The Effect of Problem-Based Learning Instruction Activities in Linear Equations on Problem Solving Ability Analytical Thinking and Reasoning

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Abstract
The purposes of this research were to compare the before and after problem solving ability analytical thinking and reasoning ability of Mathayomsuksa 1 students by using method of Problem-Based Learning Instruction with a statistic criterion. The subjects of this study were 30 Mathayomsuksa 1 students in the second semester of 2018 academic year from Srinakharinwirot University Prasarnmit Demonstration School Secondary. They were selected by using cluster random sampling technique. The experiment lasted for 10 periods. The One-Group pre-test-posttest design was used for this study. The instruments were the Problem-Based Learning plans in word problems of Linear Equations in One Variable. The data were analyzed by using t-test for dependent samples and t-test for one sample. The findings were as follows: 1. The mathematics learning achievement of problem solving ability for Mathayomsuksa 1 students after being taught by using Problem-Based Learning Instruction activities in Linear Equations in One Variable were higher than that before being taught and statistically higher than the 70% criterion at the .01 level of significance. 2. The mathematics analytical thinking and reasoning ability for Mathayomsuksa 1 students after being taught by using Problem-Based Learning Instruction activities in Linear Equations in One Variable were higher than that before being taught and statistically higher than the 70% criterion at the .01 level of significance.

Keywords: Problem-Based Learning, Analytical Thinking and Reasoning Ability

Introduction

The Thai Education system consists of 12 year free basic education: 6 years of "Prathom" (primary education, P1 to P6) and 6 years of "Mattayom" (secondary education, M1 to M6). There are over 37,000 Educational Institutions and nearly 20 million students in the Thai education system. The Basic Educational Core Curriculum 2008 (Revised version, B.E. 2017) emphasize the need for encourage learners to have skills that are essential for learning in the 21st century which are prepare students to have problem solving skills, analytical thinking and reasoning ability. The importance analytical thinking skill-oriented instruction has been highlighted in National Education Act of 1999 and the amendment versions 2019 (Ministry of Education, 2019) whereby teachers are required to incorporate analytical thinking process, situation confrontation practices, and application of knowledge in prevention and solution of problems in students 'learning process. Mathematics has a very important chapter that students will need to develop to become successful in the 21st century because math is a means of thinking, logical thinking methods, structure and linkages between the strong and clear concept (Jumaita [9]). The quality of mathematics education in Thailand on a national scale is still low observe from Mathematics mean score in Programme for International Student Assessment (PISA) 2015 only 415 which is far from standard level and average three-year trend score difference improve only 1 point. As a consequence of the PISA results, the thinking skill and problem solving abilities of students should be developed in order to fulfill Thailand educational goal. It is essential to develop the mathematics learning instruction that are considered important enough by both teachers and students at all levels from elementary through high school so that we are able to integrate analytical thinking and reasoning ability in our learning management.

One of the most effective learning instruction to improve the problem solving abilities is Problem-Based Learning Instruction. In this research, we use this learning instruction in word problems of Linear Equations in One Variable and worked with the exercises that enhance students to show more analytical thinking and reasoning ability. We aimed to compare before and after problem solving ability analytical thinking and reasoning ability of students by using method of Problem-Based Learning Instruction with a statistic criterion.

Literature Reviews

Problem-based learning (PBL) as defined by Barrows [2] is also based on what learning science considers more effective ways to learn and acquire expertise. The essential ingredients are the problem-based learning process, carefully designed problems and a teacher as a skilled guide or coach (Barrows,[3]).There are distinct stages in an effective problem-based learning process. The first stage is where students discover daily life problems that should be solved as a trigger for learning. They identify the facts from the problem, generate or explore possible ideas or hypotheses, identify learning issues determining what they need to know to work out the problem and articulate an action plan to seek, evaluate, synthesize and apply the information that they need to manage the problem (Hmelo-Silver, [6]). In this stage, teachers can guide and prepare their students to pose thought-provoking questions and seek answers through the use of open-ended questioning and discussion techniques themselves. Throughout this stage, as students understand the problem better, they

generate hypotheses about possible solutions and identify knowledge deficiencies relative to the problem. These knowledge deficiencies become what are known as the learning issues that students research during their self-directed learning (SDL). During this stage, students learn to critically evaluate the knowledge they need independently, as well as make critical judgments about the application and suitability of that particular knowledge. Next, the student perform problem solving and apply new knowledge to problem. The process ends with each of the students and sometimes the tutor, providing feedback self and peer assessment on their individual and team members' work, seeking continuous improvement. Thus, we can explain the PBL cycle as shown in Figure 1.

