

**THE DEVELOPMENT OF A MATHEMATICS
INSTRUCTIONAL MODEL USING THE
COGNITIVE APPRENTICESHIP APPROACH
FOR ENHANCING MATHEMATICS
LEARNING OUTCOMES AND SELF-
REGULATION ABILITY OF
UNDERGRADUATE STUDENTS IN SOCIAL
SCIENCES AND HUMANITIES**

Piradee Rittideche¹

Apipa Prachyapruit²

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Abstract: The purposes of this research are: 1) to develop a mathematics instructional model using the cognitive apprenticeship approach for enhancing mathematics learning outcomes and self-regulation ability of undergraduate students in social sciences and humanities; and 2) to evaluate the results of mathematics learning of students after the implementation of the developed instructional model. The research process was in 2 phases: first, a mathematics instructional model was developed by studying the findings of survey along with the concepts of cognitive apprenticeship, project based learning, self-regulated learning and authentic assessment. Next, the research involved the implementation of the developed instructional model. The samples were the freshmen in social sciences and humanities of Rajamankala University of Technology Krungthep who enrolled the course 2210101: Mathematics. They were randomly assigned into the control and experimental groups, each consisting of 28 students. The experiment took place for the duration of 13 weeks.

The findings of this study are as follows:

1. The developed instructional model consisted of principles, objectives, contents, instructional process and users' manual. The instructional process had 3 main steps: 1) the preparation: this involved the preparation of learning objectives, instructors, learners and environment; 2) the operation: this concerned the teaching on the contents using the cognitive apprenticeship approach, the teaching on mathematics project, and self-regulation activities; and 3) the evaluation: this involved pre- evaluation, formative evaluation and post- evaluation.

2. The results of mathematics learning of students after the implementation of the developed instructional model were:

2.1 Posttest scores of mathematics learning achievement, attitude towards mathematics learning, inquiry mind and self-regulation of experimental group were higher than the pretest at a significant level of 0.05.

2.2 Posttest scores of mathematics learning achievement of the experimental group were higher than the ones of control group at a significant level of 0.05. However, posttest scores of attitude towards mathematics learning, inquiry mind and self-regulation of experimental and control groups were not different at a significant level of 0.05.

2.3 Students in all experimental groups had the ability to conduct the mathematics project at a good level.

Keywords: Cognitive Apprenticeship, Mathematics Instructional Model, Mathematics Learning Outcomes, Self-Regulation Ability

Introduction

Mathematics is not only important to the development of human thinking skills but also to the foundation of any educational level. Thus, students in Arts also need to learn Mathematics. One of the manpower development strategies of the country as proposed by Thailand Development Research Institute (TDRI) is that students in Arts should be required to learn mathematics and science (Office of the Education Council, 2010). In other words, higher-education learners in social sciences and humanities need to have at least a certain level of mathematics knowledge in order that they can develop basic rational thinking skills. In spite of the importance of mathematics, its abstract contents contribute to its difficulty. While most mathematics teachers tend to give lectures focusing on content instead of interdisciplinary integration. This may lead to the lack of the relationship between mathematics and the real use, resulting in troubles for the learners, especially, those in social science and the humanities. As they have no necessary foundations in mathematics, they may not understand mathematical concepts and processes taught by their teacher, affecting their thinking system development and their ability to apply mathematics knowledge in other subject areas, which are based on such knowledge. Moreover, learners' negative attitudes towards mathematics may result in the lack of self-regulation ability, while teachers' use of assessment

¹ Ph.D. Candidate in Higher Education, Department of Educational Policy, Management and Leadership, Faculty of Education, Chulalongkorn University, Thailand

² Asst. Prof., Ph.D., Faculty of Education, Chulalongkorn University, Thailand

dominated by the end-of-semester examination fails to reflect the actual context of learning and assessment. Teachers' explicit illustration of thinking mechanisms for solving mathematics problem may be crucial for the enhancement of the learners' comprehension of the mathematical process. Learners can then observe the whole process and develop their own mathematical thinking process based on their individual intellect. In this regard, the cognitive apprenticeship approach (Collins et al., 1996) may be suitable for mathematics instruction as it helps learners in social science and humanities to clearly understand about mathematical problem-solving processes used by their teacher. It can be a way to enhance the learners' mathematical skills and processes, as well as to promote the recognition of the importance of mathematics and the application of mathematics in higher education and future works.

