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Implementation of the Learning Management Model Based on Cognitive Development Theory to Enhance Mathematical Problem-Solving Ability for Prathomsuksa 6 Students

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Abstract

This study investigates the implementation of the learning management model based on cognitive development theory to enhance mathematical problem-solving ability for Prathomsuksa 6 students. The sample group assigned by cluster random sampling was thirty Prathomsuksa 6 students of Chumchon Yot Kaeng Songkhro School. The research instruments consist of learning achievement tests and mathematical problem-solving ability tests (pre-test and post-test). The statistical analyses were percentage, mean, standard deviation, and t-test (dependent samples) was employed for testing hypothesis. The results showed that students' learning achievement after learning with the learning management model was significantly higher than before learning at a statistical level of .05. Also, the students had the mathematical problem-solving ability after learning significantly higher than before learning at a .05 level. When considering in each aspect, it was found that all of the mathematical problem-solving ability after learning was higher than before learning at a

statistical level of .05, namely, 1) finding of the problem relationship; 2) writing of mathematical diagrams; 3) problem solving; and 4) traceability.

Keywords: Cognitive development theory, Learning achievement, Mathematical problem-solving ability

1. Introduction

Student-centered learning management in mathematics is a process in which students should learn through practice and develop their own problem-solving skills. Students should have a variety of approaches to solving problems, knowing how to apply and modify solutions to suit mathematical problem situations. Students must use strategies or approaches to solve problems. It is a competence required to solve mathematical problems, including, 1) Drawing Figures; 2) Exploiting Related Problems; 3) Working Backwards; and 4) Testing and Verification Procedures (Schoenfeld, 2016).

According to the results of the Ordinary National Educational Test (O-NET) of Chumchon Yot Kaeng Songkhro School's grade 6 students in the academic year 2016 and 2017, it was found that the mathematics average scores were lower than the national level, particularly Standard MA2.1 Understand the basics of measurement Measure and predict the size of what you want to measure and Standard MA2.2 Solve measurement problems, with average scores 9.62 and 30.77, respectively, which is a big problem that should be resolved urgently. Therefore, Strand 2: Solving measurement problems was chosen to design the classroom learning management in accordance with students' daily life problems in order to improve their mathematical problem-solving ability. The reason for this is that when students face a subjective exam, most of them are unable to analyze problems and apply problem-solving strategies correctly because they have to use a variety of knowledge and methods to solve mathematical problems.

The learning management model was developed based on cognitive development theory (cognitive growth), which is a learning model that focuses on information processes or thought processes (the Information-Processing Family), and also is a key concept used in learning connected with cognitive processes to lead to the highest level of knowledge that is meaningful for students (Joyce, 2011).

In learning management, students use metacognition to solve problems until they achieve goals. It consists of sub-strategies, including; planning—know what to do and how to think; auditing—review ideas about the plans laid out in the process of solving a problem; determining the appropriateness and correctness of the strategies or procedures chosen for solving problems; assessing planning—examining the solution or strategies used to solve the problem and evaluate the results (Flavell, 1994). The application of metacognitive concepts in solving mathematical problems consists of 1) problem analysis, 2) problem understanding, 3) choice of problem-solving strategies, and 4) assessment of a solution (Schoenfeld, 1988). In student-centered learning management, students are trained to learn on their own through problem situations as well as open approaches, which are learning management with an emphasis on problem solving processes of open-ended problems that can be used as a

medium to develop students' knowledge, understanding and thinking skills in mathematics. It is a learning management where students learn by themselves through problem situations and express their opinions about problems in order to find ways to solve them. Students may have different solutions to problems (Nohda, 2000). Students' social interactions will improve their understanding of mathematical thinking. Students will use group activities in a self-study problem-solving process in a meaningful way where students discuss and share strategies for solving mathematic problems (Ryve, 2011). This is consistent with the concept of Social Constructivism that uses social interaction and cognitive cognition in teaching and learning. Teachers use real-life problem situations of students to create social structures. Students learn through group processes, discussions and collaborative exchanges (Vygotsky, 1978). As the reasons and importance of the problem mentioned above, the researcher is interested in developing a learning management model based on cognitive development theory to enhance learning achievement and mathematical problem-solving ability for Prathomsuksa 6 students.