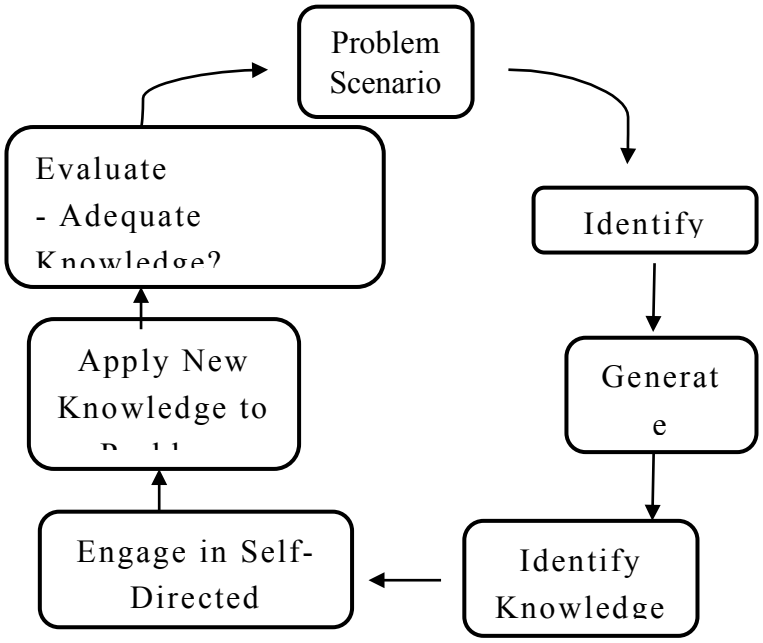

Figure 1: the PBL Cycle

In addition Jumaita N et al. [9] aimed to analyze the students' mathematical problem solving ability of class VIII-2 SMP Negeri 3 Bilah Hulu Labuhan Batuon linear equations and inequalities of one variable's material. The results of research shows the percentage of students' ability to understand the problem reached 87.10% and in the excellent category. According to Anderson [1] states that "problem-solving ability is a very important life skill that involves various processes such as analyzing, interpreting, reasoning, predicting, evaluating, and reflecting. Problem solving is one of the goals or fundamental component of the school curriculum in different countries ".

Analytical thinking is a critical component of visual thinking that gives one the ability to solve problems quickly and effectively. It involves a methodical step-by-step approach to thinking that allows students to break down complex problems into single and manageable components. Analytical thinking is necessary when an ambiguous situation requires the learner to identify or create a problem to solve. Bailin, Case,Coombs, and Daniels [4] argued that analytical thinking involves the ability to respond constructively to others during group discussion, which implies interacting in pro-social ways by encouraging and respecting the contributions of others. This type of thinking also requires students to compare sets of data from different sources;

identify possible cause and effect patterns, and draw appropriate conclusions from these datasets in order to arrive at appropriate solutions.

Joanne K. [8] summarize some of the effective programs to teach problem-solving, reasoning, and thinking skills in a classroom environment at a school serving special needs children. He defined analytical thinking is a similar behavioral sequence, but involves a further element of inquiry and situations with less well-defined parameters and outcomes. Analytical thinking is necessary when an ambiguous situation requires the learner to identify or create a problem to solve. Reasoning, an essential element of both problem solving and analytical thinking, involves the manipulation of verbal stimuli to restrict response alternatives in accord with a problem's outcome.