Project-based learning is a suitable instruction for educational provision in the 21st century since it truly maximizes learning potential development among individual learners and suits the integration with the cognitive apprenticeship approach. It aims to encourage learners to use acquired knowledge on their own for the development of products or 'mathematics project', which is a learning objective. Mathematics project is an activity that allows learners to develop their mathematical ability, particularly, the application to real life and in other subject areas. This may then promote a positive attitude towards mathematics, self-learning and group-work ability as well as communicational and problem-solving skills. In the 21st century, self-regulated learning is important because it is a process in which individuals can plan, control, and monitor their own behaviors for behavioral change towards desired goals. Self-regulated students tend to successfully realize desired behaviors. In other words, individuals with higher self-regulation ability can achieve more desired behavior than lower self-regulated counterparts. Apart from academic achievement, self-regulation ability may also be an important factor for life-long learning (Schunk & Zimmerman, 1994). According to Bandura and Schunk (1981 cited in Zimmerman, 1994), self-regulation training not only improves calculation skill but also enhances their interest in mathematics. Thus, for the promotion of self-regulation ability and of higher achievement in mathematics learning, one should consider pursuing those activities in order that learners can apply self-regulation strategies in their learning.

Hence, the researcher uses the cognitive apprenticeship approach, project-based learning, and self-regulated learning as a guideline for developing a mathematical instructional model, using the cognitive

apprenticeship approach. This is to enhance mathematics learning outcomes and self-regulation ability of undergraduate students in social sciences and the humanities.

Methodology

The methodology involved the investigation of current situations of mathematics instruction for undergraduate students in social sciences and the humanities, and of theoretical concepts pertinent to the instructional model, the cognitive apprenticeship approach, project-based learning, self-regulated learning, and authentic assessment. This aimed to develop the mathematics instructional model based on the following elements: principles, theoretical concepts, objectives, contents, instructional processes and assessment. Also, the production of the instructional model manual and lesson plans were included.

Content validity of developed mathematics instructional model, instructional model manual, and mathematics teaching plan were examined by 6 senior experts in mathematics instruction. Then, the revision and improvement were made according to their suggestions.

Instructional model assessment tools were developed, including mathematics learning achievement scale, attitude towards mathematics learning scale, self-regulation ability scale, mathematics project assessment form, and inquiry mind scale.

The implementation of the developed mathematics instructional model was pursued with 2 groups of freshmen in social sciences and the humanities at Rajamangala University of Technology Krungthep, who were enrolled in mathematics. Each group had 28 students. A test of basic knowledge of mathematics was taken by both groups and there was no difference in such regard. Group 1 and 2 were randomly assigned into the experimental and control groups, respectively. The developed instructional model was conducted for 13 weeks, 3 hours weekly, in a total of 39 hours.

The instructional model was assessed by analyzing the results of said implementation. T-test was also applied in the test of mean difference between pre- and post-test scores in the experimental and control group. This includes mathematics learning achievement, attitude towards mathematics learning, self-regulation ability, and inquiry mind. The ability to do mathematics projects in the control group only was analyzed by means of a rubric of quality assessment criteria.

The results of data analysis were used for the improvement of mathematics instructional model in order that the instruction could be pursued effectively.

Results

The findings of this study were as follows:

1. The developed instructional model consisted of principles, objectives, contents, instructional process and the users' manual. The instructional process had 3 main steps: 1) the preparation: this involved the preparation of learning objectives, instructors, learners and environment; 2) the operation: this concerned the teaching on the contents using the cognitive apprenticeship approach, the teaching on mathematics project, and self-regulation activities; and 3) the evaluation: this involved pre- evaluation, formative evaluation and post- evaluation (as displayed in Figure 1 and 2 in last page).

2. The results of mathematics learning of students after the implementation of the developed instructional model were:

2.1 Post-test mean scores of mathematics achievement in the experimental and control groups were higher than the pre-test with statistical significance level of 0.05.

2.2 Post-test mean scores of mathematics achievement in the experimental group were higher than the control group with statistical significance level of 0.05.

2.3 Post-test mean scores of attitude towards mathematics learning in the experimental and control groups were higher than the pre-test with statistical significance level of 0.05.

