MATHEMATICS PEDAGOGICAL CONTENT KNOWLEDGE IN PROBLEM-BASED LEARNING

Ifada Novikasari
IAIN Purwokerto, A. Yani Street No.40 A Central Java, Indonesia
email: ifa_da@yahoo.com

Abstract

Some researchs have shown that pre-service teachers (PSTs) are weak in content and find difficulty in making teaching plan. Therefore, there should be an effort to change learning in teacher trainning program which is previously teacher-centered into student-centered. One of learning which is student-centered is Problem-Based Learning (PBL). The study of PBL using learning models it has as efforts to improve mathematics pedagogical content knowledge (MPCK) of PSTs has not been conducted before. The results of the study, there was no effect of beginning knowledge of the PSTs on MPCK progress; the progress achievement of PSTs' MPCK was different significantly for the PSTs studying in PBL1, PBL2, and ordinary learning; the superiority of PBL1 and PBL2 implementation is that learning activities were dominated by the PSTs and learning activities made them active finding problem solution.

Keywords: MPCK, PSTs, problem-based learning,

1. Introduction

The challenge of eduation in creating Indonesian next generation, who are pious and smart, is not only the responsibility of the government as the policy maker, but also teachers as the field executors. The recent policy made by the government in the form of reformation of education curriulum, becoming 2013 Curriculum, once became a controversion. It was because there were many education practitioners especially teachers responding that the too-fast change has no adequate preparation (Novikasari, 2013). The dramatic reformation effort, according to Corcoran (1995) raised hope for students, and consequently for teachers. Teachers were demanded to master new skill and reponsibility and change in practice.

Teacher trainning has an objective to supply PSTs with qualifications of teachers. His experience in teacher trainning is influencing to strengthen someone's identity as a teacher in the future (Grevholm, et.al. 2009). The experience is reflected in the curriculum used by the trainning institution. Generally, teacher trainning curriculum covers lecture material, pedagogic knowledge, and practice. Mastery of material if related to teacher competence is meant as profession competence, pedagogic knowledge and practice as pedagogic competence.

The recent development of research on content knowledge and pedagogic content knowledge has specialized on mathematics material. This specialty is caused by the complexity of knowledge needed by teachers when teaching mathematics. According to Schoenfeld and Kilpatrick (2008), teaching mathematics needs special knowledge. The knowledge requires teacher not only to master content and be able to teach it, but also needs to have knowledge among others concept representation effectiveness in learning, unusual strategy in solving mathematics problem, understanding students' thinking, and so on. This was strengthened with a study done by Ball, Hill, and Bass (2005) and Tatto, Schwille, Senk, Ingvarson, Peck, and Rowley (2008), that knowledge of teaching mathematics consisting of mathematic content knowledge (MCK) and mathematics pedagogy contant knowledge (MPCK) are important factors for the success of students mathematics in school.

A teacher's mastery on only mathematics content knowledge without being combined with the mastery of pedagogic knowledge will cause a failure of learning objective achievement. Teachers tend to teach to achieve completeness of curriculum book, or lesson plan. They do this although they know that students will forget most of what they learn (Moursund, 2005).

1.1 Mathematics Pedagogical Content Knowledge

According to Shulman (1986) pedagogical content knowledge (PCK) is one of categories of educator knowledge. PCK is knowledge category related to teaching lesson material that is way of teaching in many forms: representation, analogy, ilustration, example, explanation, and formulation until the lesson can be understood by students. Including in this kind of knowledge is undertanding about what makes certain learning easy or difficult referring to conception and preconception of students so that educators can detemine certain strategy in teaching. In the development, this knowledge has mathematics 'specialization' known as mathematics pedagogical content knowledge (MPCK).

Projects on Learning Mathematics Teaching (LMT) in Michigan University developed MKT models based on Shulman's concept, by clarifying and developed measurement of PCK. Based on analysis of Ball, Thames, and Phelps (2008) on basic knowledge of teaching mathematics, Shulman's categories of PCK. PCK is categorized into Knowledge of Content and Students (KCS), Knowledge of Content and Teaching (KCT) and Knowledge of Content and Curriculum (KCC). The domain of KTM is ilustrated as follows:

When summerized, PCK and its components can be shown in the following table of characteristics (Ball et al., 2008; Shulman, 1986):

Table 1. Characteristics of PCK

Category	Characteristics
PCK	1. Ability to manage, represent, and adapt topic, problem, or issue to student variety of interests and competence 2. Ability to present topic for teaching
KCS	1. Ability to anticipate the way students who will interact with concept, such as error, difficulty, ease, confusion of mathematics content 2. Ability to motivate and interpret students' thinking based on their explanation
KCT	1. Knowledge on order of mathematical content 2. Ability to choose and sort example 3. Ability in choosing representation, method, and procedure 4. Ability to guide mathematical discussion, including decision making about studets' statement related to concept
KCC	1. Ability to compose topic to teach in school 2. Knowledge to use curriculum source, such as appropriate teaching book to manage student study program

