The Development of Learning Management To Enhance Mathematical Thinking Ability For Secondary School Students

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Abstract. The objectives of this research was to develop the learning management process for enhancing the Secondary School Students’ Mathematical Thinking Ability. There were 3 steps of development including: 1) the synthesis of related research literature, 2) the outlining of learning management process, and 3) the evaluation in Propriety of learning process by 5 experts in Mathematical Learning Management and Evaluation through Focus Group Discussion and usage of Evaluation Form in Propriety of Learning Management including 5 steps: 1) the experience association, 2) the association of knowledge construction, 3) the problem consideration, 4) the sharing, and 5) the learning reflection and evaluation of Propriety in learning management process, found that Propriety of the learning management process for enhancing the Secondary School Students’ Mathematical Thinking Ability, was in “The Highest” level.

1. Introduction

The trend of changing world during the 21st century impacted in economic, social, environmental, science, technology, and political aspects of every country especially the advancement in information communication and technology with unlimited limitation. As a result, it was globalization which could communicate with each other quickly. Every country in global community emphasized on and hurriedly developed to keep pace with changing world situation and could compete with various countries in the world. It was necessary to prepare readiness in many aspects especially in human resource development for being foundation of national development. Therefore, the education played an important role directly for developing the quality and potential human resource
including knowledge, skill, competency, and desirable characteristic based on the need for using human energy and being able to compete with various countries. (Office of the Education Council, 2014) For recent educational management in Thailand, it was during the 12th issue of Economic and Social Development (2017-2022), the first 5 years of 20 years for national strategic movement (2017-2036) into practice as a major master plan in Thailand national development to be secure, prosperous, and sustainable. It was the time for national reform in solving different aspects of basic problem being collected for a long period of time. It was very challenging duration of Thailand to adjust itself by hurrying to develop science, technology, research and development, and innovation to be major factors in moving every aspect of development for enhancing competitive competency level among more serious world competition. However, there were many limitations of problem situation in Thailand including low quality of Thai people, most of labors had problems in body of knowledge, skill, and attitude. The society lacked of quality with inequality which was obstacle in potential improvement. In Education, it was found that the Educational Quality and Learning of Thai people still be in low level even they obtained higher level of education. Considering the students’ O-NET learning achievement found that their average score was lower than 50%. Furthermore, national score from PISA found that their scores were lower than many countries with similar developmental level. Since there was major limitation in Thai Education including the problem of curriculum and instructional system focusing on memorization leading to the lack of creativity. (The Office of National Economic and Social Commission, Office of the Prime Minister, 2016) For national evaluation of PISA, aimed to evaluate educational system quality to prepare readiness for people’s potentiality or necessary basic competency in livelihood of changing world by focusing on the evaluation of students’ competency in applying their knowledge and skill in real life rather than learning based on school curriculum. PISA evaluated 3 aspects of evaluation in students’ knowing: knowing in reading, knowing in Mathematics and Science. In Thailand, under 20-year national strategic plan into the 12th issue of national economic and social development plan during 2017-2021, started to emphasize on using the outcome from national evaluation by determining PISA score in each subject, as a part of educational quality indicator of Thailand as well. So, it was starting point of policy significance for developing the educational quality into learning in order to apply knowledge in real life world. But, according to the report of PISA Thailand (2016) in Mathematics, found that the trend of Thai Students’ Mathematics score from PISA since 2000 to PISA 2015, were decreased. It was supported by evaluation based on project TIMSS (Trends in International Mathematics and Science Study) Project, study in the trend of educational management in Mathematics and Science through evaluation of Pratomsuksa 4 Students and Matayomsuksa 2 Students in Mathematics and Science Subjects, reflected that most of Thai Students’ Mathematical Learning Ability was in low level. Moreover, there was little number of students with advanced Mathematical Learning Achievement. It was supported by educational standard testing in Thailand, the O-NET, found that Thai Students’ Mathematical Learning Quality was decreased continuously which indicated the regression of Thai Mathematics Education. (National Institute of Educational Testing Service, 2016) There were problems in basic education level and evaluation in PISA and TIMSS indicating the international education competition. The problems were indicated that our youth needed to receive knowledge and skill equally with the youth in other places. Mathematical Curriculum in Thai Schools had to be equal with curriculum in international community. Both of TIMSS and PISA included conceptual framework of Mathematical Evaluation as a major key of Mathematics being recognized by global. The students had to obtain knowledge in content material on stable foundation sufficiently, be competent in Mathematical Thinking, apply Mathematics with real world situation, be able to interpret and evaluate Mathematical Problem Solving, and apply with real world situation. For these objectives of Mathematics Knowing, 4 aspects of special characteristics should be included in Mathematics Education: (1) the curriculum, (2) the teachers and teaching, (3) the students’ meaningful Mathematics, and (4) the decision making from policy. Each aspect was important. Considering in learning quality improvement, should be focused on enhancement and support for every group of students especially the disadvantage population group and rural area group needed to be promoted emergently. If these lower groups were supported, the whole country would be promoted as well. (PISA Thailand, 2015) In addition to the problem in educational quality, there was expectation in future work, present human power was
expected to be working energy with high level of thinking and competency which would affect their duty work. Furthermore, everyone had to face with technology changing, and needed to adjust oneself to be able to, mechanics, and information and news entering throughout the time. The importance was the trend in every occupation indicating that “the person needs to be able to understand, communicate, use, and explain one’s approach and technique based on Mathematical Approach most.” (PISA Thailand, 2014) So, Mathematics was an important variable in developing the educational quality into development in quality of life.

