The Impacts of Inquiry-Based Learning Model on Teaching Science Subject: A Case Study in Thailand

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ABSTRACT  
The study aimed to examine the impacts of inquiry-based learning model utilizing the structured, guided and open inquiry on students’ problem-solving skills, science process skills, and scientific attitudes. A total of 68 Grade 12 students were selected as respondents. One group non-experimental design was employed. The impacts of the inquiry-based learning model were reflected in the paired t-test results and the improvement in their science projects. Finally, the findings from teachers’ reflections on each of the inquiry approach were found to be effective to encourage students’ independent study as well as improve their abilities in science literacy.

Key Words: Inquiry based learning, science, learning models

INTRODUCTION  
Inquiry learning is a teaching method emphasizing on students actively develop their knowledge which is not directly transmitted from their teachers and it is compatible with the constructivist approach. Friesen (2009) emphasized that current teachers are facing more challenging teaching method due to the former concepts of knowledge, minds, and learning styles are longer relevant and they must work in different contexts. This is because teachers have to design their teaching practices focus on engaging students in both academically and intellectually by providing sufficient learning opportunities. As a result, Thailand Institute for Promotion of Teaching Science and Technology (2011) had highly emphasized learners’ knowledge, thinking process, inquiry process, problem-solving, communication ability, decision making, and ability to apply the knowledge in their daily lives. This is aimed to train students to have the scientific mind, ethics, and appropriate. Thus this issue has been stated in Thailand science curriculum manual. According to National Research Council (NRC) (2000), inquiry-based learning is depending on the amount of autonomy provided to students and covers an extensive range of approaches, stretching from teacher-directed structured and guided inquiry to student self-regulated open inquiry. In other words, inquiry-based learning is an approach that places students’ questions, ideas, and observations at the center of the learning process (Scardamalia, 2002). Teachers play an active role throughout the learning process by establishing a classroom culture where students’ ideas are respectfully challenged, tested, redefined and viewed as improvable, moving students from a position of wondering to a position of enacted understanding and further questioning (Scardamalia, 2002). Consequently, both teachers and students share the responsibility for learning is the underlying principle in inquiry-based learning approach.

Zion and Mendelovicci (2012) identified the inquiry-based learning into three levels, namely structured, guided, and open inquiry. In structured inquiry approach, students do not need to think autonomously due to the questions, processes, and results are designed through a prescribed procedure by teachers. Therefore structured inquiry is suitable to develop students’ basic inquiry skills but not sufficient to appreciate the real nature of science. In guided inquiry, although teacher provides students with questions and procedure but students have to explore and find the solutions by themselves. In short, students have to lead the inquiry process that involving decision-making and come up with their own conclusion. Open inquiry is considered as the most intricate level of inquiry-based learning which creates a learning community of teachers and students. Students need to perform like scientists and requires high order thinking abilities (Reid & Yang, 2012).

Inquiry-based learning has its potential to promote students’ intellectual engagement and foster their understanding through a hand-on, minds-on, and research-based disposition towards teaching and learning particularly in the science subject. On top of that, inquiry-based learning also creates a complex, interconnected
nurture of knowledge creation, enables teachers and students to build, test, and reflect collaboratively on their learning (Stephenson, n.d.). Stephenson further highlighted that the inquiry-based learning is an umbrella term that covers a number of other approaches to teaching and learning. Teaching practices that utilize a disposition of inquiry learning include project-based learning, design-based learning, and guided inquiry learning. In reality, teachers have to face several challenges such as knowledge is necessary for participation, basic science skills needed, cultural mismatch, excessive individualism, and lack of experiences to draw upon while implementing inquiry-based learning (Hirsch, 2006; Delpit, 2006). Knowledge is the basic requirement for inquiry-based learning because students need sufficient knowledge to pursue an investigation based on the immediate situation and personal experience (Hirsch, 2006). Hence, teachers have to ensure students have sufficient knowledge before they are able to participate fully in the classroom practices. Besides, a related point that challenging teachers is the inquiry-based learning should lead to the science skills development. Delpit (2006) clarified that inquiry-based learning will only work for some students but not others especially those from marginalized groups who need access to the societal codes of knowledge in a more direct approach. The importance of experiences in inquiry-based learning implies that teachers have to find ways to incorporate richer experiences into learning. As a result, teachers have to encourage students to critically engage with books, websites, and ideas to extend their world. Another method is teachers have to organize field trips, service learning or nature study to expand their direct experiences. All these tasks seemed to be heavy workload to the teachers.