Beside LMT, other projects were also done by Teacher Education and Development Study in Mathematics (TEDS-M) which developed MPCK assesment in teacher education enclosing assesment of belief. MPCK framework has three sub-domains, namely mathematics curricular knowledge, knowledge of planning mathematics, and knowledge of enacting mathematics. The MPCK sub-domain aspects are described in the following table:

Table 2. Sub-domain and sub-domain aspects of MPCK in TEDS-M

Sub-domain of MPCK	**Aspects**
Mathematics curricular knowledge	1. Establishing appropriate learning goals 2. Knowing different assessment formats 3. Selecting possible pathways and seeing connections within the curriculum 4. Identifying the key ideas in learning programs 5. Knowledge of mathematics curriculum
Knowledge of planning for mathematics teaching and learning	1. Planning or selecting appropriate activities 2. Choosing assessment formats 3. Predicting typical students' responses, including misconceptions 4. Planning appropriate methods for representing mathematical ideas 5. Linking the didactical methods and the instructional designs 6. Identifying different approaches for solving mathematical problems 7. Planning mathematical lessons
Enacting mathematics for teaching and learning	1. Analyzing or evaluating students' mathematical solutions or arguments 2. Analyzing the content of students' questions 3. Diagnosing typical students' responses, including misconceptions 4. Explaining or representing mathematical concepts or procedures 5. Generating fruitful questions 6. Responding to unexpected mathematical issues 7. Providing appropriate feedback

(Source: Senk et al., 2008)

The mastery of mathematics pedagogic content knowledge is aimed to make mathematics acceptable, aggree with appropriate representation for students. This is like what Cheang, Yeo, Chan, Lim-Teo, Chua, and Ng (2007) stated that teacher with strong MPCK will be able to formulate explanation and give representation of concept; rebuild mathematis knowledge form the learners' perspective; have mathematics comprehension to use like what is going to be taught; and have ability to choose the right action when face students' learning difficulties.

Based on Table 1 and Table 2 the writer interprets that MPCK is meant as knowledge related to presentation of mathematics material so that it is acceptable for students. The indicators of this ability cover: ablity to understand structure and interrelatedness in mathematics topic (mathematical curricular knowledge), establish various representation/method/procedure of mathematics to explain (enacting mathematics for teaching and learning [interactive]), and anticipate students' thinking from misconception (knowledge of planning for mathematics teaching and learning).

1.2 Problem Based Learning

PBL is resulted form the process of comprehension work or solving of problem. Problem is given in the first learning process and gives a help as attention or stimulation to apply problem solving or reasoning skill, in the same manner as information searching or knowledge needed to comprehend the mechanism of problem solving and how it can be solved. Evaluating research result or journal article, or practice problem can be attention in PBL problem (Barrows & Tamblyn, 1980; Levin et al., 2001). Extensively, in learning, according to Campbell and Campbell (2009) educator needs to relate learners' beginning knowledge to content to learn so can help learner achieve their success. Thus, studied PBL also needs to consider the aspect of beginning knowledge level of teacher candidates, so it was assumed that the candidates could develop begun from the knowledge they had. The main things as major attention in this study were the factors of knowledge of teaching mathematics namely MPCK, PBL, ordinary learning, and PSTs. Was there any difference of MPCK progress on PSTs with PBL1 approach, PBL2 approach, and ordinary learning?

2. Method

This study is a quasi experiment with non-probability group. In non-probability sample taking, the researcher chose certain group (Cohen, Manion, & Morrison, 2007). Two classes were selected as experiment classes, namely PBL model 1 (22), PBL model 2 (30), and one class as control class (17) with ordinary learning. Mathematics lectures were run 2 hours per week and were obligatory for all teacher candidates in the second year of elementary school teacher trainning program. The material on Arithmetic and Geometry were given with the topics 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. The instruments used was MPCK tests. Test instruments was developed from Ma (1999) and Cheang et al., (2007) then consulted with expert and tried. Pretests were given in the three classes to ensure that the two experiment classes and one control class were not different significantly.

3. Results and Discussion

Mathematics pedagogic content knowledge measured in this study was limited on the ability to make various representation/method/procedure of mathematics to explain, understand structure and the relatedness in mathematical topics, and ability to anticipate students' thinking from misconception. MPCK of PSTs was measured through seven description test questions. Table 9 is a summary of analysis result of average difference test using Kruskal-Wallis test to compare the three learning classes based on learning approach.