Mathematical Thinking could be explained by Piaget’s intellectual developmental theory in Mathematical Learning including the learning development from concret to abstract which was an advanced mathematical thinking. (David Tall, 2002) So, Mathematical Learning was to learn and to think. Consequently, it was necessary for Mathematical Learning to develop Mathematical Thinking, the intellectual process which cause person to be able to perceive, understand, and apply Mathematics for problem solving in facing situation systematically until new body of knowledge for applying in other situations would be occurred. It was focused on students’ thinking, and searching for thinking method which would lead to body of knowledge and understanding in Mathematical concept and principle understanding. Then, knowledge was developed and applied in problem solving. According to the studies, found that Mathematical Thinking was related to both of Mathematical Nature and Students’ Learning Experience, and socio-cultural aspect. Lev Vygotsky believed that both of society and culture would be necessary intellectual instrument for developing the intellectual model and quality. The adults or elderly such a parents and teachers would be association for socio-cultural instrument and language. These cultural instruments included the history, culture, social and language in nowadays context as well as the access in electronic data.) Sean F. Argyle, 2012) The application of Lev Vygotsky’s Social Constructivist Theory of Learning Mathematics, believed that Learning was Social activity. When students had opportunity in interacting with teachers and friends, they could be able to construct Mathematical Body of Knowledge. ) Cobb, Wood, & Yackel,1990 cited in Karen L.Fonkert, 2012) Besides, language was an important tool for Learning

) Vygotsky, 1978, 1981 cited in Karen L.Fonkert, 2012) by social interaction such as small group cooperative learning would lead to construction in body of knowledge. Moreover, Schoenfeld (1992 cited in Karen L.Fonkert, 2012) connected learning and social activity in classification of Mathematical Characteristics including: basic knowledge, problem solving strategy, Mathematical Belief and Attitude. Schoenfeld beleived that the students’ social learning activity in Mathematical Classroom was important for constructing Mathematical Thinking. Therefore, both of Schoenfeld and Lev Vygotsky emphasized on Mathematical classroom learning activity for enhancing the students’ Mathematical Thinking Development by social interaction with Mathematical Symbol as learning center. Social interaction from teachers and friends or experts in helping and suggesting and cooperative working would develop students’ learning. Besides, there was Mathematical Theory in constructing the new body of knowledge based on Constructivism being occurred by Piaget’s Intellectual Development Theory. Dubinsky (2002) stated the construction in Mathematical body of knowledge that the construction process in Reflective abstraction, and APOS. (Action – Process – Object – Schema) Dubinsky and McDonald (2001) explained that Action was to response from external stimulus. Then, the repeated responses were occurred in each person, the internal mention construction or Process was happened. Later on, the Object step, was constructed from process when the was awareness of all processes and understanding. Finally, it was the Schema, the step of each persons’ Mathematical Concepts associating general principle and approach until the Scheme was occurred leading to related problem situation.