2.4 Post-test mean scores of attitude towards mathematics learning in the experimental and control groups were not different with statistical significance level of 0.05.

2.5 The experimental group has a good level of ability to do the mathematics project.

2.6 Post-test mean scores of inquiry mind in the experimental and control groups were higher than the pre-test with statistical significance level of 0.05.

2.7 Post-test mean scores of inquiry mind in the experimental and control groups were not different with statistical significance level of 0.05.

2.8 Post-test mean scores of self-regulation in mathematics learning in the experimental group were higher than the pre-test. However, pre- and post-test mean scores in the control group were indifferent with statistical significance level of 0.05.

2.9 Post-test mean scores of self-regulation in mathematics learning in the experimental and control groups were not different with statistical significance level of 0.05.

With respect to the results from the assessment of the cognitive apprenticeship approach, the improvement of mathematics instructional processes was needed. The action to be taken in such regard should be as follows.

1. For mathematics content, there should be more variety of mathematical questions in order that students can practice different kinds of exercises. Besides, the mathematical formula memorization techniques, explanations of the process of the formula should be given to the students because most of them are still confused with the use of those formulae.

2. For the instruction on mathematics projects, the schedule for those projects should be adjusted. Students should learn all contents prior to devising a project title because they can understand all content and choose the one they are interested in for their project. This will allow students to explore and understand what they have learned more profoundly. Moreover, students' will power should be enhanced due to their concern over the content and projects.

Discussion

According to the research results, post-test mean scores of academic achievement in the experimental group were higher than the pre-test and the control group with statistical significance level of 0.05. This agreed with the assumption that this could be contributable to mathematics problem-solving instruction using the cognitive apprenticeship approach with an emphasis on systematic thinking. In 'modeling' process, the learners could observe problem-solving techniques used by the teacher who illustrated those techniques which should follow Polya's (2004) problem-solving method. It consisted of four steps: understanding the problem, devising a plan, carrying out the plan, and looking back. With respect to 'devising a plan', teacher's advice on heuristic problem-solving techniques were given to the learners. Further, the discussions and debates may allow them to find a problem solution. The novices sometimes may not know or fail to recognize the heuristic problem solving techniques, while the experts often used them. The aforementioned finding was consistent with the finding of Tonglaw's study (1993). He argued that mathematics experts had more problem-solving process in hand when compared to the novices and focused on heuristic problem-solving techniques. In this regard, Polya's four-step method and researcher's problem-solving strategies could be a guideline for learners to solve problems. Coaching and scaffolding in the cognitive apprenticeship approach, moreover, referred to the teacher's advice and help given to the learners, while practicing problem-solving techniques in the 'articulation' process. Meanwhile, 'reflection' was a process in which learners exchanged and reflected their understanding among them. When they gave a reason to support their own ideas or to debate with others, they can reconsider their own comprehension in comparison with the thinking process of other

classmates resulting in the improvement of their understanding. Davidson (1992) argued that the understanding by learners be expressed to others in their own language, so that, they would achieve profound comprehension because they have systemized their knowledge beforehand for effective communication purposes. Also, this could be a chance for either good or poor performance learners to help each other. As they communicated with the same language, their learning would be better. Lastly, 'exploration' was the last process of the cognitive apprenticeship approach. This concerned the opportunities that learners could do more exercises so that they were enabled to solve problems on their own.

Consequently, all these factors may contribute to the improvement of the post-test mean scores of academic achievement in the experimental group when compared to the pre-test and the control group. This finding was consistent with Johnson and Fischbach's study (1992), which found that the impact of the cognitive apprenticeship approach on students in light of the attitude towards mathematics learning and problem solving. According to the attitude test, students in the experimental group had higher enthusiasm to learn mathematics and to solve problems than the control group. Also, students in the experimental group had self-confidence and could successfully build the network with other groups. According to Cash and Others (1997), the cognitive apprenticeship instructional method could significantly increase the effectiveness, namely knowing the information as well as having knowledge in dealing with problems and judgment skills. Therefore, this may confirm that the mathematics instructional model using the cognitive apprenticeship approach, as developed in this study, could be implemented for the improvement of students with poor mathematical skills and of their problem-solving skills. Moreover, it enhanced the mathematics achievement in greater extent than traditional instruction, because, for the latter, the teacher tended to put an emphasis on finding a correct answer without taking into account problem-solving methods. Therefore, learners had no opportunity to develop their thinking competence as much as possible (Duangduen Onnuam, 1995). One could say that the learners and contents were the important factor for the mathematics instruction. This was according to the research by Akarawuti Chindanuks (2008) who examined the problems of mathematics instruction of students in Rajamankala University of Technology Krungthep. This study concluded that mathematical foundation of those students was poor; they did not like calculation; and they were confused with the use of formulae. With respect to academic curriculum problem, mathematics was regarded as a boring

