning activities (Chandrapatya, 1988). This research was designed and implemented in the format of a one-group pretest-posttest design (Cohen *et al*., 2000: 212) where the participants who attended the workshop completed a pretest before and a posttest after the implementation of the learning activities. Although a pre-experimental design would provide research results less validity and reliability than those of a true experimental design, it was more practical and appropriate in the real situation of this research (Choochom, 2009).

The workshop was launched during 29 August – 1 September 2014 at a local hotel in Chiang Mai, Thailand. The workshop participants included overall 120 science teachers and supervisors who were from 60 educational area offices (two persons for each area). Most of the participants (102) were representatives of the educational area offices at elementary level, which had extended their service into lower secondary level so-called extended-opportunity schools, while the remaining participants (18) were representatives of secondary educational area offices. In this workshop, the participants attended an introductory lecture about the rational of the project, which was followed by a pretest about scientific literacy. Next, the participants engaged in the learning activities respectively in the role-play format. In doing so, the participants acted as students while the instructors (i.e., the activity developers) acted as teachers. After completing all the learning activities, there was a closing lecture to summarize the emphasis of each activity as well as what needs to be done for dissemination. This was followed by a posttest about scientific literacy and then a questionnaire to explore the participants' opinions about the learning activities. Since the pretest, the posttest, and the questionnaire were sent to the participants in different periods of time, the number of the participants who completed and sent the pretest, the posttest, and the questionnaire back to the researchers were different. Some participants denied doing the pretest and the posttest. Moreover, some of them came to the workshop quite late because they were from long-distance provinces while some participants went out the workshop as soon as they completed the learning activities without completing the posttest and the questionnaire.

Data in this research were collected using the pretest and the posttest about scientific literacy, which were translated and adapted from those of Fives, Huebner, Birnbaum, & Nicolich (2014). Both the pretest and the posttest were constructed and proved to be equal in terms of content validity, reliability, and difficulty. Each test consists of 26 four-choice questions focusing on aspects of scientific literacy, which include (1) the role of science, (2) scientific thinking and doing, (3) science and society, (4) science media literacy, and (5) mathematics in science. These tests were used in this research for some reasons. Firstly, the tests were designed for assessing students at lower secondary levels at which the participants are responsible to teach (for the teachers) or to supervise the teachers (for the supervisors). Secondly, the tests were designed to be used without or with little requirement of content knowledge background on part of the participants. Thirdly, the tests were in a multiple choice format, which is easy to govern in a short period of time—that is, it could help provide the participants feedbacks about their scientific literacy. In doing so, the participants used 30 – 40 minutes to complete each test.

Data were analyzed using the SPSS program to determine mean, standard deviation, and t-test. Dependence t-test analyses were done to (1) compare the teachers' mean scores on the pretest and the posttest and to (2) compare the supervisors' mean scores on the pretest and the posttest while independence t-test analysis was done to (3) compare the teachers' and the supervisors' mean scores on the sum of both the pretest and the posttest. For all analyses, the statistical significance at .05 was considered as appropriate because of the nature of a traditional one-shot workshop, as each participant group was large (8 – 10 persons per each group; for overall groups were 15) who varied by age, teaching experience, content background. Moreover the workshop content was inevitably condensed into four days, leaving little time for questioning and answering.

4. Research Results

The initial data analysis revealed that there were 80 (66.7%) and 74 (61.7%) participants who completed the pretest and the posttest respectively. As previously mentioned, this was because some of the participants denied doing the pretest and the posttest. Moreover, some of the participants came to the workshop quite late while some of them went out the workshop room too early. This was uncontrollable because these participants had a long-distance transportation between their provinces and the hotel. All the research results are presented as follows.

4.1 Research Objective 1: Comparing the teachers' mean score on the pretest and that on the posttest.

In order to compare the teachers' mean scores on the pretest and the posttest using a paired-sample t-test, the researchers selected only data from the teachers who completed both the pretest and the posttest, resulting in data from 47 teachers. These teachers got the mean score on the pretest about 19.26 (74.1%) with standard deviation at 2.90 and received the mean score on the posttest about 20.89 (80.3%) with standard deviation at 2.48 as shown in Figure 1. The pair-sample t-test analysis revealed that these teachers' mean score of the pretest and that of the posttest are significantly different at .05 (Sig = .001) as shown in Table 1. In other words, this shows that these teachers performed better on the posttest than on the pretest.