Thailand science education aimed to align science curriculum to be relevant to students' real life experience. Since science subject is a compulsory subject in Thailand Education System from Grade 1 to Grade 12, students are expected to reach common scientific literacy as indicated by Yuanyong and Narjaikaew (2009). Yuanyong and Narjaikaew highlighted the basic scientific literacy: Firstly, students hold an understanding of scientific knowledge and the relationship between science, technology, society, and environment. Secondly, students have scientific habits and guided inquiry-based learning helps students learn science content, master scientific skills, and understand the nature of scientific knowledge. Moreover, Trautmann, MaKinster, and Avery (2004) revealed that the structured and guided inquiry approach prevents wasting of learning time, reduces students’ frustration of the undesirable results or experiencing failure as well as their fear of unknown.

Besides, past research findings indicated that open inquiry approach is an effective method to achieve a higher level of inquiry whereby students become accustomed to the nature of scientific knowledge, develop greater inquiry skills and practices, and employ in higher order thinking (Berg, Bergendahl, Lunberg & Tibell, 2003; Chinn & Mahlhotra, 2002; Krystyniak & Heikkinen, 2007). Moreover, Jordan, Rubal-Villasenor, Hmelo-silver and Etkina (2011), and Zion and Slezak (2005) found that student’s functioning is closely related to teacher’s determinations to assist the student’s scientific literacy, creativity, initiative, responsibility, and motivation.

Tatar, Tüysüz, Tosun, and Ilhan (2016) had used Questionnaire of Factors Affecting Students’ Science Achievement (QFASSA) to examine the influencing factors to a total of 606 science program university students from four state universities in Turkey. Their results showed that the most significant factors that affecting students’ achievement are teacher and curriculum dimensions. Furthermore, Tatar et al. indicated that the most significant predictor is ‘teaching the topics in a way that may arouse the students’ curiosity’ as one of the teacher dimensions. Tatar et al.’s findings were supported by Wolpert-Gawron (2016) who stated that inquiry-based learning is more than asking a student what he or she wants to know. It is about triggering curiosity as well as activating his or her curiosity.

Harris and Rooks (2010) investigated on the effective method to organize inquiry-based science learning in K-8 science classroom to cause extensive changes in classroom management practices. Harris and Rooks introduced a pyramid model about how the five interconnected management areas namely students, instructional materials, tasks, science ideas, and the overall social context of students’ inquiry learning environment work together in such a way that the effectiveness of any of them is influenced by how the other management areas are managed. In addition, Harris and Rooks also proposed a close-knit relationship between management and instruction to recognize the prevalent nature of managing the classroom for effective inquiry learning.
Sungur, Tekkaya, and Geban (2006) had studied the effect of problem-based learning to 10th grade students’ academic achievement and performance skills. A total of 61 students from two classes which instructed by the same biology teacher were involved in their study using Motivated Strategies for Learning questionnaire. Sungur et al.’s results showed that students instructed with problem-based learning earned higher scores than those instructed with traditionally-designed biology instruction in both academic achievement and performance skills. Sungur et al. concluded that students in the experimental group seemed to be more capable in the use and organization of relevant information, in assembling knowledge and stirring toward better decision compared to the control group.

RESEARCH AIM
The main aim of this research was to investigate the impacts of the developed structured to open inquiry learning activities as an inquiry-based learning on students’ learning outcomes particularly on problem-solving competency, science process skills, scientific attitudes.

METHOD

Research design and samples
One group non-experimental design was utilized. There was only a single group of 68 Grade 12 students from Koksi Pittayasan School in Northeast of Thailand who enrolled the science project class in the first semester of 2015 academic year were purposively selected in this study. Researchers created a treatment condition involving three phases namely structure inquiry approach, guided inquiry approach, and open inquiry approach and this single group of students was observed. The pretest-posttest design involves two measurements of the 68 participants were applied before and after the treatment surrounding in time the administration or occurrence of a single treatment that is structured to open inquiry approach. In this design, participants serve as their own control and comparisons are made before and after treatment. An assumption is made that differences between pretest and posttest are due to the treatment.