Methods of the research

Researchers utilized Problem-Based Learning Instruction to develop problem solving ability, analytical thinking and reasoning ability of Mathayomsuksa 1 students in the second semester of 2018 academic year from Srinakharinwirot University Prasarnmit Demonstration School Secondary, Thailand. Subjects in this study was conducted in class Mathayomsuksa 1 with 30 students. Researcher aimed to develop the mathematics learning achievement of problem solving ability, mathematics analytical thinking and reasoning ability. We consider word problems of Linear Equations in One Variable the difficult part of solving word problems is converting the words into equations. Moreover, students need to show and verify to be sure that their answers satisfy the conditions of the problem. The researcher has created the Problem-Based Learning lesson plans in word problems of Linear Equations in One Variable. We created 4 lesson plans in 8 periods with learning areas as following

- Algebra word problems
- Age problems
- Geometry problems
- Problems on fraction

There are two types of evaluation tools. The first type of evaluation tool is a 15 items full-fill test used to evaluate achievement of problem solving ability in Mathematics of word problems of Linear Equations in One Variable before and after being taught by using Problem-Based Learning Instruction activities. It had been tested for content validity with the Index-Objective Congruence (IOC) as within 0.50 to 1.00, item difficulty level as within 0.20 to 0.80, item discrimination factor as 0.40 to 0.75, and reliability value as 0.88. The second type of evaluation tool is a 5 subjective examination test used to evaluate the mathematics analytical thinking and reasoning ability of word problems of Linear Equations in One Variable before and after being taught by using Problem-Based Learning Instruction activities. It had been tested for content validity with the Index-Objective Congruence (IOC) as within 0.50 to 1.00, item difficulty level as within 0.20 to 0.80, item discrimination factor as 0.50 to 0.67, and reliability value as 0.77. The subjective examination test in the form of questions regarding the content of word problems of Linear Equations in One Variable. Problem in the form of contextual questions it needs to be grating test instrument problem solving capabilities analytical thinking and reasoning ability are presented in Table 1.

Table 1: Guidelines scoring of mathematics analytical thinking and reasoning ability

Rated Aspect	Score	Information
Understanding the problem by showing the concepts from problems and what the problem requires	2	Writing is known, gives a correct and logical reasons
	1	One wrote that note, one gives the right reasons
	0	There is no answer at all
Show linear equations that leads to solving problem	2	Writing a correct of linear equations
	1	Writing a partially correct of linear equations
	0	There is no answer at all
Show the analysis of guidelines for solving problems or showing step to solve linear equations	3	Showing correct analysis of guidelines or calculations and find correct answer
	2	Showing partially correct analysis of guidelines or calculations
	0	There is no answer at all
Show steps and providing the reason to check answers of linear equations	3	Show steps and providing the correct reason to check answers of linear equations
	2	Show step and providing the partially correct reason to check answers of linear equations
	0	There is no answer at all

Therefore, we can conclude the steps of this research following figure 2.