Figure 1: The teachers' mean scores on the pretest and on the posttest.

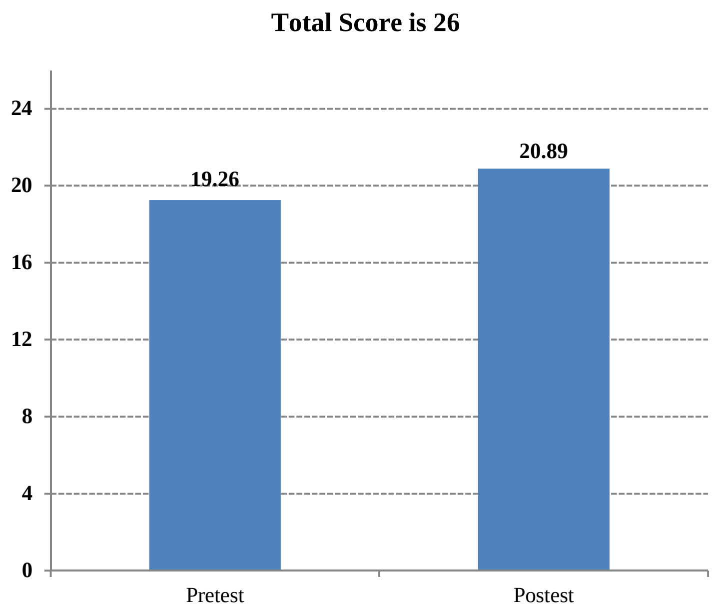

Table 1: Result of comparing between the teachers' mean score on the pretest and that on the posttest.

	Paried Differences					t	df	Sig (2-tailed)
				95% confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pretest - posttest	-1.638	3.053	.445	-2.535	-.742	3.678	46	.001

4.2 Research Objective 2: Comparing the supervisors' mean score on the pretest and that of the posttest.

Like the analysis of the teachers' mean scores on the pretest and the posttest, the researchers selected only data from the supervisors who completed both the pretest and the posttest, resulting in data from 27 supervisors, to be analyzed using a paired-sample t-test. These supervisors got the mean score on the pretest about 17.93 (67.0%) with standard deviation at 3.26 and received the mean score on the posttest about 19.11 (73.5%) with standard deviation at 3.38 as shown in Figure 2. The pair-sample t-test analysis revealed that these supervisors' mean score of the pretest and that of the posttest are significantly different at .05 (Sig = .047) as shown in Table 2. In other words, this shows that these supervisors performed little better on the posttest than on the pretest.

Figure 2: The supervisors' mean scores on the pretest and on the posttest.

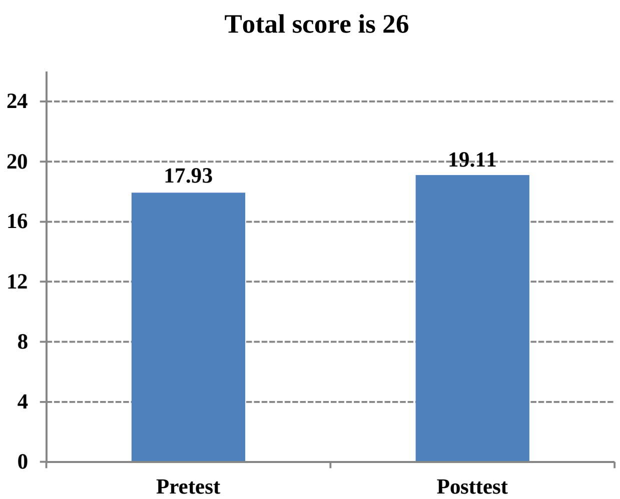

Table 2: Result of comparing between the supervisors' mean score on the pretest and that on the posttest.