1.1 Research Questions

How is the learning management model based on cognitive development theory able to enhance mathematical problem-solving ability for Prathomsuksa 6 students?

1.2 Research Objectives

To study the results of implementation of the learning management model on two aspects as follows:

(1) To compare the students' learning achievement in mathematics between before and after learning through the model.

(2) To compare the students' mathematical problem-solving ability between before and after learning through the model.

2. Literature Review

2.1 Mathematical Problem-Solving Ability

Mathematical problem solving is a process or procedure for solving a problem based on the principle of solving a problem (Anderson, 1988). Mathematics problems must be interesting to the learner so that they can use their knowledge and understanding to solve the problem as planned goals (Schoenfeld, 1988). Mathematical problem solving strategies are the abilities students must use in problem-solving processes: guessing and testing, looking at sub-problems, drawing, formulating rules or patterns, building relationships, revising, searching schemes and checking (Souviney, 1981). Mathematical problem solving strategies are strategies or techniques which are competencies necessary to solve mathematical problems, consisting of 1) drawing figures; 2) exploiting related problems; 3) working backwards; and 4) testing and verification procedures (Schoenfeld, 1988). The procedure for solving a mathematical problem involves proceeding with the planned solution: 1) understanding the problem; 2) solving the problem; and 3) confirming the answer (Tambychik, 2010). Likewise, Polya (1981) proposes 4 steps for solving mathematical problems: 1) understand the Problem; 2) devise a plan; 3) carry out the plan; and 4) look back.

In addition, Krulik (1996) describes the mathematical problem solving process as having five steps: 1) reading and thinking; 2) analysis and planning; 3) organizing strategies; 4) acquiring answers; and 5) confirming the answer.

Based on the principle of solving a problem, the mathematical problem-solving ability in this model as strategies or procedures for solving a problem consists of 4 abilities as follows: 1) The finding of the problem relationship means students are able to analyze problems and understand problems from everyday mathematical problem situations; 2) The writing of mathematical diagrams means students are able to describe what they have learned or reflect on their ideas about solving problems, and then draw them into mathematical diagrams to plan solutions; 3) The problem solving means students are able to solve problems according to steps or strategies for solving problems; 4) The traceability means that students are able to verify the correctness of answers and the correctness of a mathematical strategies or procedures. The model's mathematical problem-solving ability can be illustrated by Figure 1.

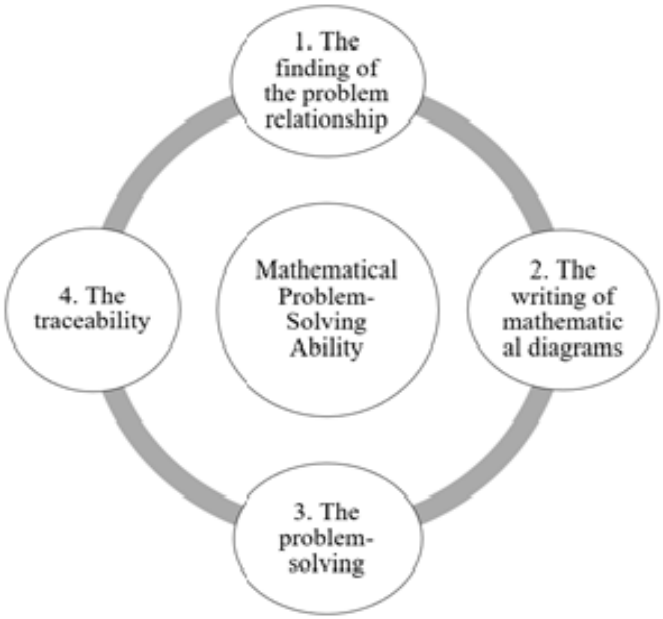

Figure 1. The model's mathematical problem-solving ability (Kanjana Ninnuan)

