THE IMPROVEMENT OF MATHEMATICS CONTENT KNOWLEDGE ON ELEMENTARY SCHOOL TEACHER CANDIDATES IN PROBLEM-BASED LEARNING MODELS

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Abstract

The mastery of teacher candidates on mathematics content knowledge became a focus of attention when some previous researchers showed that they were weak in the knowledge. Whereas, mathematics content knowledge contains interconnected mathematical ideas. Weakness in certain mathematics content will influence the mastery of other ones. This study is one effort to improve mathematics content knowledge (MCK) using problem-based learning (PBL) models. The study group consisted of three research classes, covering one control class and two experiment classes. Control class used conventional learning model. Experiment classes used problem-based learning (PBL) models, namely content competence model as the first model (PBL1) and a combination of content competence model and professional action model as the second one (PBL2). The result showed that teacher candidates in PBL2 had more competence in MCK compared to those of PBL1 class and control class.

Keywords: teacher candidates, mathematics content knowledge (MCK), PBL models

INTRODUCTION

In the middle of 80-es, teacher's complexity of knowledge had been identified by Schulman, one of which as content knowledge. Schulman (1986) stated that content knowledge refers to "the amount and organization of knowledge per se in the mind of the teacher" (p.9). Yet, in the development, this knowledge has mathematics 'specialization' with the term mathematics content knowledge (MCK). This is because teachers do not only give explanation of true or wrong, but are also able to master the effectiveness of concept representation in learning, uncommon strategy in solving mathematics problem, and understand students thinking (Schoenfeld and Kilpatrick, 2008), help the students develop idea and mathematics reasoning (Powell & Hanna, 2006), and are able to diagnose students' error also give the right directive (Ball & Bass, 2009).

Many studies have been conducted on the mastery of MCK. Some of them show that teachers are weak, among others in the material of fraction (Ma, 1999); multiplication and decimal place value (Sullivan, Virgona, Siemon, & Lasso, 2002), basic of geometry (Adholphus, 2011). Not only teachers are weak on MCK, teacher candidates experience the same thing. The study of Livy, Muir, & Maher (2012) shows that teacher candidates find difficulty in defining the term of space and periphery. They also find the same thing in defining geometric structure (Marchis, 2012).

According to Hill, Ball, and Schilling (2008), this weakness can be improved in two ways, namely within the development of teacher professionalism or during mathematics lecture in teacher training program. MCK development for teacher candidates can be a choice. Since teacher candidates learn as self-evident and self-reflection (Kennedy, 1999), they can recheck their knowledge and balance their experience (Kiely, Sandmann, & Truluck, 2004; Kajander, 2007).

Learning method in teacher training, according to Darling-Hammond (1997), can be done by teacher candidates, by examining learning case, teacher research, assessment capability, and portofolio evaluation to measure learning which can be applied on real practical problem. The learning case study, according to Barrows & Tamblyn (1980) and Levin (2001) makes recent learnings; among others is *Problem Based Learning* relevant to learners' needs.

Mathematics Content Knowledge

Someone's ability in defining argument validity or choosing suitable mathematics representation requires basic mathematical knowledge about the material. Such knowledge was defined by Ball, Thames, & Phelps (2008) as teacher knowledge related to lesson content basic or material origin, with the term of subject matter knowledge (SMK). Ball et al. (2008) divided SMK into three kinds of knowledge: firstly common content knowledge (CCK), which is the knowledge commonly used in teaching mathematics, like procedural counting, mathematical problem solving and ability to make mathematical definition. Secondly, horizon content knowledge (HCK), that is knowledge in connecting mathematical ideas. The third is specialized content knowledge (SCK), teacher's skill to present mathematical idea correctly.

Beside the MCK frame formulated by Ball et al. (2008) in Learning Mathematics Teaching (LMT) project, Teacher Education And Development Study in Mathematics (TEDS-M) also made a frame of MCK following TIMSS evaluation using cognitive domain, namely knowing, applying, and reasoning (Tatto et al., 2008). Aspect of knowing is similar to CCK, that is on the ability to memorize, make definition, and run algorithmic procedure. Aspect of applying has sameness of characteristic to SCK on the knowledge to express mathematical idea correctly. And aspect of reasoning has the same characteristic with HCK, on the ability to connect interrelated mathematical ideas.

This PBL study on teacher candidates of Elementary School/MI was focused on the mastery of the candidates on mathematics material, thus PBL is defined as ability to give definition in mathematics (CCK/knowing), represent mathematical idea exactly (SCK/*applying*), and make correlation of interrelated mathematical ideas (HCK/ *reasoning*).