	Paried Differences					t	df	Sig (2-tailed)
				95% confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pretest - posttest	-1.185	2.949	.567	-2.352	-.019	-2.088	26	.047

4.3 Research Objective 3: Comparing the teachers' and the supervisors' mean score on the sum of both the pretest and the posttest.

In order to compare the teachers' and the supervisors' mean scores on scientific literacy regardless the pretest or the protest, the researchers decided to collectively analyze data from both the pretest and the posttest using an independent-sample t-test. This was because all the participants experienced the same learning activities during the same period of time. Thus, there was no need to separately analyze their scores either on the pretest or on the posttest. As a result, the data set included 96 test scores (both the pretest and the posttest) completed by the teachers and 85 test scores (both the pretest and the posttest) completed by the supervisors. The teachers' mean score was about 20.11 (77.3%) with standard deviation at 2.79 while the supervisors' mean score was about 18.34 (70.5%) with standard deviation at 3.38 as shown in Figure 3. The independent-sample t-test analysis revealed that the teachers' mean score is significantly different from that of the supervisors at .05 (Sig = .017) as shown in Table 3. In other words, this shows that, when considering the sum of the scores on the pretest and the posttest, the teachers performed better than the supervisors.

Figure 3: The teachers' and the supervisors' mean scores on the sum of the pretest and the posttest.

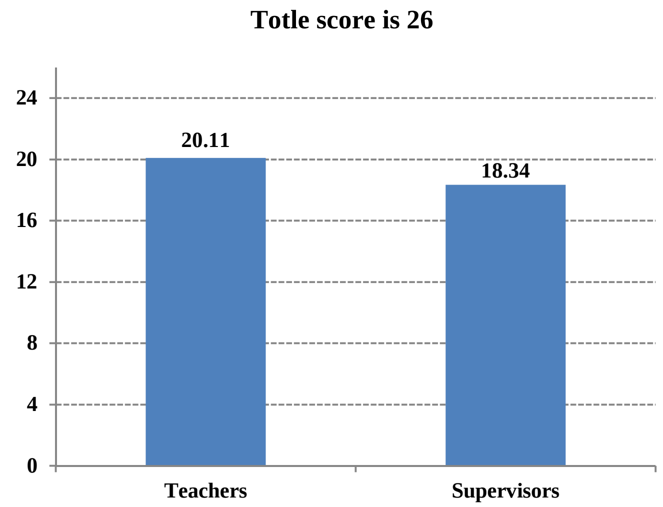

Table 3: Result of comparing between the teachers' and the supervisors' mean scores.

	Levene;s Test for Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig	t	df	Sig (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	5.873	.017	3.513	152	.001	1.770	.504	.774	2.765
Equal variances not assumed			3.351	103.109	.001	1.770	.528	.772	2.817

5. Conclusion

This research aimed at (1) comparing science teachers' scientific literacy before and after the implementation of the learning activities, (2) comparing supervisors' scientific literacy before and after the implementation of the learning activities, and (3) comparing science teachers' and supervisors' scientific literacy. The participants were overall 120 teachers and supervisors who attended a traditional four-day workshop lunched for implementing six learning activities with emphases on authentic scientific inquiry namely (1) Global Warming, (2) Finch Puzzle, (3) Origin of the Moon, (4), Tides, (5) Sink and Float, and (6) Volume Missing. These participants were from educational area offices at both elementary and secondary levels from all provinces in the northern region of Thailand.

The research instruments consisted of a pretest and a posttest aimed at measuring scientific literacy developed by Fives *et al*. (2014). The pretest and the posttest each consisted of 26 four-choice questions, focusing on (1) the role of science, (2) scientific thinking and doing, (3) science and society, (4) science media literacy, and (5) mathematics in science. Both tests were constructed and proved to be equal in terms of content validity, reliability, and difficulty. Data were analyzed using t-test with the SPSS program.