2.2 Constructivism

Constructivism is an important learning management theory that leads to the development of students' math problem solving abilities. Cognitive growth, a learning model that is categorized into a group that focuses on the process of thinking (The Information-Processing Family) is an important concept used to support learning management that is linked to cognitive processes that are important factors supporting student learning including the adoption of cognitive structures to bring about the highest level of knowledge that is

meaningful for students. Learning is the sum of interactions with the environment. Good learning must be able to sum up new knowledge, known as the discovery of new knowledge (Joyce, 2011). The concept of intellectual development or cognitive development in which the intellectual development of each child is continually growing, with cognitive abilities manifested through thought processes and physical responses. Piaget describes cognition as a process involving actions or interactions occurring under conditions and reasoning between the person and the environment as the past and future perspectives. It is a process that does not arise from within the individual or arises from only one aspect of the external environment (Piaget, 1969). Henson (2003) applied Piaget's concepts in teaching and learning, consisting of 1) guiding or guiding students to understand through group discussion activities to summarize answers and solve problems; 2) Encourage students to have the opportunity to express their opinions together; 3) grouping students into assorted or diverse group members; 4) creating opportunities for students to discuss action planning and assess their performance with their classmates; and 5) encouraging students to use their efforts to discover knowledge and link knowledge in the lesson content.

Social Constructivism is social interaction which is an important element in helping students to have a good learning. In particular, group activities for learning in kindergarten and elementary school are organized in the manner of rejoicing and encouraging students' learning. Vygotsky, a Russian psychologist who proposed the concept of Cognitive Development, believed that the sociocultural status of students influences cognitive development, especially language learning and cognitive development. A good learning design should therefore involve the contextual environment, peer relationships, lifestyle events, and language communication (Vygotsky, 1978). Application of social constructivist theory in teaching and learning management as a learning process, it focuses on problem-solving processes rather than outcomes. Student interaction, whether through discussion or commenting, is part of a problem-solving process where students work together as a group to find solutions. During the group process, students will use colloquial communication that allows them to share their ideas in the process of solving problems with their peers, as well as in the classroom discussions that students will need a deep knowledge of thought processes and strategies for solving mathematical problems (Budd, 2005).

2.3 Metacognition

Metacognition is the ability of self-cognition and self-regulation arising from the individual learning to apply knowledge to what is learned. Students are required to apply their own cognitive knowledge in accordance with problem situations. To manage student learning to be successful, students must use competence. The three areas of metacognition include reading, math, and others. The students must apply the concept of metacognition in their learning. Metacognition is seen as an advanced thinking in student learning, consisting of a process of awareness to help students plan, and self-regulation to help students take control of their learning (Sternberg, 1986). Woolfolk Hoy said that using metacognition to solve math problems in students' learning includes: 1) Cognitive awareness; students are self-aware of what skills or strategies are needed in the problem-solving process. Students can explain to others planning or choosing strategies for solving math problems. What students think is

consistent with the problem situation in learning management; and 2) Self-regulation; it is a metacognitive experience to monitor one's own thought processes while students are solving problems, determining whether one has an understanding of it, assessing problem-solving abilities, planning, reviewing ideas about methods used to solve problems, evaluating outcomes and reviewing methods or strategies used in solving problems whether they are correct or not (Woolfolk Hoy, 1999). In addition, Van Garderen describes the effective use of metacognition in solving mathematical problems: 1) self-learning; students will understand problems and choose strategies for solving mathematical problems; 2) Self-examination of problem-solving methods or strategies used to solve mathematical problems; and 3) self-review of cognition and problem-solving strategies (Van Garderen, 2003).

