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Problem-based Learning to Promote Learning Achievement and Scientific Reasoning on Fundamental Chemistry in the Topic of Chemical Reaction for the 10th Grade Students

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Abstract
The purpose of this action research aimed to promote the educational achievement and scientific reasoning ability of students in a secondary school by using Problem-based Learning in Fundamental Chemistry class in the topic of Chemical Reaction. 58 research participants were 10th grade students from a secondary school in Pathum Thani province in the first semester of the 2017 Academic year. They were selected by the cluster random sampling technique. The representative samples of students were divided into 2 groups: 28 students in the experimental group and other 28 students in the controlled group. There were three types of research instruments as follows: (1) experimental tools: seven problem-based learning lesson plans on Fundamental Chemistry in the topic of Chemical Reaction; (2) reflective tools: Student Learning Behavior Observation Form, Teaching Behavior Observation Form, Students' Opinion Questionnaire, Post-class Reflection Form, and quizzes; and (3) evaluation tools: Educational Achievement Test with reliability of 0.751 and a Scientific Reasoning Test. The data were analyzed by using t-test for Independent sample and calculated for the growth score with the relative gain score. This study showed the achievement of the experimental group was higher than that of the controlled group on Fundamental Chemistry at the significance level of .05 and the scientific reasoning of the experimental group was higher than that of the controlled group on Fundamental Chemistry at the significance level of .05.

Keywords*: Achievement, Scientific Reasoning, Problem-based Learning, Chemical Reaction*

1. Introduction

Science is playing an important part in our everyday life because the things that we use in our daily life are mostly the products of science. In addition, science can help us to develop a way of thinking reasonably, imaginarily, and analytically. It also helps develop plenty of skills such as seeking skill knowledge, systematical problems solving skills, and decision making skills. Thus, it is important for everyone to know science clearly in order to understand the nature and technology created by humans so that they can apply this knowledge reasonably, imaginatively, and morally (Ministry of Education, 2008). Nowadays, Thailand uses the basic education core from 2008 which is believe that everyone can learn and be able to develop themselves with full potential. It focuses on communicate skills, thinking skills, problems solving skills, and using technology effectively. Chemistry is one branch of science that studies substances and changes of the

matter. It will provide the basis for the further study. However, some part of basic in chemistry is intangible and hard to understand. Moreover, the information should be related reasonably so that it can lead to deeper understanding (Sutapan, 2005).

According to the results of the Ordinary National Educational Test (O-NET) of the 12th grade students in 2016 Academic year, it showed that the average of the overall score for science subject of 50 percent is lower than the standard (National Institute of Educational Testing Service: online, 2015) which was consistent with the result from Programme for International Student Assessment, known as PISA. It aims to explore the entire educational system in order to make students ready to live and participate in future society. The project evaluation showed that Thai students had the average science score of 425, 444, and 421 points during 2009 to 2015, which is lower than the OECD's standard average score of 500 points (Ministry of Education).

As a result of the evaluation project, it showed that Thai students were still lack of analytical and reasoning skills; thus, there was a possibility of reduced competitive edge of Thailand (Sudjanan, 2011). So, it could be seem that the educational management in Thailand was unsuccessful as it should be.

Studying of variety methods in educational management revealed that Problem-based Learning was an effective method in raising analytical and reasoning skills because Problem-based Learning would stimulate thoughts and problem-solving abilities. Thus, the approach turns students to be the center of education, while instructors as a learning supporter. These factors could help the learners to integrate their old and new knowledge systematically. So, learners will become autonomous when applying self-direct learning (Tantiplacheeva, 2005). Problem-based Learning, as explained by the Office of the Education Council of Thailand in 1999, consists of 6 steps; 1) setting up the problem, 2) understanding the problem, 3) researching, 4) knowledge synthesizing, 5) result conclusion and evaluation, and 6) presentation and project evaluation. Several researchers found that students who studied by using Problem–based Learning had better achievement test results, better problem solving skills in science and better attitudes toward science learning than anyone who studied by using the 5E learning cycle (Khammaneejan, 2009). This result was consistent with Laoklang's study (2015) on Problem-based Learning on the Plant Response Learning Unit. It showed higher achievement and problem solving ability in students.