Table 3. Average Difference Test of MPCK Progress Viewed from Learning Approach

Class	Class	Kruskal-Wallis test	Mann Whitney test
Ordinary L.	PBL1		0,015*
	PBL2	0,018*	0,009*
PBL1	PBL2		0,774

The MPCK progress in experiment and control classes using Kruskal-Wallis test resulted in significance value = 0,018 < α =0,05 so H_o was rejected. It meant there was significant difference among the three research classes in MPCK progress. In other word, there was difference of MPCK progress among teacher candidates in ordinary learning class, PBL1, and PBL2.

MPCK progress in ordinary learning class toward PBL1, and PBL 2 with significance value of 0,015 and 0,009 smaller than α =0,05, so H_o was rejected. It meant, there was significant difference of MPCK progress between ordinary learning class and PBL1 and PBL2. MPCK progress in PBL1 was higher than in ordinary learning class. MPCK progress in PBL2 was higher than in ordinary learning class. If compared, between PBL1 class and PBL2 class it appeared significance value of 0,774 bigger than α =0,05, so H_o was accepted. It meant there was no significant difference of MPCK progress between PBL1 class and PBL2 class.

Based on the result of the study, PBL1 and PBL2 approaches showed no difference of MPCK progress. The problems presented in learning SAS showed achievement that PSTs' MPCK had improved. The beginning assumption of the researcher, PBL2 was designed to improve pedagogic knowledge more than PBL1, but in fact, there was no difference. The activities of PSTs in PBL2 did not really have tendention to improve their MPCK. As stated by Duch (2001, p. 48), a problem is called effective if involves students' interest and motivate them to investigate deeper understanding on known concept in the form of mathematics material in primary school. In this research, the problems given as part of content competence model PBL had been able to improve MPCK of the PSTs. The same result was also found by Martin, Grimbeek, and Jamieson-Proctor (2013), MPCK progress was higher on PBL class compared to speech class on algebra, measuring, geometry, and probability & statistics lectures.

The following is Kruskall-Wallis Test on gain comparison between control class and two experiment classes.

Table 4. Average Difference Test of Aspect in MPCK

Aspect of MPCK	Class	Mean	Median	Dev.Std.	*Asymp.Sig.*	
Create representation to explain	Ordinary L.	0,880	0,000	1,576	0,171	0,000*
	PBL 1	1,770	1,500	2,022		
	PBL 2	2,200	2,000	2,670		
Understad mathematical structure	Ordinary L.	0,290	0,000	0,772	0,512	
	PBL 1	0,270	0,000	0,985		
	PBL 2	0,600	0,000	1,404		
Anticipate students' thinking	Ordinary L.	2,120	2,000	1,799	0,114	
	PBL 1	3,590	3,500	2,323		
	PBL 2	3,200	3,00	2,203		

The MPCK progress aspect of making representation to explain, understanding mathematical structure, and anticipating students' thinking in the three research classes showed differences. Examined further, each of the aspects showed no differences in the three research classes. It meant, the difference occured if we compare among MPCK aspects in three research classes. Quantitative analysis showed a tendency that there was no effect of treatment toward MPCK progress.

On the aspect of ability to make representation to explain in three research classes, there was no differences occured. On this aspect in three research classes, it was found that PSTs found difficulty in giving meaningful example in division. According to Petrou & Goulding (2011, p.17), this aspect could not be differenciated with the aspect of idea representation in MCK. However, in learning it was found that some PSTs made analogy of fraction division operation with living things. This aspect is different from the one existing in MCK, because this aspect focuses mainly on the ability to give representation to explain. Specifically, development of aspects started to appear in three research classes. This aspect was identified by Fandiño (2007) as didactic transposition that is changing "knowledge" into "taught knowledge". According to him, this aspect needs PSTs who are creative. The creativeness of PSTs on this aspect had not developed well in three research classes.

The aspect of ability to understand mathematical structure in the three research classes showed no difference. In ordinary learning class, PBL1, and PBL2 this aspect was dominated by PSTs with high mathematics knowledge or those mastering mathematical concept well. Most teacher candidates in ordinary learning class could not follow the learning on this aspect well. In PBL1 and PBL2 classes, the groups were dominated by clever PSTs and uniqueness in connecting relations of space and periphery in various possibilities of answers could not be followed well by other teacher candidates. This caused the PSTs tended to wait answers from other clever candidates. This aspect appeared only on small portion of PSTs.

The aspect of ability to anticipate students' thinking in three research classes showed no difference. This aspect which is the highest aspect of MPCK in ordinary learning class, PBL1, and PBL2 qualitatively tended to follow the development of previous aspects. Fennema and Franke (Petrou & Goulding, 2011) stated that knowledge of how students think and learn is the core of teaching effective mathematics. This aspect appeared only on few PSTs in three research classes. On this aspect some PSTs were able to give appropriate responds on students' mathematics idea probability.