2.4 Open Approach

According to principles of learning management with an open approach, teachers must focus on students as the center, giving students freedom in learning. Learning management must be consistent with the nature of mathematical knowledge consisting of 3 principles: 1) learning management must respond to students' independent self-learning; 2) learning management must be consistent with the nature of mathematical knowledge, which is systematic and theoretical knowledge; and 3) learning management depends on the convenience or decision-making power of the teachers (Nohda, 2000). Open approach is the process of solving mathematical problems that are open-ended, with multiple answers, different strategies or solutions according to students' different levels of mathematical knowledge (Schoenfeld, 1988). As Nohda explains, open-ended problems are characterized by multiple solutions, multiple problem-solving processes, and can be developed into other problems (Nohda, 2000). The process of learning management based on the open approach consists of 5 steps: 1) lesson review, which examines students' prior knowledge to be used in solving problems; 2) presenting a mathematical problem for students to analyze and talk about the problem; 3) students work individually or in groups where students work together to come up with solutions or methods for solving problems; 4) discussion of problem-solving methods in which students have various approaches to solving problem; and 5) Outlining methods or approaches to solving problems (Hiebert, 1999).

3. Methodology

3.1 Research Design

The research and development (R&D) process was employed to develop the learning management model. The samples assigned by cluster random sampling ware thirty Prathomsuksa 6 students of Chumchon Yot Kaeng Songkhro School. The research variables were; 1) the independent variable which was the learning management model based on cognitive development theory to enhance mathematical problem-solving ability for Prathomsuksa 6 students, and 2) the dependent variables which were the learning achievement and the mathematical problem-solving ability.

3.2 Data Collection

The study in Phase 1 was studied of the concept, the theory, the learning management

problem, the needs of students towards the management of mathematics learning, Mathematical teachers and experts based on cognitive development theory to enhance learning achievement and mathematical problem-solving ability for Prathomsuksa 6 students. Informant group were: 1) the sample group in the questionnaire were Prathomsuksa 6 students of 3 classrooms in total of 60 students acquired by cluster random sampling from 120 students of 5 schools divided into 6 classrooms. The instruments evaluated by 5 experts were in part 1, Mathematical on learning management problem in the past semester had suitable in highest ($\bar{x}$ = 4.48, S.D. = 0.61) and in part 2, the needs of students towards the management of mathematics learning had suitable in high; 2) the sample interview were Mathematical teacher of Prathomsuksa 6 students from 5 students of 5 schools who had specific selection by instrument created through quality qualification from 5 experts found that had suitable in highest ($\bar{x}$ = 4.72, S.D. = 0.49); 3) the sample interview of Mathematical experts was 4 Mathematical experts who had specific selection by instrument created through quality qualification from 5 experts found that had suitable in highest ($\bar{x}$ = 4.75 , S.D. = 0.48).

The study in phase 2 were used the data which gathered in phase 1 to create a model and check for quality of the learning management model based on cognitive development theory to enhance mathematical problem-solving ability for Prathomsuksa 6 students. And, the developed instrument which created through quality qualification from 5 experts were: 1) 12 lesson plans in total 25 hours had suitable in highest ($\bar{x}$ = 4.56, S.D. = 0.52); and 2) learning management manual had suitable in highes t ($\bar{x}$ = 4.60, S.D. = 0.51); 3) the learning achievement tests had 30 items with 4 multiple choices found that total of difficulty index or easiness had 0.63, total of sensitivity index had 0.47 and total of reliability had 0.75; and 4) the mathematical problem-solving ability tests in 6 items of subjective tests used for evaluating 4 mathematical problem-solving abilities, namely, 1) finding of the problem relationship; 2) writing of mathematical diagrams; 3) problem solving; and 4) traceability found that total of sensitivity index had 0.60 and total of reliability had 0.76. After used experimental model on learning management with experimental groups, for Prathomsuksa 6 students in 1 classroom of 20 students of Chumchon Lak Liam Witthayakhom School by cluster random sampling group. Then improved and applied to the sample.

The study in Phase 3 was conducted to examine the implementation of the learning management model based on cognitive development theory to enhance learning achievement and mathematical problem-solving ability for Prathomsuksa 6 students. The samples were 30 Prathomsuksa 6 students in 1 classroom of Chumchon Yot Kaeng Songkhro School assigned by cluster random sampling from 120 students of 5 schools divided into 6 classrooms. The data were collected through 12 weeks in the second semester of the academic year 2019. The instruments evaluated by 5 experts were, 1) the learning achievement tests (pre-test and post-test): 30 items with 4 multiple choices (p = 0.63, r = 0.47 and r_{tt} = 0.75; and 2) the mathematical problem-solving ability tests (pre-test and post-test): 6 items of subjective tests used for evaluating 4 mathematical problem-solving abilities, namely, 1) finding of the problem relationship; 2) writing of mathematical diagrams; 3) problem solving; and 4) traceability (D = 0.60 and α = 0.76).