The overall intervention treatment was taken place for 20 weeks, two hours per week. Structured inquiry approach was applied in the first phase for the duration of of for weeks. At this phase, researchers provided the knowledge about water quality and how to analyze water quality. This is followed by students used the knowledge to prepare a structured science project entitled as ‘Water quality in our school’. In the second phase, researchers utilized the guided inquiry approach for the duration of six weeks. There were two learning activities in the second phase that involving galvanic cell from the metal electrode in the chemical electrolyte and galvanic cell from fruit electrolyte as well as non-corrosion metal. Researchers provided science knowledge which was associated with each of the projects. For example, knowledge related to the components of the galvanic cell and how it works as well as the corrosion of metals and corrosion protection of metals. Participants were assigned two science projects. This first project was creation a galvanic cell from metal electrodes in the electrolyte solution and galvanic cell from fruit electrolyte. The second project was protection the iron nail from corrosion.

Open inquiry approach was used in the final phase for the duration of eight weeks, followed by two weeks presentation. In this phase, each group consisted of six to seven participants who have to define a problem for doing a science project. While participants were planning for the science project, researchers observed and recorded the following issues such as (i) Source of the issue and selection of issue to do the project; (ii) Investigation for scientific knowledge that forms the basis of a science project, knowledge linkages, applying the knowledge to plan for a science project; (iii) Defining variables, setting hypothesis, planning to do a science project; (iv) Doing a science project, recording data, and presentation; (v) Discussion and conclusion, and writing a project report.

Research instrument
Research instruments were mainly used as tests to measure learning outcomes encompassing three areas namely problem-solving competency, science process skills, and scientific attitudes. Therefore three types of tests were used to measure the three areas of learning outcomes. All the three types of tests were adapted from Tornee (2014). Specifically, Tornee had adapted his instruments from two sources namely the problem-solving competency test from Organizational for Economic Co-operation and Development OECD (2013) while the science process skill test and scientific attitudes test from Vangpoomvai (2012).

The problem-solving competency test is a 32-multiple choice items, mainly used to assess four components of problem-solving process namely exploring and understanding, representing and formulating, planning and executing, and monitoring and reflecting (OECD, 2013). The reliability (KR20) value was 0.89, discrimination
The reliability (KR20) value was 0.72. Burterm et al., (2014) reasoned, responsible and persevering, organizing and carefulness, honesty and open-mindedness.

The initial results highlight the change on problem-solving competency as 32.93 percent (85.56% - 52.63%). This is the greatest increment of the total score. The least increment of the total score is problem-solving competency as 32.93 percent (85.56% - 52.63%). This is the least increment of the total score.

In addition, findings revealed that all the three categories of ability were more than 80 percent of the total score. In addition, findings revealed that all the three categories of ability were more than 80 percent of the total score.

Data analysis
Quantitative data was analyzed by descriptive statistic using the mean score and standard deviation and inferential statistic using paired t-test. Paired t-test was used in ‘before-after’ structured to open inquiry approach. Paired t-test was identified to be suitable for this study because all the participants were matched pairs and it was considered as a case-control group. Researchers provided 40 hours of treatment that is structured to open inquiry approach for 20 weeks to the 68 Grade 12 students and followed by the investigation on the impacts of treatment related to problem-solving competency, science process skills, and scientific attitudes. On the other hand, qualitative data from observation and interviews were analyzed using content analysis.

RESULTS
Results are demonstrated according to the research aim as indicated above. The results present in two parts namely quantitative and qualitative findings. The initial results highlight the change on problem-solving competency, science process skills, and scientific attitudes of 12th Grade students before and after the intervention of structured to open inquiry approach in science learning activities. This is followed by evaluating the effectiveness of structured to open inquiry approach on the progress of Grade 12 students through feedback from teachers’ reflections. Finally, the quality of the science projects is measured from quantitative finding from rubric rating scales as well as qualitative data by interviewing three science teachers.

Findings of Paired t-Test
The descriptive statistics of pretest vs. posttest of problem-solving competency, science process skills, and scientific attitudes for the 68 Grade 12 students are presented in Table 1. Their abilities are measured based on three categories namely problem-solving competency, science process skills, and scientific attitudes. All the posttest results show an increment compared to the pretest results after utilizing structured to open inquiry approach.

In addition, findings revealed that all the three categories of ability were more than 80 percent of the total score of each posttest compared to pretests which ranged from 52.63 percent to 72.23 percent. Specifically, the greatest increment of the total score is problem-solving competency as 32.93 percent (85.56% - 52.63%). This is followed by science process skills as 23.80 percent (82.20% - 58.40%). The least increment of the total score is scientific attitudes 17.37 percent (89.60% - 72.23%). The highest standardized gain score
([posttest-pretest]/pretest SD) were science process skills, followed by scientific attitudes and problem-solving competency.