4. Conclusion

The MPCK progress of PSTs using PBL1, PBL2, and ordinary learning classes showed significant difference. PBL1 and PBL2 showed significant difference to ordinary learning class. MPCK progress in PBL1 and PBL2 classes showed no difference. This could be because of the learning process that involved problem relating to mathematics teaching in primary school. PSTs were trainned on real problem situation agree with their future profession so that they had higher respond on the problem.

References

Ball, D., Hill, H. C., & Bass, H. (2005). Knowing Mathematics for Teaching: Who Knows Mathematics Well Enough to Teach Third Grade, and How Can We Decide? *Journal of the American Federation of Teachers*, 2005, pp. 14-22.

Ball, D., Thames, M., & Phelps, G. (2008). Content Knowledge for Teaching What Makes It Special? *Journal of Teacher Education*, 59 (5), pp. 389-407.

Barrows, H., & Tamblyn, R. (1980). *Problem-Based Learning An Approach to Medical Education*. New York: Springer Publishing Company.

Campbell, L., & Campbell, B. (2009). *Mindful Learning: 101 Proves Strategies for Student Teacher Succes*. California: Corwin Press.

Cheang W. K., Yeo K. J., Chan C. , Lim-Teo S. K., Chua K. G., & Ng L. E. (2007). Development of Mathematics Pedagogical Content Knowledge in Student Teachers. *The Mathematics Educator*, 10 (2), pp. 27-54.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research Methods in Education*, sixth edition. USA: Taylor & Francis Group.

Corcoran, T. (1995). *Helping Teachers Teach Well*: *Transforming Professional Development*. CPRE Policy Briefs. RB-16 June 1995.

Duch, B. (2001). Model for Problem-Based Instruction in Undergraduate Courses, in Duch, B., Groh, S., Allen, Eds. *The Power of Problem-Based Learning*.Virginia: Stylus Publishing.

Fandiño, P. M. I. (2007). Fractions: conceptual and didactic aspects. *Acta Didactica Universitatis Comenianae*, 7, pp. 23-45.

Grevholm, B., Millman, R, & Clarke, B. (2009) Function, Form and Focus: The Role of Tasks in Elementary Mathematics Teacher Education. In B. Clarke, B. Grevholm, and

R. Millman (eds.), *Tasks in Primary Mathematics Teacher Education: Purpose, Use and Exemplars*, Mathematics Teacher Education (4), Springer.

Levin, B., Dean, C., & Pierce, J. (2001). In Barbara Levin (Ed), *Energizing Teacher Education and Professional Development with Problem-Based Learning*. Virginia: Association for Supervision and Curriculum Development.

Ma, L. (1999). *Knowing and teaching elementary mathematics: Teachers' understanding of fundamental mathematics in China and the United States*. Mahwah, N.J: Lawrence Erlbaum Associates.

Martin, D.A., Grimbeek, P., & Jamieson-Proctor, R. (2013). Measuring problem-based learning's impact on pre-service teachers' mathematics pedagogical content knowledge. *Proceedings 2nd International Higher Education Teaching and Learning Conference*.

Moursund, D. (2005). *Improving Math Education in Elementary Schools: A Short Book for Teachers*. http://darkwing.uoregon.edu/~moursund/Math/El Math Book.pdf (10 September 2012).

Novikasari, I. (2013). Analysis a New Curriculum in Mathematical Aspects. *Proceeding Mathematics Education Seminar in Yogyakarta*, Indonesia, November 2013.

Petrou, M., & Goulding, M. (2011). Concetualising Teachers' Mathematical Knowledge in Teaching. In Rowland, T & Ruthven, K (Ed.), *Mathematical Knowledge in Teaching*. www.springer.com (15 November 2014).

Schoenfeld, A. H., & Kilpatrick, J. (2008). Toward a Theory of Proficiency in Teaching Mathematics. In D. Tirosh & T. Wood (Eds.), *The international handbook of mathematics teacher education*: Tools and processes in mathematics teacher education. Rotterdam: Sense Publishers.

Senk, S., Peck, R., Bankov, K, & Tatto, M. (2008). *Conceptualizing and Measuring Mathematical Knowledge for Teaching*: Issues from TEDS-M, an IEA Cross-National Study. Mexico: ICME 11, www. e11.org/document/ get/746 (21 Agustus 2014).

Shulman, Lee, S. (1986). Those Who Understand: Knowledge Growth in teaching. *Educational Researcher*, Vol.15, No.2 (Feb. 1986), pp. 4-14.

Tatto, M. T., Schwille, J., Senk, S., Ingvarson, L., Peck, R., & Rowley, G. (2008). *Teacher Education and Development Study in Mathematics* (TEDS-M): Policy, practice, and readiness to teach primary and secondary mathematics. Conceptual framework. East Lansing, MI: Teacher Education and Development International Study Center, College of Education, Michigan State University.