Fundamental Chemistry teachers in the 10th graders in one of the schools in Pathum Thani, the research site, reported that the 10th Grade students' educational achievement in Fundamental Chemistry of 2016th Academic year, was below than the standard, especially in Chemical Reaction topic. This topic confused the students resulting in the lack of understanding in the lessons because chemical equation is a complex topic. Teachers mentioned that students could only explain the daily chemical reactions which were from the textbook, but they were unable to apply their knowledge in chemical reaction that they faced in daily life due to a lack of imagination and scientific reasoning skills. This indeed showed that they were lack of knowledge integration skill, reasoning skill and scientific method skill. Therefore, researchers were interested in using Problem-based Learning by using a problem to trigger learning in order to stimulate reasoning skills in students from information researching to make them understand the problem and provide reasonable ways to solve the problem by themselves. This method made students integrate their knowledge systematically, apply those knowledge and skills which they learnt from Problem-based Learning method in their daily life's situations.

The researcher is interested in applying Problem-based Learning for the development of educational achievement and scientific reasoning skill in order to help the

students increase skills in the scientific procedure that is useful towards the development of the country in the future.

2. Research Objectives

1. To promote the educational achievement of students in a secondary school by using Problem-based Learning in Fundamental Chemistry class in the topic of Chemical Reaction

2. To promote the scientific reasoning ability of students in a secondary school by using Problem-based Learning in Fundamental Chemistry class in the topic of Chemical Reaction

3. Research Methodology

The purpose of this research aimed to study educational achievement and scientific reasoning ability of students in a secondary school by using Problem-based Learning in Fundamental Chemistry class in the topic of Chemical Reaction. The research methodology was described below:

3.1 Research Design

The design of this study was of an action research applying the concept of Kemmis and McTaggart (1988) comprising four steps: Planning, Action, Observing and Reflecting.

3.2 The Subjects

The subjects were 58 Grade 10^{th} students in the Science-Math English program, which is the responsibility of the researcher's class. These students were divided into 2 groups: 28 students for the experimental group and the other 28 for the control group by using cluster random sampling method. They were studying Fundamental Chemistry in the topic of Chemical Reaction in Semester 1, Academic Year 2017.

3.3 Research Instruments

There were three types of research instruments:

3.3.1 *Experimental tools* were seven Problem-based Learning lesson plans on Chemical Reaction, covering 12 fifty-minute periods. These seven Problem-based Learning lesson plans on Chemical Reaction were carried out following components of the implementation plan:

1. Introduction
    1.1 The teacher presented media or situations about teaching and learning.
    1.2 Students were put in groups of 3-4 mixed ability students.
2. Teaching and learning

Step 1 Setting up the Problem

Students would choose the problems. Teacher will set up the environment for the problem and used questions or media to stimulate their curiosity.

Step 2 Understanding the Problem

Each group of the students tried to understand the problem and planned the way to solve it. They shared the responsibility within groups and worked as a team to plan the experiment and found out the answer systematically by using theories and reasons to describe their answer.

Step 3 Researching

Students found out the answers by themselves from several sources such as books, worksheets, handouts, or reliable websites as suggested in the plan. Then, they had to make a scientific experiment to discover the answer.

Step 4 Synthesizing knowledge

Students would share and analyze the information with each other. And also, they could integrate old information with new knowledge in order to continuously apply their knowledge. The teacher was the supporter and used more questions to stimulate students in searching for information for correct conclusion.

Step 5 Result conclusion and evaluation

Each group of students made the conclusion and evaluation by themselves through group discussion independently in order to see the whole problem thoroughly and build up the perfect concept. They could do it by making a mind-map, doing worksheet group activities, reporting, or setting up the presentation.