Table 1. Descriptive statistics of students’ abilities

<table>
<thead>
<tr>
<th>Abilities</th>
<th>Pretest</th>
<th>Posttest</th>
<th>% Gain</th>
<th>% SD</th>
<th>Standardized Gain Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \bar{x} )</td>
<td>SD</td>
<td>( \bar{x} )</td>
<td>SD</td>
<td></td>
</tr>
<tr>
<td>Problem-solving</td>
<td>16.84</td>
<td>2.25</td>
<td>27.38</td>
<td>2.11</td>
<td>52.63</td>
</tr>
<tr>
<td>Science process skills</td>
<td>26.28</td>
<td>1.49</td>
<td>36.99</td>
<td>2.12</td>
<td>58.40</td>
</tr>
<tr>
<td>Scientific attitudes</td>
<td>90.28</td>
<td>4.33</td>
<td>112.00</td>
<td>4.01</td>
<td>72.23</td>
</tr>
</tbody>
</table>

The assumption was made at the initial stage of the mean scores of the paired samples are equal which means that the pretest scores for each category of ability in students’ learning outcomes are equal to the posttest scores. The level of significant was identified as .05. Results of the study revealed that the mean scores between the pretest and posttest were different. Therefore, researchers rejected the initial assumption made and concluded that there was a significant mean difference between all the paired samples. In other words, all the students gained a higher score in their posttest compared to their pretest.

Table 2. Paired samples t-test

<table>
<thead>
<tr>
<th>Paired posttest-pretest</th>
<th>( \bar{x} )</th>
<th>SD</th>
<th>Std. error</th>
<th>t</th>
<th>df</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem-solving competency</td>
<td>10.54</td>
<td>1.43</td>
<td>.17</td>
<td>60.84</td>
<td>67</td>
<td>0.001</td>
</tr>
<tr>
<td>Science process skills</td>
<td>10.71</td>
<td>1.85</td>
<td>.22</td>
<td>47.64</td>
<td>67</td>
<td>0.001</td>
</tr>
<tr>
<td>Scientific attitudes</td>
<td>21.72</td>
<td>4.15</td>
<td>.50</td>
<td>43.20</td>
<td>67</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Findings of the quality of Science project

There are three sets of qualitative data to quantify in order to determine the quality of science projects. The three science teachers evaluated a total of 10 science projects separately using rubrics rating scales. The mean score was calculated to make the decision about quality ranged from very poor, poor, fair, good, and very good. The results from the rubrics evaluation were shown in Figure 1 and Table 3.

Table 3 shows the summary of the quality of science project as well as teachers’ interview data. The overall mean score was good for each component of quality science project except originality component which was at the fair level. Nevertheless, all the rubrics rating scales findings were supported by teachers’ opinions. Rubrics rating scales and interview findings were focused on six components of quality, namely 1 as originality; 2 as practicality; 3 as elaboration; 4 as multi-dimensional knowledge used; 5 as environmental friendliness, and 6 as aesthetic and attractive. In summary, the three science teachers had their desirable quality of science project but they are satisfied with the improvement shown by students.

Table 3. Quality of 10 science projects and teachers’ opinions

<table>
<thead>
<tr>
<th>Part of assessment</th>
<th>( \bar{x} )</th>
<th>SD</th>
<th>Teachers’ opinions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Originality</td>
<td>3.40</td>
<td>0.48</td>
<td>‘Students can choose the issues around the school to work as a projects.’</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>‘Their works using the scientific process to replace the local or inherent knowledge, or do as their mothers do.’</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>‘They try to find new ideas, new methods to support their science projects.’</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>‘Some are like old works, but are more variables in this time.’</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>‘They can search a relevant theory that involves variables for adding in their works.’</td>
</tr>
<tr>
<td>Practicality</td>
<td>3.70</td>
<td>0.64</td>
<td>‘Their tasks are able to be developed to be a better product.’</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>‘The project result is clear, has a quantitative result so one can further developed.’</td>
</tr>
<tr>
<td>Elaboration</td>
<td>4.00</td>
<td>0.77</td>
<td>‘They use the correct knowledge in defining the variables and design the experiment. Their works are reliable and they can do it successfully.’</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>‘They use the group process. There is a clear task assignment. It is’</td>
</tr>
</tbody>
</table>
an important factor that makes the work successful.’