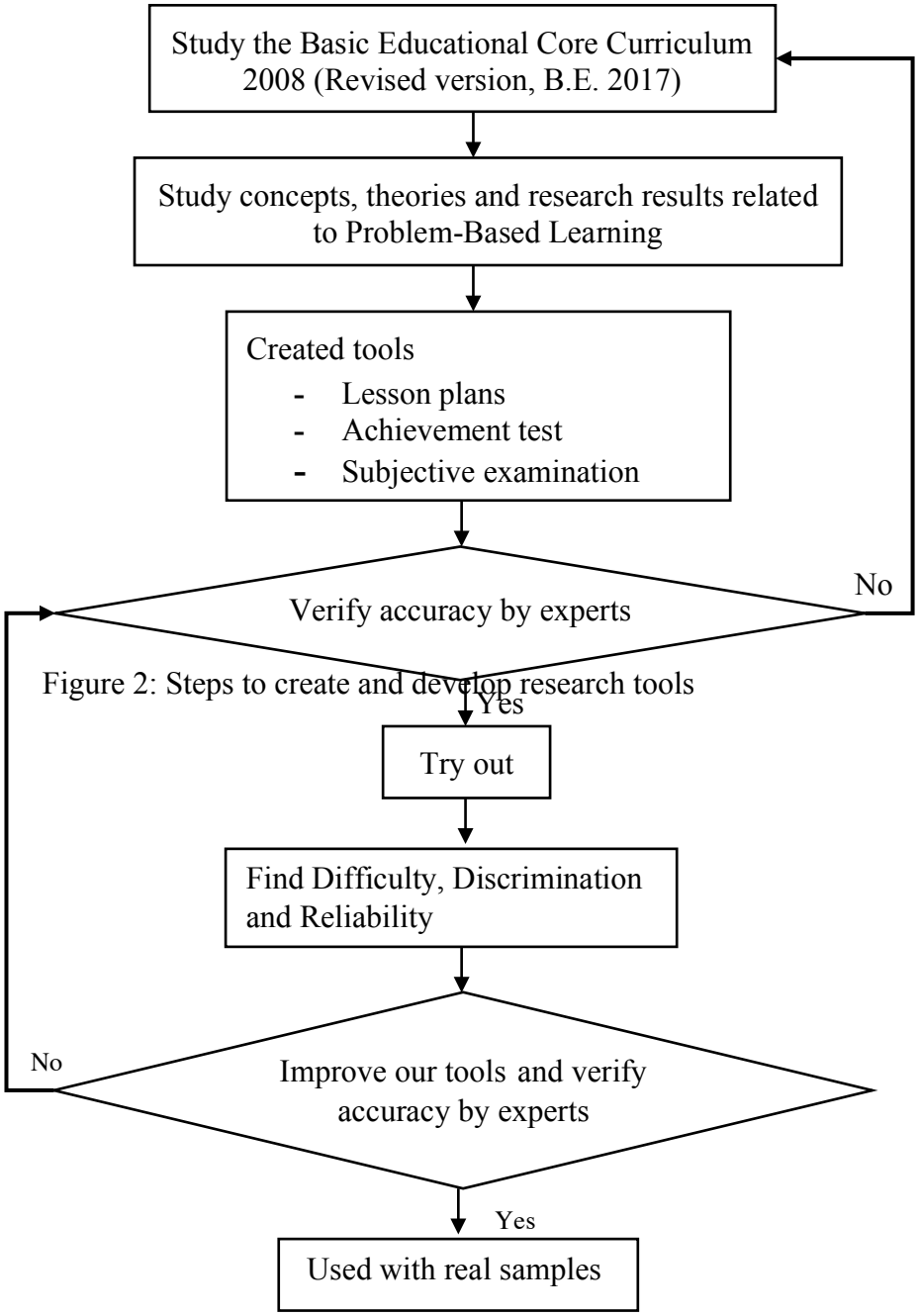

Figure 2: Steps to create and develop research tools

Result of the research

Development of mathematics learning achievement of problem solving ability for Mathayomsuksa 1 students before and after being taught by using PBL Instruction activities in Linear Equations in One Variable was shown in figure 3.