According to the above, there was significance of learning management into Mathematical Thinking Development. Although there were Thai Educators studied learning management model for enhancing the Secondary School Students’ Mathematical Thinking. In addition, Marasi Mechoke (2015) studied the Development of problem-based learning management model for Secondary School Students. Suthin Bunpattanaporn, Rungtiwa Yamrung, and Laddawan Kasemnet (2015) studied the Development of learning management to enhancing the Secondary School Students’ Mathematical Thinking. But, in this study, the different theories were studied, body of knowledge theory called Constructivist, and Mathematical Theory called APOS, Vygotsky’s Socio-cultural Theory, and
Problem Solving Approach by real life situation. So, it was supported by international evaluation, PISA including the collaborative problem solving and problem situation facing by themselves. According to the study of Mathematical related research literature, the significance of Mathematical Thinking and Real Life Situation were shown. It was supported by Stacey's (2007) statement in 3 issues of Mathematical Importance including: being important goal of instruction, being important guideline for Mathematical Learning, and being important guideline for Mathematical Teaching. Therefore, Mathematical Thinking Ability in Problem Solving was a basic goal of Mathematical Teaching in order to apply the studied knowledge in real life situation. Furthermore, the 21st century in learning management guidelines as changing world, learning was not limited in only classroom. If the students could develop Mathematical Thinking, they would learn from Mathematical World for solving the real life problem. Developing the students’ Mathematical Thinking Ability, teachers were important persons in developing their students’ learning. However, according to the studies of Mathematical Problem Situation in instructional management in Thailand, found that the Thai Teachers still emphasized on content material, development of outcome rather than the students’ learning how to learn. (IPST, 2015) It was necessary to develop the learning management model systematically on the basis of learning theories, instructional principle in instructional management for enhancing the Secondary School Students’ Mathematical Thinking in order to be guidelines for learning activity management for enhancing the Mathematical Thinking Ability.

2. Research Objective
To develop the learning management process for enhancing the Secondary School Students’ Mathematical Thinking Ability.

3. Research Delimitation
3.1 The Research Key Informants
In this research, 5 experts evaluated the Propriety of develop the learning management process. They were selected by Purposive Sampling including the experts in Mathematical develop the learning management and measurement and evaluation.

3.2 Studied Variable
3.2.1 Independent Variable was the learning management process for enhancing the Secondary School Students’ Mathematical Thinking Ability.

3.2.2 Dependent Variable was the Propriety of learning management process for enhancing the Secondary School Students’ Mathematical Thinking Ability.

3.3 The research instrument using for learning management process
The research instrument using for learning management process included the Evaluation Form of Propriety in learning management process.

4. The Steps in Research Implementation
4.1 Step 1: The synthesis of related research literature and documents of Mathematical Thinking, Learning Theories, and Learning Management Model for enhancing the Secondary School Students’ Mathematical Thinking Ability consisted of following details:

4.1.1 The Mathematical Thinking was the person’s Mathematical Thinking Technique as intellectual process which cause the person to be able to construct body of knowledge and use Mathematics for problem solving in facing situation and be able to adjust the technique in other situations appropriately. So, Mathematical Thinking Ability was the person’s thinking ability for constructing the body of knowledge and using in solving the problems from other situations through process of
4.1.2 Learning Theories consisted of Mathematical Nature Theories and Related Learning Theories applying in Learning management for enhancing the students’ thinking. The Constructivist Theory emphasized on students’ body of knowledge and theories explaining in students’ nature and thinking. Learning Theories using in this study consisted of: 1) Piaget’s Intellectual Developmental Theory, 2) Constructivist Theory, Mathematical Learning Theory, and Mathematical Problem Solving and Metacognition. The details of process in Mathematical Body of Knowledge and Knowledge Application were as follows

Table 1: The theoretical approach and guidelines for Mathematical Learning Management.