Step 6 Presentation and project evaluation

Students presented their project and evaluated what they learned in several ways such as comparing errors with every group after the result discussion, using the mind map in the presentation after which everyone evaluated the project

3.3.2 *Reflective tools* were three as follows:-

- The Learning Behaviour Form for the students and the Teaching Behaviour Form recorded by the teacher mentor.
- The Students' Opinion Questionnaire by students.
- The Post-class Reflection Form recorded by the researcher
- 4 quizzes after class

3.3.3 *Evaluation forms* were five as follows:-

- Examination of educational achievement evaluation in the topic of Chemical Reaction consisted of 20 questions with 4 choices in each question.
- Examination of scientific reasoning ability evaluation in the topic of Chemical Reaction consists of 6 open ended questions.

4. Data Collection

The researchers collected data by using seven Problem-based Learning lesson plans with 28 students. The steps of data collection were as follows:

1. The researchers studied basic information of the school and the students.

2. Data derived from the Pre-test to examine educational achievement and scientific reasoning ability evaluation in the topic of Chemical Reaction of the experimental group and the control group of 58 10^{th} grade students who studied in the first semester of the 2017 Academic year.

3. The students were orientated in order to understand the responsibility, class objectives, goals and study agreement, and assigned activities in class.

4. The researcher taught the students with general seven lesson plans for the control group and seven Problem-based Learning lesson plans for the experimental group for 12 periods, 50 minutes each. Details are shown in Table 1.

Table 1: Data Collection for seven Problem-based Learning Lesson Plans

Lesson Plans	Topic	Time (periods)	Collecting Data
1	Chemical reaction occurrence	1	12-16 June 2017
2	Chemical reaction occurrence experimentation	2	12-16 June 2017
3	Chemical Equation	1	19-23 June 2017
4	Energy and rate of Chemical Reaction	2	19-23 June 2017
5	Factors that affect chemical reaction	3	26-30 June 2017
6	Acid Rain	1	3-7 July 2017
7	Chemical Reaction use in daily life	2	3-7 July 2017

5. All data were collected from every lesson plan and the results were gathered from reflective tools--Student Learning Behavior Observation Form, Teaching Behavior Observation Form, Students' Opinion Questionnaire, Post-class Reflection Form, and quizzes.

6. After teaching with all the lesson plans, the teacher would evaluate the efficiency of Problem-based Learning by post-testing all the students in both groups with the same test as the pre-test.

7. The first researcher as the teacher collected all evaluation forms and examinations for data analysis and summary, followed by data interpretation.

5. Data Analysis

The researcher and the teacher mentor collected data from the records of each lesson plan, Learning Behavior Form and Teaching Behavior, Students' Opinion Questionnaire, Post-class Reflection Form, and quizzes to evaluate suitability of Problem-based Learning for the experimental group study. Content analysis of qualitative data showed the results in brief descriptions of exemplified responses or comments. All collected data were analyzed by the researcher and the mentor in order to develop the Problem-based Learning lesson plans. In addition, both the pre-test and the post-test results from both groups were quantitatively analyzed by calculating the growth score with relative gain scores, including the mean ($\bar{x}$) and standard deviation (SD). Then, the mean score will be compared with the statistical score of t-test Independent calculated by a computer program.

The relative gain score presented by Kanjanawasee, 1989 (The Social Science Research Association of Thailand, 2014) was calculated by using this formula:

$$\text{Relative Gain Score } (\%) = \frac{(\text{Posttest} - \text{Pretest})}{(\text{Full Score} - \text{Pretest})} \times 100$$

6. Results

This research studied whether the application of activities by using Problem-based Learning or situations related to daily stimulates students' learning. The learner could acquire knowledge by working in groups. Also, they participated with enthusiasm and actively searched for knowledge. In the comparison between the pre-test's and the post-test's percentage, the result showed that Problem-based Learning method had the relative gain score of educational achievement of 54.24 percent, and had the relative gain score of scientific reasoning of 54.40 percent. On the other hand, the traditional method group gave the relative gain score of educational achievement of 43.71 percent and the relative gain score of scientific reasoning only 33.83 percent. See Tables 2 and 3 below.