Problem-Based Learning

PBL approach describes learner-centered principle, among others showing the students how to represent developed knowledge; giving time to students to reflect the learning process; giving choice and control to the students in collaborative context; and appreciating individual perspective with the plan it has (Pierce & Lange, 2001). The principle, according to Delisle (1997), makes the students try to understand the correlation between the studied material and the reality. The learning conducted using PBL is in line with the theory of Dewey (1997), that giving relevant problem situation and the existence of group work as stimulus for interaction in lecture can develop students' knowledge and skill to become teachers in the future.

Problem-based learning, according to Barrows and Tamblyn (1980), is "*the learning that results from the process of working toward the understanding or resolution of a problem*" (p.18). The problem given has the authentic and ill-structured characteristics. The characteristics, according to Torp and Sage (2007), support students to learn actively, support knowledge construction, and naturally combine learning and real world. The activities of PBL cover discussion, reflection, research, project, and presentation. The role of lecturer are as speaker, facilitator, trainer, and evaluator in the form of guidance, teaching, and resource to help students gain knowledge and skill of problem solving. The evaluation is authentic, competence-based, and done continuously (Levin, Dean, & Pierce. 2001).

The development of PBL has been done in many universities, either in medical or education. The model of PBL, based on the objective, contains among others content competence model and professional action model (Matusov, Julien, & Whitson, 2001; Savin-Baden, 2003). The first is a model expecting teacher candidates to learn content with having the competence to apply knowledge in context solving and enabling them to rule the problem. The later model is aimed at making the candidates "know-how." Learning enables teacher candidates to do and become competent in practice. In this case, the candidates learn how to solve problem and be competent to apply ability in certain scenario and other situation. The stressing is to result effective skill based on the right knowledge. Being competent to practice does not only result in right knowledge and skill but also attitude known by the facilitators that is suitable for profession life (Matusov et al., 2001). The steps of PBL refer to Torp and Sage (2002), namely: presenting problem, identifying problem, defining problem statement, gaining information and sharing, deciding solution and checking the truth, presenting the solution, and reflex the problem. The steps of PBL in this study combined step 4 and 5, because from the source of information and sharing steps, teacher candidates can decide solution chosen to solve the problem.

The following is a summary of the difference of learning application used in this research.

Table 1 Summary of Mathematics Learning Application

Conventional Learning	PBL 1 Approach	PBL 2 Approach
Teaching materials cover Number & Geometry which are considered weak in Elementary School (ES), the method used is speech /expository.	Teaching materials are designed to present authentic mathematics problem related to teacher and student.	Teaching materials are designed to present authentic mathematics problem related to teacher and student, and groups analyze & do professional action, that is teaching related to mathematics material that is difficult to teach in ES.
Lecturer acts as learning source, who explains concept, gives example of question, do question, and evaluates learning result of teacher candidates.	In this study, lecturer acts as facilitator, who helps teacher candidates in exploring problem.	In this study, lecturer acts as facilitator, who helps teacher candidates in exploring problem.
Teacher candidates play a role as passive knowledge receiver.	Teacher candidates play a role as individual in class, who are actively involved in problem solving.	Teacher candidates play a role as individual in class, who are actively involved in problem solving.

Learning activity in experiment classes is closed with making reflection of learning process and having class discussion on presentation performed by each group. Therefore, the objective of this study is to investigate the influence of PBL models on the content knowledge improvement of teacher candidates. This study was conducted based on a hypothesis that PBL has positive influence on the success of content knowledge mastery. This program was implemented to teacher candidates to know the effect toward the improvement of their MCK.

METHOD

Participants

The participants of this study are 69 teacher candidate students from three different classes joining mathematics lecture in Elementary School teacher training program. From the participants two classes were selected randomly as experiment classes, namely PBL model 1 (22), PBL model 2 (30), and one control class (17) with conventional learning. Mathematics lecture was run for 2 hours each week and was obligatory lecture for all teacher candidates in the second year. Arithmetic and Geometric material took the topic of number, fraction, space and periphery, and volume. All teacher candidates were taught by the same lecturer and all the three research classes got 12 teaching hours.

Instruments

To answer the research question, MCK tests were given in the beginning and in the end of learning. The tests were composed based on the material taught in teacher training program, and were developed through some literary studies and considered suggestions from expert. The MCK test used was developed from Ma (1999) and Cheang, et al. (2007), then consulted to experts and tried. To make the assessment of MCK test easier, the researcher compiled a test scoring guide based on *Holistic Scoring Rubrics* by Cai, Lane and Jacobcsin (1996). Thus scoring criteria for MCK was necessary to make.