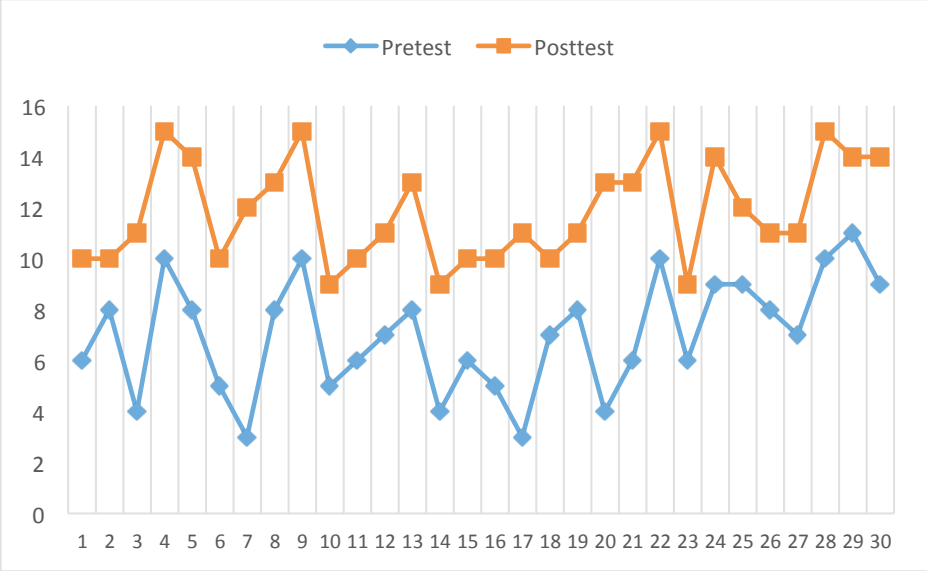

Figure 3: The problem solving ability for Mathayomsuksa 1 students before and after being taught by using Problem-Based Learning Instruction activities.

Fig 3 shown the problem solving ability before and after being taught by using PBL. The pre-test mean is 7 and post-test mean is 11.83 thus, the problem solving ability of everybody after activities was higher than before activities. The comparison of the pre-test and post-test problem solving ability score by using Problem-Based Learning Instruction activities was found at the significance level of 0.01, shown in Table 2.

Table 2: The mathematics learning achievement of problem solving ability for Mathayomsuksa 1 students by using PBL Instruction activities in Linear Equations in One Variable

Problem solving ability	*n*	*k*	$\bar{X}$	*s*	*t*
Pre-test	30	15	7	2.2	15.18**
Post-test	30	15	11.83	1.97	
df = 29		t at 0.01 = 2.756			**Significant

Table 2 shown the problem solving ability post-test was higher than pre-test. The Problem-Based Learning Instruction activities can improve student's problem solving ability. The two means was found to be highly significant that t-test for dependent samples was calculated by the following formula

$$t = \frac{\sum D}{\sqrt{\frac{n\sum D^2 - \left(\sum D\right)^2}{n-1}}} \; ; \quad df = n - 1$$

Where

t is a paired t test

$\sum D$ is Sum of the differences between before and after being taught by using PBL

$\left(\sum D\right)^2$ is Sum of the squared difference between before and after being taught by using PBL

n is the size of the given sample

The comparison of the mathematics learning achievement of problem solving ability for Mathayomsuksa 1 students after being taught by using PBL activities in Linear Equations in One Variable statistically and the statistically 70% criterion, shown in Table 3.

Table 3: The mathematics learning achievement of problem solving ability for Mathayomsuksa 1 students after being taught by using PBL Instruction activities in Linear Equations in One Variable statistically 70% criterion

Points	*n*	*k*	$\bar{X}$	*s*	μ_0*(70%)*	*t*
The mathematics learning achievement	30	15	11.83	1.97	10.5	3.7**
df = 29			t at 0.01 = 2.756		**Significant	

Table 3 shown the mathematics learning achievement of problem solving ability was higher than statistically 70% criterion. The means was found to be highly significant that t-score was computed based on the following equation

$$t = \frac{\bar{X} - \mu_0}{\frac{s}{\sqrt{n}}} \; ; \; df = n - 1$$

Where

t is the t-distribution

$\bar{X}$ is the sample mean

μ_0 is the population mean

s is the standard deviation

n is the size of the given sample

Development of mathematics analytical thinking and reasoning ability for Mathayomsuksa 1 students before and after being taught by using PBL Instruction activities in Linear Equations in One Variable was shown in figure 4.