The research results show that (1) the teachers' mean score on the pretest is significantly higher than that of the posttest at .05, (2) the supervisors' mean score on the pretest is significantly higher than that of the posttest at .05, and (3) the teachers' mean score on the sum of the pretest and the posttest is significant higher than that of the supervisors at 0.05. These research results indicate that, if the learning activities focusing on authentic scientific inquiry were carefully developed and implemented by engaging the learners to think, do, discuss, and reason as close as ways scientists actually do (Chinn & Malhotra, 2002), they can facilitate development of the learners' meaningful learning about science (Minner *et al*., 2010). As the ability to engage in scientific inquiry (both doing by themselves and evaluating those of others) is a component of scientific literacy (OECD, 2013), the learning activities in this project can help the learners develop their scientific literacy.

The results of this research support Chinn & Malhotra's (2002) claim that science learning activities should contain some degree of complexity that allows the learners to think conceptually. Given an experimental question, for example, students can learn to design and conduct a scientifically acceptable experiment to answer that question. Given a scientific question with a set of evidences, students can learn to use those evidences to construct an explanation addressing the question. Given a set of theoretical ideas with some evidence, students can learn to evaluate and justify consistency between both in order to decide which theoretical idea would be most valid according to the given evidence. Given a scientific question with a set of complex data, students can learn to use their creativity to manipulate and analyze the data to answer the question. All of these allow students to simultaneously engage in both theoretical thinking and empirical consideration, which can be seen as "dual space search" (Klahr & Dunbar, 1988) that facilitates deep learning.

However, a research's results (McConnet, Oliver, Woods-Conney, Schibeci, & Maor, 2014) suggest that it is not always that students who "often" experienced doing scientific inquiry would have high achievement in scientific literacy assessments like PISA. This research shows that even some students who had "less often" experiences doing scientific inquiry performed better on PISA that those who have "less often" experiences doing scientific inquiry. This result clearly contradicted to that of this study. As "*not all inquiry is created equal*" (McConnet *et al*., 2014: 978), one possible explanation is that "quantity" of experiences doing scientific inquiry may not a good predictor of how well an individual performs in a scientific literacy assessment, but "quality" of those could be. Thus, even though students have often experienced some so-called inquiry learning without emphasis on do "scientifically," those learning experiences may not help develop their scientific literacy.

One interesting result of this research is that the supervisors who are supposed to supervise the teachers performed worse than the teachers themselves. Since, according to the researcher's literature review, there is no appearance of researches examining Thai supervisors' scientific literacy, it is necessary to make conjectures to explain this interesting result. One possible explanation is that many of the supervisors attending the workshop do not have background in science, but unfortunately they are assigned by their educational area offices to be responsible to working on the field of science education. Another possible explanation is that, despite having background in science, many of the supervisors have been concentrating on educational management and administration, leaving a focus on science teaching and learning, scientific inquiry, and scientific literacy far less important. This interesting result make a question come into the fore: Whether and how these supervisors can supervise their local teachers about teaching and learning science in general as well as scientific inquiry and scientific literacy in particular.

6. Acknowledgements

This research shows that the scientific inquiry learning activities can facilitate the development of the teachers' and the supervisors' scientific literacy. It is thus important to support and promote teachers to use these learning activities. In doing so, the teachers can use and adapt these learning activities in their own context with their own students. However, since students at lower secondary levels could have weaker background in science than their teachers and supervisors, it is very important to investigate further that whether and how the students could develop their scientific literacy after engaging in these learning activities as well. Moreover, the researchers agree with Keys & Bryan's (2001) suggestion that teachers should have opportunities to design and develop their own lessons, which in this case focus on scientific inquiry. This is because developing a learning activity for the teachers to follow is at best a short-term solution. It is believed that a more sustainable solution could be facilitating the teachers to create scientific-inquiry lessons for their own uses. This would foster a successful reform of Thailand's science education in the long term.

As scientific inquiry can be both "means" and "end" of teaching and learning science (Abd-El-Khalick *et al*., 2004) in that students can use scientific inquiry as a means to achieve some particular instructional goals such as understanding of scientific concepts, mastering scientific process kills, having scientific attitude, and so on while scientific inquiry can and should be an instructional goal by its own right, this research did not examine whether the participants had developed their content knowledge, scientific process skills, and other learning goals. A very short duration of the workshop did not allow doing so. Therefore, future research should focus more on this issue. Moreover, the future research should investigate whether and to what extent these participants' scientific literacy will retain after a period of time.