Content validation was done to show that the instrument composed agreed with the curriculum, material and learning objectives expected (Cohen et al. 2007) from MCK instrument. Kendall's W test resulted significance value of (0,829) > α (0,05). This meant that validators had the same perception on MCK test instrument. The instrument reliability was shown by the result of Cronbach's Alpha which yielded a value of 0,619.

Table 2 ANOVA results on MCK pre-test scores

Source of Variance	Sum of Square	df	Mean Squares	F	P	Significant Difference
Between Groups	19.009	2	9.504	.636	.544	-
Within Groups	209.345	14	14.953			
Total	228.354	16				

To know the significant difference of MCK scores among the research groups, One-Way Analysis of Variance test was done. The results are shown in Table 2. Based on the table, one-way analysis of variance showed no significant difference among the three research classes, considering the results of F (0,636) = 0,544 p > 0,05. It can be interpreted that the three research classes had the same chances to be successful before the experiment was done.

The Analysis in this research used normalized gain <g> developed by Hake (1998) to know the progress of MCK.

$$<g>= \frac{\text{(postest-pretest)}}{\text{(100-pretes)}}$$

Treatment

There were two models of PBL used in this study, namely content competence model that is the mastery of mathematical concept, and the model which combine this model and professional action model. The first learning (PBL1) was assumed to be able to solve the problem of teacher candidates of their weak mastery on content knowledge, all at once investigate the problem of students and teachers that are relevant to their future profession. The second learning (PBL2), was assumed to be able to improve content knowledge of the teacher candidates through relevant problem situation, also enable them to make analysis of weak mathematics material in ES and do professional action to design learning on the weak material.

The learning in PBL1 and PBL2 have sameness on content competence, as follow:

Table 3 PBL Content Competence

Learning Activities	Development Aspects	
	Progress	**MCK**
1. a. Write all possible numbers between -2 to 2 on numeral line b. of any kind of r, s, and t, give arguments to support or deny if: 1) r > s and s > t, so r > t 2) r + t > s + t 3) t > s > r, so s.r > t.s 2. Give three situations around the students that can be meant as “ 6 + (-8)”	Beginner	1.a. Students give example only of round numbers b. Able to give representation for 1) and 2), find difficulty for 3), not able to correlate the idea of negative round number multiplication. 2. Situation given are limited and less meaningful
	Middle	1.a. Students are able to identify round, fraction, and decimal numbers to support and deny b. Able to give representation for 1) and 2), able to identify 3) including negative round number 2. The situation is suitable and almost meaningful
	Mature	1.a. Students are able to identify round, fraction, and decimal numbers to support and deny, followed with explanation. b. Able to finish 1), 2), and 3) completely with various possibilities. 2. Case situation are suitable and meaningful

Example of learning plan design on Table 3 was done by giving preliminary identification of respond possibility on teacher candidates’ MCK progress. The addition of professional actions in PBL2 was done in the following design, Tabel 4 PBL Professional Actions

Learning Activities	Development Aspects	
	Progress	**MCK**
Mention the difficulty of material of numbers in Elementary School and the solution.	Beginner	Able to mention obstacles of material of numbers in ES but solution is limited.
	Middle	Able to mention obstacles of material of numbers in ES with almost complete solution.
	Mature	Able to mention obstacles of material of numbers in ES with complete solution.

The model of professional actions with the design example in Table 4 was done in order that teacher candidates obtain a deep understanding on certain material of mathematics in Elementary School learning. The identification of formed respond enable lecture to give appropriate direction to change the view of teacher candidates. According to Moursund (2005), Elementary School teacher candidate educator needs to know the mathematics expertise level of teacher candidates to help improve their mathematical expertise.

RESULTS AND DISCUSSION

To examine the effect of learning toward MCK using PBL1, PBL2, and conventional learning, MCK post-test average scores of teacher candidates were compared to One-Way Analysis of Variance (Anova). LSD test was used to define which group was significantly different as the result of ANOVA analysis.

The first hypothesis that was discussed in this research was “PBL1 model would cause more success in MCK improvement than conventional learning”. The second hypothesis was “PBL2 model would cause more success in MCK improvement than conventional learning”. The third hypothesis was “PBL1 and PBL 2 models would not cause more success in MCK improvement compared to conventional learning. To examine the hypothesis, fraction gain <g> scores were compared among three research classes.