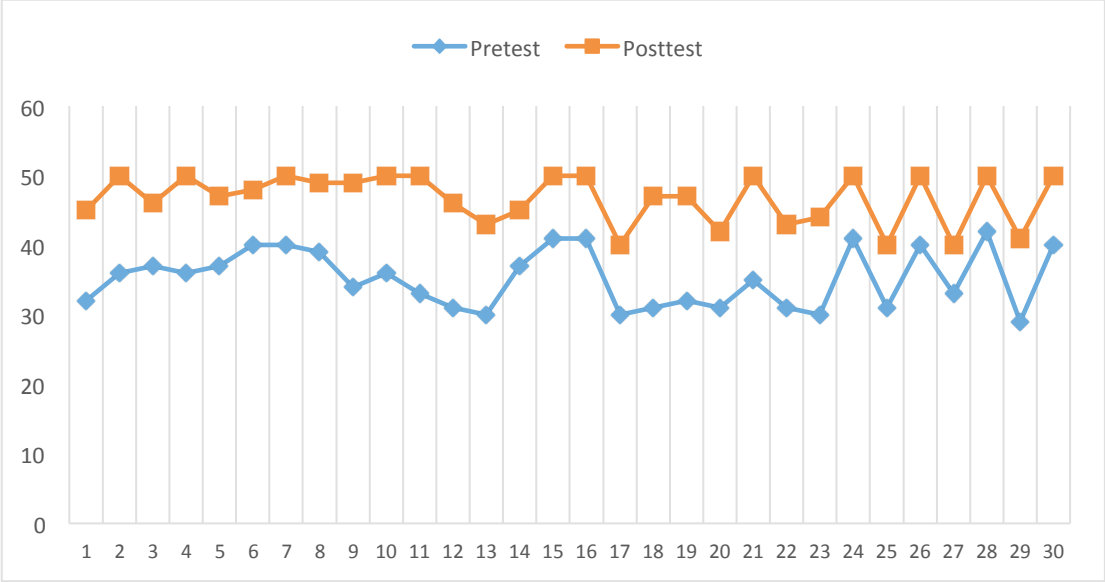

Figure 4: The mathematics analytical thinking and reasoning ability for Mathayomsuksa 1 students before and after being taught by using PBL Instruction activities

Fig 4 shown the mathematics analytical thinking and reasoning ability before and after being taught by using PBL. The pre-test mean is 35.2 and post-test mean is 46.73 thus, the analytical thinking and reasoning ability of everybody after activities was higher than before activities. The comparison of the pre-test and post-test analytical thinking and reasoning ability score by using PBL Instruction activities was found at the significance level of 0.01, shown in Table 4.

Table 4: The mathematics analytical thinking and reasoning ability for Mathayomsuksa 1 students by using PBL Instruction activities in Linear Equations in One Variable

Test	*n*	*k*	$\bar{X}$	*s*	*t*
Pre-test	30	50	35.2	4.1	22.37**
Post-test	30	50	46.73	3.53	
df = 29		t at 0.01 = 2.756			**Significant

The comparison of the mathematics analytical thinking and reasoning ability for Mathayomsuksa 1 students after being taught by using PBL activities in Linear Equations in One Variable statistically and the statistically 70% criterion, shown in Table 5.

Table 5: The mathematics analytical thinking and reasoning ability for Mathayomsuksa 1 students after being taught by using PBL Instruction activities in Linear Equations in One Variable statistically 70%

Points	*n*	*k*	$\bar{X}$	*s*	μ_0*(70%)*	*t*
The mathematics analytical thinking and reasoning ability	30	50	46.73	3.53	35	18.2**

df = 29 t at 0.01 = 2.756 **Significant

Table 5 shown the mathematics of analytical thinking and reasoning ability was higher than statistically 70% criterion.

Conclusions

In this research, a case has been developed for PBL as a powerful pedagogical approach to improve the problem solving ability analytical thinking and reasoning ability. The research had explain Linear Equations in One Variable lesson plans that merge the problem solving and analytic thinking which students can transfer word problem to linear equation (focused on how students use the algebra to find a method to solve equations) and reasoning ability (student need to give reason to support their own answers). Research outcomes are tied to learning goals and student are independent to think and solve problems and the answer also must show reasonable. Overall, then, the potential power of problem-based learning as an aligned educational system and pedagogy is in its curriculum focused on both essential twenty-first century knowledge and skills and on making these relevant to students' future career or work place contexts [7]. For future work, PBL can indeed be applied to other mathematics topics. It is especially useful for teaching problem solving skills in order to improve learning abilities of students.

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