<table>
<thead>
<tr>
<th>Multi-dimensional knowledge used</th>
<th>4.00</th>
<th>0.77</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Students search the science knowledge of each variable, make knowledge linkage to describe their projects.’</td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘Students apply their knowledge to be associated with the new knowledge and use the knowledge for planning the experiment.’</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Environmental friendliness</th>
<th>4.40</th>
<th>0.66</th>
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<tr>
<td>‘There are many projects that involve local participants and the community. They can use local materials and use the chemicals appropriately.’</td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘Their designs are based on their best study so they can use chemical materials and equipment efficiently, successfully.’</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Aesthetic and attractive</th>
<th>4.50</th>
<th>0.67</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Their works are attractive, look great.’</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 1: Quality of science project

Findings of the Teachers’ Reflection

This study was conducted in three phases involving three approaches namely structured inquiry, guided inquiry, and open inquiry. After completing each phase, teachers would do the reflections through their observations. The results are revealed into three parts namely teachers’ reflection after structured inquiry approach, teachers’ reflections after guided inquiry approach, and teachers’ reflections after open inquiry approach as follows:

Teachers’ reflections after structured inquiry approach indicated that students found to be understood the process of doing the science project. They understood the scientific method and practiced the science process skills by doing the structured science project that assigned to them. Students are able to do the experiment by following the lab direction.

After guided inquiry approach, teachers’ reflections revealed that students were able to use their knowledge about the galvanic cell to define the variables for making their galvanic cell by themselves. They designed the experiments by themselves. Their designs were not the same. They did the experiment, collected data, and did their projects by themselves. Because of each group selected a variety of electrodes so their results were a difference. They are able to define the dependent and independent variables. Finally, each group was successfully making the galvanic cell that produced electricity. They were very happy with their works. The same as making the galvanic cell using electrolyte solution from fruits, students are able to define different independent variables. Some students used different electrodes, the distance between electrodes, and different fruits as independent variables. However, teachers have to help them in the discussion and conclusion part. It can conclude that students can integrate relevance knowledge from textbook to define variables and to plan for doing the assigned projects by themselves except at the discussion and conclusion part that needs some assistance from teachers. Finally, students can do their two guided science projects, write reports and make the project presentations.

The proposed science projects in open inquiry approach were classified into two types. The first type was using
their ideas while the second type was adapted from other previous projects but tried to add new variable or study in another dimension. From the teachers’ reflections showed that students studied the knowledge that relevance to their variables to construct their knowledge to define the hypothesis and design the experiment. Students can do science projects. They are able to collect data, analyze, discuss, and make a conclusion by themselves.

DISCUSSION
The novel opinions on teaching and learning science are started to restructure the setting of classrooms. Therefore this research was aimed to combine the concept of outcome-based learning and the continuity of inquiry from structured through guided and open inquiry approach. Findings of this study indicated that all the three abilities namely problem-solving competency, science process skills, and scientific attitudes were improved with a higher total score of more than 80 percent. This implies that students had been provided more opportunities to practice their science process skills while they did the structured and guided science projects. Moreover, they also had to solve the real problems that occurred during the implementation of their science projects. As a result, they have been trained directly or indirectly to establish their positive scientific attitudes. This is because they have to think and act like scientists which may affect their scientific attitudes.

Science process skills have been highly emphasized particularly in a structured inquiry of learning whereby students were trained to do science project via the laboratory experiment. They learned the process and steps of doing the science project, thus practicing their science process skills while they were conducting their experiments. In addition, teachers provided information about the project as well as appropriate practices on the proposed problems while implementing guided inquiry of learning. This implies that guided inquiry learning should be considered by means of a kind of problem-solving training whereby students had to share their ideas in defining variables, design the experiments, and conduct the experiments independently. At this stage, students will be provided sufficient opportunities to design the patterns of the experiment to solve the entire question. Therefore they are trained to do science projects using problem-solving process and the scientific method.

After the students have been trained with structured and guided inquiry approach, they are able to do their independent thinking at every step of the created science process. This implies that they are able to integrate their knowledge to identify the problems. Firstly, they are able to think of the issues around their community and investigate by using their science knowledge that relevance with their science projects. Next, they are able to make knowledge linkage to identify, plan, and conduct the project successfully.

The ultimate findings are found to be in accordance with Zion and Mendelovici’s (2012) findings. Zion and Mendelovici had proposed the three levels of inquiry from structured, guided to open in teaching the biology of high school in Israel. In addition, the implication from this study has shown that structured to open inquiry approach will be very useful particularly in teaching science because this approach is found to be able to support students to construct their knowledge from their experiential learning, using their basic abilities to improve their learning science literacy.

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