| Theory                      | Major Approach                                                                 | Learning Management Guideline                                                                 |
|-----------------------------|--------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|
| Piaget’s Intellectual       | It is believed that since everyone is born, one is ready to interact with      | The teachers should consider intellectual development started from action by using sensory nerve or concrete to the usage of object or symbol. Then, the rules are constructed from knowing characteristic in grouping and developing for constructing the new abstract thing. It should be focused on students’ thinking ability level as well as learning experience management for enhancing the students’ thinking ability fully. |
| Developmental Theory        | environment. Naturally, human beings are ready for Action on the basis of: 1  |                                                                                                |
|                             | (management and collection, 2 adjustment includes assimilation and accommodation) |                                                                                                |
| Constructivist              | 1 Cognitive Constructivism: Learning is to construct understanding from association or connection of experience by students themselves with what is existed in environment, and/or what is obtained by managing data with what is learned | The teachers should emphasized on students’ knowledge construction by themselves based on process in developing one’s internal knowledge structure and perception in surroundings. The knowledge construction process is to think associated with former experience and new experience which might be occurred by conflict. The cognitive structure would adjust to be balance by students. |
|                             | 2 Social Constructivism: believes that the social interaction would support the students’ knowledge construction. | The usage of learning and thinking learning facility is to interact with environment in learning management, and consider the students’ need which might be helped and supported in learning called Scaffolding based on development. |
| Bruner’s Theory             | Mathematical Thinking Level: 1 (the direct experience and touchable level, 2 | The teachers should consider how to develop students’ learning motivation, design students’ major learning management by doing and solving the problem by themselves through interaction with environment which cause the cognitive structure development. |
|                             | (the picture using for seeing, and 3 (the relation development and symbol usage). |                                                                                                |
| Pirie & Kieren’s Mathematical Understanding | There are 8 levels of Mathematical Understanding Levels including: 1 (basic knowledge, 2 (image development, 3 (image, 4 (characteristic observation, 5 (abstract conclusion, 6 (observation, 7 (structure development, and 8 (new concept development.) | Learning management for students’ Mathematical Understanding Development indicates the steps of Mathematical Thinking from basic knowledge to process in constructing new body of knowledge.)abstract. |
| Theory                     | Major Approach                                                                 | Learning Management Guideline                                                                 |
|---------------------------|--------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
| van Hiele’s Geometrical   | The Thinking Level includes: 1 (the perception from vision), 2 (the characteristic description or association ranking), 3 (the unsystematic deductive reasoning), 4 (the systematic deductive reasoning), and 5 (the abstract being) | The Geometrical Learning Management leads to abstract thinking, starting from sensory nerve for exploring, analyzing, and observing the relationship until the abstract conclusion would be occurred. |
| Thinking                   |                                                                                   |                                                                                               |
| APOS’s Theory              | Mathematical Understanding Level: 1) Action, 2) Process, 3) Object, and 4) Schema | The Mathematical Understanding occurred by Mathematical Thinking Process including: action, process, object, and schema are basic thinking level into higher order of thinking for constructing the body of knowledge leading to the balanced schema adjustment when facing with new situation. |

According to related research literature in Mathematical Thinking in being the guideline for learning management was important in learning management, the important thing for Secondary School Students’ learning was the association and application in real life world as the Model of Mathematical Problem Solving Process. (PISA Thailand Project, 2014)

![Figure 1: Model of Mathematical Problem Solving Process](PISA Thailand Project, 2014)

4.2 Step 2: The Outlining of Learning Management Process
In this step, the learning management process was outlined for enhancing the Secondary School Students’ Mathematical Thinking Ability including 5 steps: 1) the experience association, 2) the association of knowledge construction, 3) the problem consideration, 4) the sharing, and 5) the learning reflection obtaining from synthesis of different models of learning management as shown in Table.

4.3 Step 3: The Evaluation of Propriety in Learning Management Process
4.3.1 The researcher presented the tentative learning management process was outlined for enhancing the Secondary School Students’ Mathematical Thinking Ability to her advisor as the expert in learning management for investigating the process and improving according to their advice.

4.3.2 The researcher presented the improved tentative learning management process for being considered by 5 experts through focus group discussion. The Propriety of learning management
process was considered. The experts’ suggestions were used in revising and improving the learning management process for enhancing the Secondary School Students’ Mathematical Thinking Ability to be completed.

4.3.3 The learning management process for enhancing the Secondary School Students’ Mathematical Thinking Ability was revised according to the experts’ suggestions.

5. Research Finding Analysis

5.1 The findings of the study, analysis, and synthesis of related theoretical research literature as well as the evaluative findings of learning management process for enhancing the Secondary School Students’ Mathematical Thinking Ability included 5 steps with following details:

Step 1: the experience association, was the beginning step in activity for developing one’s learning readiness and interest by focusing on incidence or experience in real life before associating into the learning activity or the games or activities might be used at the beginning in order to review one’s former knowledge.