3.3 Data Analysis

The quantitative data were analyzed by percentage, mean, standard deviation, and t-test (dependent samples) was employed for testing hypothesis. The qualitative data were analyzed using a qualitative analysis.

4. Results

The learning management model based on cognitive development theory to enhance learning achievement and mathematical problem-solving ability for Prathomsuksa 6 students is a student-centered learning management; students must have knowledge, understanding, and ability to analyze problems or problem situations and then plan and make decisions to solve problems properly. It consists of 5 steps of learning management as follows: 1) The problem situation presentation step; a step of group activity where the teacher presents the students' daily mathematical problem situations, so that students will understand by talking and jointly analyze the problem situation to set goals for solving problems together; 2) The problem finding step; a step of group activity where teachers will review students' prior knowledge to stimulate students' learning by asking about their prior knowledge and students will have to study new knowledge from additional knowledge sheets on the subject that the teacher will teach. Students are asked to combine prior knowledge with new knowledge to be used in problem solving. Each group uses their perceptions to analyze the problem through discussion, expressing opinions about the problem situation to help each other find out strategies for solving problems. Students will use open-ended problems with a variety of processes or solutions; 3) The problem solving implementation step; a step of group activity where students use their perceptions to analyze the relationship of a problem in which each group discusses finding a strategy or approach to solving the problem. Students together explain what they have learned or reflect on their own problem solving ideas to their peers, draw a mathematical diagram for planning the problem, write mathematical symbolic sentences, and then solve problems as planned, which may have a variety of mathematical solutions; 4) The discussion step; a step of group activity where, when students complete a problem-solving process, they use their knowledge of the problem situation to assess their procedural abilities including planning, reviewing ideas on the strategies students use to solve problems, evaluating answers and examining the methods students use to solve problems. If the answers and strategies students use to solve problems are incorrect students have to improve their solutions, then each group of students presents a mathematical diagram for solving problems in front of the class, where students discuss and share their opinions to exchange and learn together about how to solve problems; 5) The summary of learning step; a step of group activity where teachers and students work together to summarize problem-solving methods and summarize the content learned so that students can apply their knowledge and problem-solving strategies to solving mathematical problems in daily life. The model's 5 steps of learning management can be demonstrated by Figure 2.

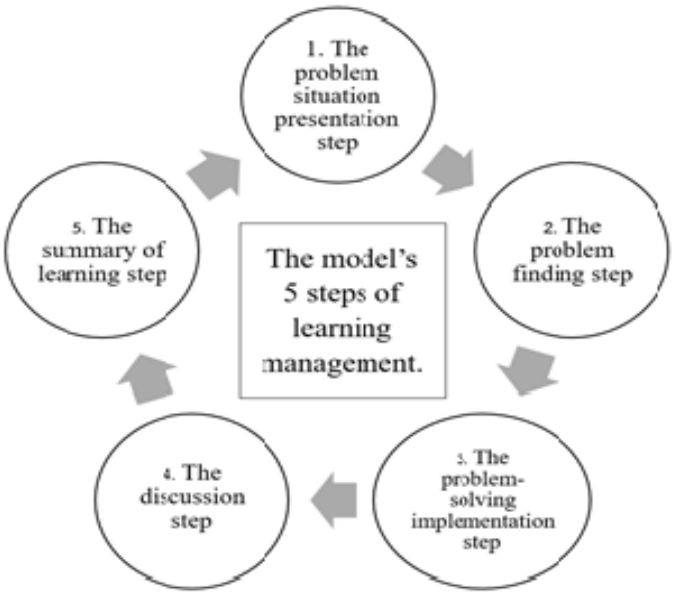

Figure 2. The model's 5 steps of learning management (Kanjana Ninnuan)

4.1 To compare the students' learning achievement in mathematics between before and after learning through the model, the findings can be shown in Table 1.