It is interesting to say the fact that supervisors normally have more experiences in attending in workshops about teaching and learning science than typical teachers since the supervisors are supposed to learn and then disseminate what they have learned to their local teachers. However, this is shown that the supervisors participating in this research perform on scientific literacy tests worse than the teachers do. Among a huge and long effort of supporting and promoting inquiry-based instruction to achieve scientific literacy (Bureau of Academic Affairs and Educational Standards, 2010; Supasorn,2011; Ketsing & Roadrangka, 2010; 2011; Faikhamta, 2008; Pongsophon, 2009; Musikul, 2007; Bongkotphet & Roadrangka, 2010; Liangkrilas & Yutakom, 2010), supervisors become another target, besides science teachers, that needs to learn more about scientific inquiry, nature of science, and scientific literacy. A following question is that what real causes make this result happen. Perhaps, in-depth researches on supervisors about their background, practices, obstacles of those practices, and perceptions of ways to overcome those obstacles are needed. Since supervisors' work is different from that of teachers, they may perhaps need professional development different from that of teachers.

References

Abd-El-Khalick, F., Boujaoude, S., Duschl, P., Lederman, N. G., Mamlok-Naaman, R., Hofstein, A., Niaz, M., Treagust, D., & Tuan, H. (2004). Inquiry in Science Education: International Perspectives. *Science Education*. 88(3), 397 – 419.

Abd-El-Khalick, F. & Lederman, N. G. (2000). Improving Science Teachers' Conceptions of Nature of Science: A Critical Review of the Literature. *International Journal of Science Education*, 27(7), 665 – 701.

Anderson, R. D. (2002). Reforming Science Teaching: What Research Says about Inquiry. *Journal of Science Teacher Education*. 13(1), 1 – 12.

Bingle, W. H., & Gaskell, P. L. (1994). Scientific Literacy for Decision Making and the Social Construction of Scientific Knowledge. *Science Education*. 78(2), 185 – 201.

Bloome, D., Puro, P., & Theodorou, E. (1989). Procedural Display and Classroom Lessons. *Curriculum Inquiry*. 19(3), 265 – 291.

Boag, P. T., & Grant, P. R. (1981). Intense Natural Selection in a Population of Darwin's Finches (*Geospizinae*) in the Galapagoa. *Nature*. 214(2), 82 – 85.

Bongkotphat, T., & Roadrangka, V. (2010). Sixth Grade Science Teachers' Knowledge/Belief of Inquiry-Based Astronomy Teaching. *Journal of Social Sciences and Humanities, Mahasarakham University*,29(3), 85 –97. (in Thai)

Bongkotphat, T., Roadrangka, V., & Panacharoensaward, B. (2009). The Study of the State of Teaching and Learning Science of Sixth Grade Elementary Science Teachers in Schools under the Bangkok Metropolitan Administration. *KKU Research Journal*, 14(4), 346 – 359. (in Thai)

Britt, R. R. (2006). *Pluto Demoted: No Longer a Planet in Highly Controversial Definition*. Retrived November 11, 2014, from http://www.space.com/2791-pluto-demoted-longer-planet-highly-controversial-definition.html.

Bureau of Academic Affairs and Educational Standards. (2010). *Indicators and Core Learning Content in Science According to the 2008 National Science Curriculum Standards*. Bangkok: The Press of the Agricultural Co-operative Federation of Thailand. (in Thai)

Bureau of Academic Affairs and Educational Standards. (2014). *Learning Activities with Scientific Inquiry*. Bangkok: Aksornthai Press. (in Thai)

Bybee, R. W., Taylor, J. A., Gadner, A., Scotter, P. V., Powell, J. C., Wesbrook, A., & Landes, N. (2006). *The BSCS 5E Instructional Model: Origin, Effectiveness, and Applications*. Retrieved April 4, 2014, from http://bscs.org/sites/default/files/_legacy/BSCS_5E_Instructional_ModelExecutive_Summary_0.pdf