Step 2: the association of knowledge construction, was the activity for implementing each group’s problem solving. In grouping, the researcher determined 3-5 persons each group. Then, the group would be taken turn every time so that the students would experience the group working with every classmate. For problem solving activity, when the students studied and understood, 5 questions leading to problem solving would be used: 1) the known information from the problem, 2) the knowledge needed to be sued, 3) the plan in searching for the answer, 4) the technique for obtaining solution, and 5) the solution checking. Besides, there were other questions indicated the knowledge and thinking being extended in other viewpoints. Consequently, the students collaborated in applying their knowledge for problem solving again. When every group received the group answer, the representative presented and concluded with their classmate. In addition, the answers were added in context.

Step 3: the problem consideration, during this step the researcher determined activity as problem situation being congruent with learning activity in the step of knowledge association by indicating the differences in different viewpoints from the former one which needed to be adjusted for solving the problem in new situation.

Step 4: the sharing, during this step the performance or outcome from activity participation was presented in order to investigate, compare, and conclude the problem solving technique.

Step 5: the learning outcome reflection was to reflect students’ learning outcome obtaining from group and individual activity in the issues of sensation/satisfaction, obtained knowledge and experience, examples using in real life, problem and obstacle needed to be supported, and self-confidence/esteem. The students presented in different styles or techniques based on individual preference such as picture, table, or mind mapping. Later on, the learning reflection outcome was put on the board in front of the classroom.

5.2. The evaluative findings in Propriety of learning management process for enhancing the Secondary School Students’ Mathematical Thinking Ability by 5 experts with competency in learning management of Mathematical and Measurement and Evaluation. The researcher calculated the mean scores from evaluation form of Propriety as 5 Level Rating Scale. The Propriety Level was interpreted. The appropriate average score as learning management, needed to be 3.50 and up. (Prakong Kannasoot cited in Sutinan Boonpattanapon, Rungtiwa Yamroong, and Laddawan Kasemnet (2015). The criteria were as follows:

- The average score 3.50-4.49 were in High level of Propriety.
- The average score 2.50-3.49 were in Moderate level of Propriety.
- The average score 1.50-2.49 were in Low level of Propriety.
- The average score 1.00-1.49 were in Very Low level of Propriety.
The evaluative findings of learning management process for enhancing the Secondary School Students’ Mathematical Thinking Ability shown inn Table 2.

**Table 2** The expert s opinion on Propriety of Learning Management Process for Enhancing the Secondary School Students’ Mathematical Thinking Ability.

| Item | Evaluative List |  \( \bar{x} \) | SD. | Evaluative Outcome |
|------|----------------|----------|-----|-------------------|
| 1    | The Learning Management Process is precise. | 4.80     | 0.45 | The Highest       |
| 2    | The Learning Management Process is practical. | 5.00     | 0.00 | The Highest       |
| 3    | The Learning Management Process enhances thinking ability. | 4.40     | 0.55 | The Highest       |
| 4    | The Learning Management Process is ranked in order suitably. | 4.60     | 0.55 | The Highest       |
| 5    | The Learning Management Process is appropriate with secondary school students. | 4.60     | 0.55 | The Highest       |
|      | **Average Score** | **4.68** | **0.42** | **The Highest** |

6. Discussions

6.1 The learning management process for enhancing the Secondary School Students consisted of 5 steps: 1) the experience association, 2) the association of knowledge construction, 3) the problem consideration, 4) the sharing, and 5) the learning reflection.

6.2 The evaluative findings of Propriety in learning management process, found that Propriety of the learning management process for enhancing the Secondary School Students’ Mathematical Thinking Ability by experts. Considering, found that it was in “The Highest” level. The scores were ranked in order from high to low: the learning management process for real practice \( \bar{x} = 5.0, \ SD = 0.0 \), the learning management process was precise, \( \bar{x} = 4.8, \ SD = 0.45 \), the learning management processes were ranked in order appropriately, and learning management process was suitable for Secondary School Students \( \bar{x} = 4.6, \ SD = 0.55 \), and the learning management process enhanced Mathematical Thinking Ability precisely, \( \bar{x} = 4.4, \ SD = 0.55 \). The Propriety of learning management process for enhancing the Secondary School Students’ Mathematical Thinking Ability, was in “The Highest” level since the learning management process was occurred by the analysis and synthesis of study of related research literature and approach.

7. Recommendations

Recommendations for application of research findings:

The usage of learning management process to be efficient, teachers had to study and understand various factors precisely.

Recommendations for application of future research:

The learning management process should be used for proving or confirming the efficient of learning management process.

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