Table 1. The comparison of students' learning achievement in mathematics between before and after learning through the model

Item	Pre-test (N = 30)		Post-test (N = 30)		t	P
	$\bar{x}$	S.D.	$\bar{x}$	S.D.		
learning achievement in mathematics	18.13	3.71	24.03	4.21	27.974	0.000

As table illustrates, it reveals that students had learning achievement in mathematics after learning higher than that before learning at the 0.05 level of significance; the score before learning as ($\bar{x}$ = 18.13, S.D. = 3.71), while the score after learning as ($\bar{x}$ = 24.03, S.D. = 4.21), and t = 27.974 (p = 0.000).

4.2 To compare the students' mathematical problem-solving ability in mathematics between before and after learning through the model, the findings can be shown in Table 2.

Table 2. The comparison of students' mathematical problem-solving ability between before and after learning through the model

Items	Pre-test (N = 30)		Post-test (N = 30)		t	P
	$\bar{x}$	S.D.	$\bar{x}$	S.D.		
Mathematical Problem-Solving Ability	25.79	3.58	36.00	1.44	12.525	0.000
1. The finding of the problem relationship	36.17	3.19	46.83	1.60	7.460	0.001
2. The writing of mathematical diagrams	29.17	2.64	39.33	1.03	8.936	0.000
3. The problem solving	20	1.41	30	1.79	8.452	0.000
4. The traceability	17.83	1.72	27.83	1.33	10.351	0.000

As seen in Table 2, Prathomsuksa 6 students had mathematical problem-solving ability after learning higher than that before learning at the 0.05 level of significance; the score before learning as ($\bar{x}$ = 25.79, S.D. = 3.58), while the score after learning as ($\bar{x}$ = 36.00, S.D. = 1.44), and t = 12.525 (p = 0.000). When considering in each aspect, it was found that students had mathematical problem-solving ability after learning higher than that before learning in all aspects. The scores were as follows: 1) The finding of the problem relationship; the score before learning as ($\bar{x}$ = 36.17, S.D. = 3.19), while the score after learning as ($\bar{x}$ = 46.83, S.D. = 1.60), and t = 7.460 (p = 0.001); 2) The writing of mathematical diagrams; the score before learning as ($\bar{x}$ = 29.17, S.D. = 2.64), while the score after learning as ($\bar{x}$ = 39.33, S.D. = 1.03), and t = 8.936 (p = 0.000); 3) the problem solving; the score before learning as ($\bar{x}$ = 20, S.D. = 1.41), while the score after learning as ($\bar{x}$ = 30, S.D. = 1.79), and t = 8.452 (p = 0.000); and 4) the traceability; the score before learning as ($\bar{x}$ = 17.83, S.D. = 1.72), while the score after learning as ($\bar{x}$ = 27.83, S.D. = 1.33), and t = 10.351 (p = 0.000).

5. Discussion

The learning management model based on cognitive development theory to enhance learning achievement and mathematical problem-solving ability for Prathomsuksa 6 students was well-developed. Firstly, the researcher investigated teachers and students' problems and needs, and related literatures. Next, the drafted model was evaluated by the experts, and then was tried out by the experimental group. Finally, the developed model was implemented to the sample group. The findings indicated that the developed model is effective to enhance learning achievement and mathematical problem-solving ability for Prathomsuksa 6 students which can be discussed below.

5.1 students' learning achievement after learning with the learning management model was significantly higher than before learning at a statistical level of .05. This indicated that the developed model based on the theoretical concepts is effective to enhance students' learning achievement which is consistent with Bullock's study (2017) who examined teaching elementary mathematics through problem solving and its relationship to mathematics

achievement. The results revealed that teaching mathematics through solving mathematical problems showed a positive correlation with academic achievement in mathematics. This may be because in solving mathematical problems, students must understand the problem, plan and solve it together. The stages of learning management were able to enhance leaning achievement in mathematics.