Chaiyen, Y., Bunsawansong, P., & Yutakom, N. (2007). Integrated Science Process Skills on Chemical Equilibrium of High School Students from Schools in Chanthaburi Province. *Kasetsart Journal (Social Sciences)*,28 (1), 11 – 22. (in Thai)

Chamrat, S., Yutakom, N., &Chaiso, P. (2009). Grade 10 Science Students' Understanding of the Nature of Science .*KKU Research Journal*. 14(4), 360 – 374. (in Thai)

Chandrapatya, S. (1988). The Use of the One-Group Pretest-Posttest Design for the Evaluation on Skills Learning of Participants. *The 26th Academic Conference of Kasetsart University*, 3 – 5 February 1988. Bangkok: Kasetsart University. (in Thai)

Chinn, C. A., & Malhotra, B. A. (2002). Epistemologically Authentic Inquiry in Schools: A Theoretical Framework for Evaluating Inquiry Tasks. *Science Education*. 86(2), 175 – 218.

Choochom, O. (2009). Quasi-Experimental Research. *Journal of Behavioral Science*, 15(1), 1 – 15. (in Thai)

Cohen, L., Manion, L., & Morrison, K. (2000). *Research Methods in Education*. (Fifth Edition). London: RoutledgeFalmer.

Corcoran, T., Mosher, F. A., & Rogat, A. (2009). *Learning Progressions in Science: An Evidence-Based Approach to Reform*. Center on Continuous Instructional Improvement: Teachers College-Columbia University.

Dahsah, C., & Faikhamta, C. (2008). Science Education in Thailand: Science Curriculum Reform in Transition. In R. K. Coll & N. Taylor. (Eds). *Science Education in Context: An International Examination of the Influence of Context on Science Curricula Development and Implementation* (pp. 291 – 300). Rotterdam: Sense Publishers.

DeBoer, G. E. (2000). Scientific Literacy: Another Look at Its Historical Contemporary Meanings and Its Relationship to Science Education Reform. *Journal of Research in Science Teaching*, 37(6), 582 – 601.

Faikhamta, C. (2008). Inquiry-Based Teaching and Learning. *Journal of Education, Naresuan University*, 11(1), 31 – 45. (in Thai)

Fives, H., Huebner, W., Birnbaum, A. S., & Nicolich, M. (2014). Developing a Measure of Scientific Literacy for Middle School Students. *Science Education*. 98(4), 549 – 580.

Hodson, D. (1988). Toward a Philosophically More Valid Science Curriculum. *Science Education*, 72(1), 19 – 40.

Hurd, P. D. (1998). Scientific Literacy: New Minds for a Changing World. *Science Education*, 82(3), 407 – 416.

Kang, H., Thompson, J. & Windschitl, M. (2014). Creating Opportunities for Students to Show What They Know: The Role of Scaffolding in Assessment Tasks. *Science Education*, 98(4), 674 – 704.

Keys, C. W. & Bryan, L. A. (2001). Co-Constructing Inquiry-Based Science with Teachers: Essential Research for Lasing Reform. *Journal of Research in Science Teaching*, 38(6), 631 – 645.

Ketsing, J. & Roadrangka, V. (2010). A Case Study of Science Teachers' Understanding and Practice of Inquiry-Based Instruction. *Kasetsart Journal (Social Sciences)*, 31(1), 1 – 16. (in Thai)

Ketsing, J. & Roadrangka, V. (2011). Inquiry-Based Instruction for Science Teaching. *Journal of Social Sciences and Humanities, Makasarakham University*, 30(1), 84 – 105. (in Thai)

Klahr, D. & Dunbar, K. (1988). Dual Space Search during Scientific Reasoning. *Cognitive Science*, 12(1), 1 – 48.

Kolsto, S. D. (2001). Scientific Literacy for Citizenship: Tools for Dealing with the Science Dimension of Controversial Socioscientific Issues. *Science Education*, 85(3), 291 – 310.