Table 2: The comparison between the pre-test and the post-test scores in educational achievement of the samples

Sample	Number of students	Full score	$\bar{x}$ Pre-test	$\bar{x}$ Post-test	Relative gain score
Experimental group	28	20	6.68	13.82	54.24
Control group	28	20	6.71	12.54	43.71

Table 3: The comparison between the pre-test and the post-test scores in scientific reasoning of the samples

Sample	Number of student	Full score	$\bar{x}$ Pre-test	$\bar{x}$ Post-test	Relative gain score
Experimental group	28	18	6.61	12.61	54.40
Control group	28	18	6.89	10.64	33.83

According to the results above, including the calculation of t-test Independent statistic score, it showed that (1) the achievement on Fundamental Chemistry in the topic of Chemical Reaction for the 10^{th} grade students by using Problem-based Learning methods was higher than using regular methods at the significance level of .05 (2) The 10^{th} grade students' scientific reasoning on Fundamental Chemistry in the Topic of Chemical Reaction by using Problem-based Learning methods was higher than those who were in the group exposed to regular methods at the .05 level of significance.

7. Discussion

According to the research of Problem-based Learning to promote learning achievement and scientific reasoning on Fundamental Chemistry in the topic of Chemical

Reaction for the 10th Grade Students, we found that the Problem-based Learning methods increased educational achievement and scientific reasoning ability. This result was consistent with Namnimitranon's research (2015), which found that the activities with Problem-based Learning methods could help students develop their scientific concept, analysis, and reasoning. In addition, Intanon (2008) concluded in his research that students participating in activities with Problem-based Learning methods had higher scores in both educational achievement and scientific problem solving skill than others who were exposed to traditional learning activities. Using the Six-step Problem-based Learning Method as suggested by the Office of the Education Council of Thailand (2007) promotes student-centred learning. Each step of learning in this method started from students setting up their problem from the media and the questionnaire which was made by teacher. These stimulated them to seek for knowledge and attempt to understand those problems. Students divided the responsibilities among group members and discussed the ways that could be used to solve the problems. Then, students managed to do research by themselves as their plan such as conducting researches, participating in group activities, or conducting experiments by using scientific theories reasonably. Then, students had to share the information with other groups to synthesize the knowledge, considered being the most important step for this method. We found that some groups argued with each other due to the difference in prior experience of each student. During the discussion, reasons were exchanged to support their information which led to conclude the new knowledge. Then, the teacher would ask students questions to check information accuracy. Finally, they would be able to present the results with proper reasons and accurate knowledge by explaining with the mind map, explaining with writing on the board, or presentation in front of the class. The results from the lessons made the students know that there was more than one way to solve their problems. This led them to learn from reality and enhance reasonable problem-solving skills. From using various interesting activities for seven Problem-based Learning lesson plans with daily life-related media, it was found that these students were more enthusiastic in learning than others who were taught by using the traditional method. This group of students liked the competition, conducted experiments, and enjoyed group activities. These led them to understand the theories and practical lessons because they had to find their answers and participate activities by themselves due to the self-directed learning concept of Problem-based Learning. Students needed to gather facts and reasons to support their understanding of the problems and made their own ways to find the answers. Before students could conclude their answers, they needed to use reasons to consider information through their knowledge integration and experience and correctly explain their synthesized concept based on scientific knowledge. This method was considered to be the Deductive Reasoning and Inductive Reasoning. According to Greenes and Findell's theory (1999), which was consistent with Savery's research (2006), the use of Problem-based Learning method in learning activities was found to help students to accept opinions of others, work as a team, and use reasons with problem solving. Therefore, the students possessed scientific reasoning skill and understood scientific knowledge accurately. Educational achievement of the students was increased too. However, proper time management and preparation by the teacher were crucial factors because they would give students a chance to show their opinions and participate in each step of activities in order to learn to reach their full potential.

8. Conclusion

This research studied how using Problem-based Learning in activities affected the educational achievement and ability in scientific reasoning in fundamental chemistry class in the topic of Chemical Reaction. The researcher used questions and situations which were related to daily life to stimulate the thinking process of students in finding the answers while the teacher only supported and facilitated them in order to develop educational achievement and effective scientific reasoning skill. The researcher emphasized that students should participate in the activities by themselves under proper time management because some steps of the activity might have taken more time as students were trying to understand and solve the problems. Furthermore, according to the research, it was found that each step used a scientific method to answer Problem-based Learning, so this method could be applied to other branches of science classes.

9. The Authors

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