subject with a heavy content load. This finding confirmed Jiraporn Chompikul and Arisa Rattanaphet's study (2008) on Basic Mathematics 1 Learning of Prince of Songkhla University's freshmen. In their study, an in-depth interview with a group of students who argued that mathematics instruction in the university were different from school-level one, was conducted. According to this study, the teaching by university lecturers was faster to cope with a heavy content load; while mathematics instruction in higher education level focused on content. Lecture-style teaching was then used in order that the lecturer could teach within the specific schedule. Thus, when students had no time for self-study, they would not be able to clearly understand the problem-solving process and to understand why their teacher used such formulae. Nevertheless, mathematics instruction in Singapore (a country where mathematics achievement was one of the world's highest) focused on the thinking process rather than content (Yeap, 2006 cited in Pawinee Thungthaisong, 2008). Such findings are consistent with the mathematics instructional model using the cognitive apprenticeship approach, developed by the researcher in this study, because this also emphasized learners' problem-solving skills rather than content.

According to the research results, post-test self-regulation in the experimental group was higher when compared to the pre-test with statistical significance level of 0.05. However, for the control group, no difference between pre- and post-test self-regulation was found. This may imply that the developed instructional model could enhance learners' self-regulation. One could say thus that self-regulation was a method that allowed learners to change their individual behaviors toward their desired needs. Self-regulated learners tended to take responsibility, to control, to monitor and to assess their learning behaviors at all times in order that they could achieve their desired academic goals. According to the survey on self-regulation among the university students by Wolter (1998), they used the intellect, determination, and different persuasive strategies to monitor their working efforts level. In this regard, self-regulated students were able to adjust their strategies to suit the situation. Hence, higher self-regulation of students in the experiment group in the post-test was higher than the pre- test, while pre- and post-test self-regulation of the students in the control group was not different. This may be attributed to the instruction of self-regulation techniques by the researcher for those in the experimental group. The students of the experimental group could then engage in behavioral practices according to what they have written in their self-regulation form, which was attached to 4 lessons (one lesson each). They needed to make self-assessment from time to time in order to adjust their

learning behaviors towards desired goal. According to self-assessment by 75% of the students rated their self-regulation at medium to high level (5-10 points). It could be assumed that students in the experimental group had self-regulation behavior. Schunk (2008) argued that, by teaching learners to set goals and to assess their own progress, it could be predicted that learners would archive self-regulation and academic achievement. Besides, students in the experimental group wrote in the self-regulation form that the goals set by most of them were practical and reachable by their ability, for example, understanding content, doing exercises on their own, and passing the test, etc. In this regard, one could say that the aforesaid findings of Schunk are consistent with Bandura's claim (1986 cited in Woranat Molieri, 2007) that goal setting should depend on self-efficacy in which working skills and belief in learning capacity were interrelated.

Monitoring as part of self-regulation was a used by students in doing self-assessment when they learned each lesson. They could consider whether the goals they have set could be achieved. If they could do so, what reward should they give to themselves? On the contrary, if those goals were not achieved, what would they do next? For most of the students who assessed themselves to achieve their goals, they wrote that "I do not have any special reward for myself. I will keep working hard." However, for those who assessed themselves not to achieve their goals, they would not punish themselves. Rather, they wrote that "I will improve my learning behaviors such as working hard and putting more effort in learning. If I have any doubt, I will ask my teacher or classmates immediately. I will do more exercises or review lessons." One could say that those behaviors were regarded not only as positive reactions which they expressed but also as the internal motivation that should be enhanced within the students. This would then be translated into the improvement of students' mathematical performance. According to the study of Hannula (2006) concerning the reflection of mathematics learning motivation, it was found that such motivation did not derive from classroom environment alone. Rather, it was also attributed to learning behaviors and needs to understand what they have learned. It can be said that learning motivation could be a factor for improved mathematics performance. This study likewise was revealed that self-regulation could enhance learning motivation as well.