Ladachart, L. Suttakun, L., & Faikhamta, C. (2013). A Critical Difference Between the Promotion of "Nature of Science" Instruction Outside and Inside Thailand. *Kasetsart Journal (Social Sciences)*, 34(2), 269 – 282. (in Thai)

Laugksch, R. C. (2000). Scientific Literacy: A Conceptual Overview. *Science Education*, 84(1), 71 – 94.

Lederman, J. S., Lederman, N. G., Bartos, S. A., Bartels, S. L., Meyer, A. A., & Schwartz, R. S. (2014). Meaningful Assessment of Learners' Understandings about Scientific Inquiry—The Views about Scientific Inquiry (VASI) Questionnaire. *Journal of Research in Science Teaching*, 51(1), 65 – 83.

Liangkrilas, J. & Yutakom, N. (2010). Case Study: Perception among Biological Teachers of an Inquiry-Based Approach to Teaching and Teaching Practices. *Journal of Social Sciences and Humanities, Mahasarakham University*, 29(4), 23 – 37. (in Thai)

Mahalee, K. & Faikhamta, C. (2010). The Seventh Grade Students' Understandings of Nature of Science. *Songklanakarin Journal of Social Sciences and Humanities*, 16(5), 795 – 809. (in Thai)

McConney, A., Oliver, M. C., Woods-McConney, A., Schibeci, R., & Maor, D. (2014). Inquiry, Engagement, and Literacy in Science: A Retrospective, Cross-National Analysis Using PISA 2006. *Science Education*, 98(6), 963 – 980.

Minner, D. D. Levy, A. J., & Century, J. (2010). Inquiry-Based Science Instruction—What Is It and Does It Matter? Results from a Research Synthesis Years 1984 – 2002. *Journal of Research in Science Teaching*, 47(4), 474 – 496.

Musikul, K. (2007). Teaching and Learning through Scientific Inquiry. *IPST Journal*, 65(149), 36 – 37. (in Thai)

Nakthong, U., Anuntasethakul, T., & Yutakom, N. (2009). Science Process Skills of Grade 10 Students Related to Cells and Cell Processes. *Songklanakarin Journal of Social Science and Humanities*, 13(3), 383 – 394. (in Thai)

Northwestern Univeristy. (2009). *The Galapagos Finches*. Retrieved November 5, 2014 from http://bguile.northwestern.edu/

National Institute of Educational Testing Service (Public Organization) [NIETS]. (2012). *Research and Academic*. Retrieved March 11, 2014 from http://www.niets.or.th/ (in Thai)

Organisation for Economic Cooperation and Development [OECD]. (2013). *PISA 2015: Draft Science Framework*. Retrieved March 11, 2014 from http://www.oecd.org/pisa/pisaproducts/Draft%20PISA%202015%20Science%20Framework %20.pdf

Pongsophan. P. (2009). Teach Science as Science Is. *Journal of Science*, 63(1), 84 – 89. (in Thai)

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a Scientific Conception: Toward a Theory of Conceptual Change. *Science Education*, 66(2), 211 – 227.

Ruzhitskaya, L. & Montfrooij, W. (2011). Teaching Gravity and Tides: Use Textbooks, Simulations or Videos? *Earth and Space Science: Making Connections in Education and Public Outreach, ASP Conference Series*, 443, 481 – 485.

Supasorn, S. (2011). Science Inquiry Process in High School Chemistry Experiments: A Review of Science Education Research Studies from Ubon Ratchathani University. *Journal of Education, Prince of Songkla University (Pattani Campus)*, 22(3), 331 – 343. (in Thai)

University of Colorado. (2013). PhET: Free Online Physics, Chemistry, Biology, Earth Science and Math Simulations. Retrieved November 6, 2014 from https://phet.colorado.edu

Viiri, J. (2000). Students' Understanding of Tides. *Physics Education*, 35(2), 105 – 110.

Yuenyong, C. & Narjaikaew, P. (2009). Scientific Literacy and Thailand Science Education. *International Journal of Environmental and Science Education*, 4(3), 335 – 349.