5.2 Prathomsuksa 6 students had mathematical problem-solving ability after learning higher than that before learning at the 0.05 level of significance. When considering in each aspect, it was found that students had mathematical problem-solving ability after learning higher than that before learning in all aspects. The scores were respectively as follows: 1) The finding of the problem relationship (46.83); 2) The writing of mathematical diagrams (39.33); 3) the problem solving (30); and 4) the traceability (27.83). It indicates that the fundamental theories and concepts employed in the development of the learning management model developed by the researcher can improve students' mathematical problem-solving abilities. This finding is in line with Novriani's (2017) study that studied the analysis of student difficulties in mathematics problem-solving ability at MTs SWASTA IRA Medan. The results showed that the indicators of students' mathematical problem-solving abilities were 1) understanding problem (84.62%); 2) planning (61.54%); 3) proceeding as plan (39.74%); and 4) confirming the answer (32.05%). And the difficulties in solving math problems were found that the students had problems with reading the problem, and interpreted the problem incorrectly, could not interpret it in symbolic form, could not predict the answer to the problem. Therefore, students were not able to solve mathematical problems correctly. In addition, Sangpom's (2016) study examined Advanced Mathematical Thinking and Students' Mathematical Learning: Reflection from Students' Problem-Solving in Mathematics Classroom. The results revealed that solving math problems was advanced mathematical thinking using Inprasitha's (2010a) learning management process consisting of 1) presenting math problems; 2) students were able to learn on their own and teachers could assemble solutions; 3) students discuss math problems together and compare students' solutions; and 4) students draw conclusions to link their answers to mathematical concepts. It was found that students were successful in solving math problems in calculus by using open-ended problems, giving students a variety of problem-solving ideas, and improving their thinking from simple to complex. Promraksa (2014) studied characteristics of computational thinking about the estimation of the students in mathematics classroom applying lesson study and open approach. The results showed that for the learning management with open approach, teachers will use open-ended problems to stimulate students' mathematical problem-solving process so that students can learn and solve problems by themselves by using Inprasitha's open approach (2010a) consisting of 1) presenting open-ended problems; 2) student self-study; 3) class discussion and comparison, and 4) summarizing the connections of students' math concepts. Furthermore, a study by Ulfah (2017) examined Students' mathematical creative thinking through problem posing learning. The results of the research showed that 1) students who studied with the learning management based on metacognition had higher math problem-solving abilities than those who studied with normal learning management; and 2) A student's ability to solve mathematical problems depends on the characteristics of each individual student's mathematical abilities and teaching methods. In addition, students who

studied with the learning management based on metacognition have higher development of thinking processes and mathematical problem-solving abilities than normal.

6. Conclusion

According to the findings, the learning management model based on cognitive development theory to enhance mathematical problem-solving ability for Prathomsuksa 6 students is a student-centered learning management model where students can apply their knowledge to solve mathematical problems by choosing the correct and appropriate problem-solving strategies. The learning management model developed by the researcher is considered as an effective model because it can develop students' learning achievement in mathematics and mathematical problem-solving abilities.

7. Recommendation

Based on the learning management model based on cognitive development theory to enhance mathematical problem-solving ability for Prathomsuksa 6 students, mathematics teachers should apply the developed model in teaching and learning in order to develop students' academic achievement and problem-solving abilities in mathematics, especially mathematical problem-solving strategies in which learners learn and solve problems on their own including 1) The finding of the problem relationship; 2) The writing of mathematical diagrams; 3) The problem solving; and 4) The traceability. It was found that most students were able to solve mathematical problems better with group and individual learning activities. Overall, students had higher mathematical problem-solving abilities. However, in the area of individual development, there were some students who had a low level of development, particularly the problem solving and the traceability. Therefore, teachers should organize a variety of learning activities that are consistent with the needs and aptitudes of students, focus on students to do their own work, and to learn more about solving math problems, which can encourage students to develop creative mathematical problem-solving skills that are essential for mathematics learning management.

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