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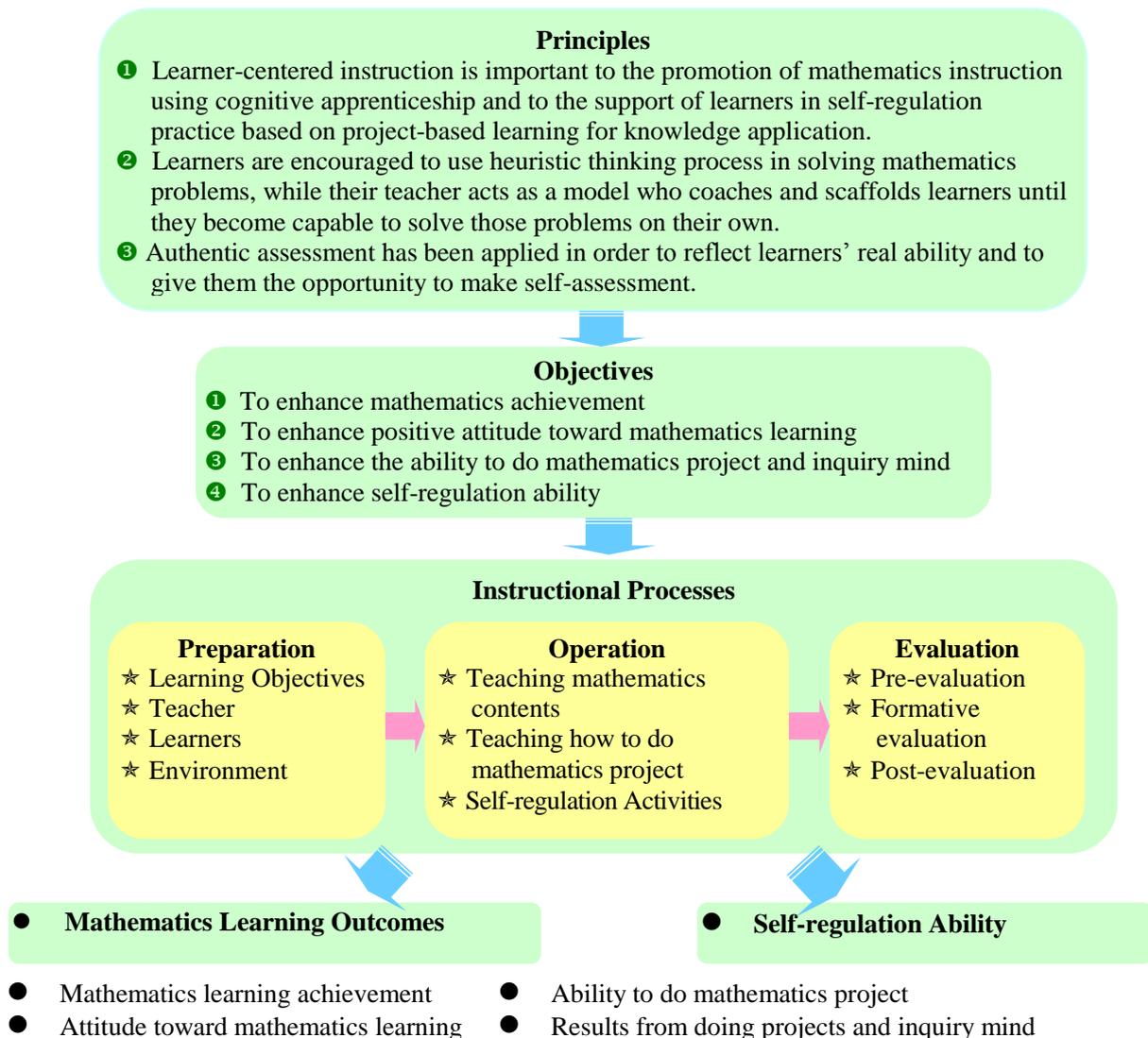


Figure 1: Mathematics Instructional Model using the Cognitive Apprenticeship Approach



Figure 2: The Instruction based on the Developed Instructional Model