One-way analysis of variance was done to determine whether there was significant difference among the three research classes as given in table 5. Advanced post hoc test to know the difference of fraction gain MCK is presented in Table 6.

Tablel 5 ANOVA results on normalized gain scores MCK

Source of Variance	Sum of Square	df	Mean Squares	F	P	Significant Difference
Between Groups	.305	2	.152	8.490	.001	1-3
Within Groups	1.185	66	.018			2-3
Total	1.490	68				

Table 6 MCK Progress Post Hoc Test Viewed from Learning Approach Aspect

(I) Learning	(J) Learning	*Mean Difference* (I-J)	*Std. Error*	Sig.
Conventional Learning	PBL1	-.031326	.043269	.472
	PBL2	-.149669*	.040676	.000*
PBL1	PBL2	-.118342*	.037610	.002*

Anova Test on Table 5 above shows F value (8.490) = 0.001 $p < \alpha = 0.005$ which means that MCK improvement score average showed significant difference in three research classes. Post hoc test result on Table 6 above shows that significance value is smaller than $\alpha = 0,05$ occurred between common learning class and PBL2 and between PBL1 and PBL2. Mean difference shows (-) negative mark, meaning that PBL 2 was higher on MCK improvement than in conventional learning class and in PBL1 class. In addition, MCK improvement between teacher candidates using conventional learning and PBL1 showed no difference.

Basically, the MCK improvement result was better for teacher candidates who experienced PBL2 combining content competence and professional action. The progress could be caused by the weak material study done by teacher candidates, where they got the best solution of how to teach it. PBL1 class which was content competence model had MCK progress that was not different from that of conventional learning class. Dewey's opinion (1997) can explain the phenomenon, with his statement that teacher candidates' intellectualism can improve if lecture can create environment which give their students maturity of experience. Better maturity existed in PBL2 compared to PBL1 and conventional learning.

The study that had been conducted on teacher preparation program using PBL for teaching mathematics supported this study result. Schmude, Serow, and Tobias (2011) studied the mathematics knowledge of Elementary School teacher candidates showed better result through pedagogical understanding construction in PBL with interaction-rich environment. In PBL2 teacher candidates got freedom to give solution for mathematics teaching that was interactive, and there were feedback from other candidates about the effectiveness of the practiced teaching design. The research of Padmavathy and Mareesh (2013) found that PBL affects the progress of students' content knowledge because in the learning, PBL can develop creative thinking, critical decision making, and problem solving. PBL process offers wider opportunities for the learners to learn content with active involvement, be motivated, and interest-drawn in the meaning that using PBL, learners have positive attitude toward material. Finally, it prompts them to be successful, and the shaped experience can strengthen the long term memory more. In PBL environment (Erickson, 1999; Lubienski, 1999) learners have more opportunities to learn mathematics process connected to communication, representation, modeling, and reasoning.

Students who were taught mathematics with conventional teaching environment were given exercises, rules, an equation needed to learn, but only in unusual situation. This supported Kirschner, Sweller, and Clark study (2006) that conventional learning is suitable with human cognitive structure. Human can learn well if they get guidance which complete and based on the explanation they can develop. It is different from learning which is minimum in guidance such as PBL. It exactly obstructs learner development, when learners are demanded to learn something new with minimal knowledge about the thing. The result of the study showed the contrary fact. The MCK progress of teacher candidates in conventional learning class compared to PBL1 showed no difference in result. It means teacher candidates who study by getting complete explanation about a concept and procedure have no difference with those who learn concept and procedure through authentic problem given. After being investigated, activities in PBL2 were the same as those of PBL1, but there was difference on activity of 'professional action' in PBL2 that was interactive. In PBL2 teacher candidates explained mathematics material considered difficult for students/teachers of Elementary School. PBL2 approach could run well because the lecturers gave the teacher candidates freedom to explore mathematics concept that was by studying in group then in turn explainning in front of the class. In addition, in PBL2, teacher candidates group explained material then other candidates gave responds about the acceptability of the given explanation. The process prompted communication, representation, mathematics reasoning through problem presentation process in elementary school and group success was obtained based on the cooperation that was formed in the group.

CONCLUSION

The main objective of this study was to know the effectiveness of PBL learning model toward the development of teacher candidates' MCK. The result showed that MCK development in PBL1 orienting in content competence and conventional learning showed no difference. In PBL2 teacher candidates were trainned to study the weak mathematics content material of Elementary School, then taught it to other groups in class. The process orienting on content competence and professonal action developed the abilities of knowing, applying, and reasoning on Mathematics, thus caused progress significant MCK progress compared to other classes.

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