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EFFECTS OF ACTION RESEARCH ON PROFESSIONAL LEARNING COMMUNITY FOR TEACHERS' MPCK

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Abstract: *This study is an action research to investigate the effects of the professional learning community (PLC) for improving teachers' mathematical pedagogical content knowledge (MPCK). The PLC is organized by mathematics teacher educator and primary teachers together so as to improve MPCK of primary school teachers. The team of mathematics PLC develops this platform based on the cooperation of mathematics teacher educators and primary school teachers. In terms of mathematics PLC, the mathematics teacher educators survey the need for primary school teachers and then increase their MPCK. Major activities are effective strategies for mathematics instruction, including worked examples of life mathematics, children's schema of learning mathematics and instructional strategies for mathematics reading comprehension. An internet platform system also helps primary school teachers access the practical examples of effective mathematics instruction and share their video of mathematics instruction. Within one semester, these primary school teachers participate in two workshops and one conference. They adopt these remedial instruction strategies in the mathematics classroom, especially for those students of low mathematics achievement. They do reflections about their mathematics instruction and these primary schools reveal high improvement on MPCK. The results conclude that the action research could improve teachers' MPCK and proficiency in mathematics instruction. All the teachers could be properly classified into six clusters based on the increment score of MPCK. Based on the findings, some suggestions and recommendations are discussed for future research.*

Keywords: *Mathematics Instruction, Mathematical Pedagogical Content Knowledge (MPCK), Mathematics Teacher Educators, Professional Learning Community (PLC)*

Introduction

Many literatures related to education indicate that subject matter knowledge is the most essential knowledge for teachers to provide effective learning experiences for their students. Numerous studies also have provided some evidence in support of this belief, showing that a greater of student achievement growth is being assigned to a teacher with deeper content knowledge. Besides, much of these evidences is most persuasive in mathematics (Tchoshanov, 2008). In terms of in-service teachers, professional development in promoting teaching is the responsibility of teachers. As described in the earlier literatures, findings on teachers' degrees completed and the number of coursework took were positively associated with student achievement, and the evidence was most persuasive in mathematics (Darling-Hammond, 2000). It suggested teachers' knowledge of mathematics was likely to have a strong influence on student achievement when that knowledge was directly relevant to their teaching.

Literature Review

Mathematical Knowledge and Mathematics Instruction

About twenty years ago, studies in subject matter knowledge gained much attention when Shulman (1987) indicated teacher knowledge include the following dimensions: (1) content knowledge; (2) general pedagogical knowledge; (3) curriculum knowledge; (4) pedagogical content knowledge; (5) knowledge of learners and their characteristics; (6) knowledge of educational contexts and (7) knowledge of educational ends, purposes, and values. Shulman (1986) also suggested two kinds of understanding of the subject matter knowledge that teachers need to have. The two kinds of understanding are 'knowing that' and 'knowing why'. It is because teacher needs to understand that something is so and also why it is so. In tersm of "knowing that", it is the most basic level of subject-matter knowledge and adequate pedagogical content knowledge. They include declarative knowledge of rules, algorithms, procedures and concepts related to specific mathematical topics in the school curriculum. On the other hand, 'Knowing why' is the knowledge about underlying meaning and understanding of why things are the way they are. Similarly, in accordance with Shulman's (1986) conceptualization of teacher subject matter knowledge, Ball (1991) claimed that subject matter knowledge incorporates an understanding of the intellectual fabric and essence of the subject matter itself. Therefore, issue of subject matter knowledge of teachers become an important research field related to teacher education, in particular with respect to mathematics teachers (Hill, Rowan, & Ball, 2005). Based on the viewpoints of Shulman's (1987) dimensions of subject matter, Ball, Thames, & Phelps (2008) and Hill, Rowan, & Ball, (2005) proposed a special kind of knowledge required only for teaching mathematics and this kind of knowledge is mathematical knowledge for instruction.

Since the knowledge of mathematics teachers is quite different from that needed by other subject, mathematics teachers need to make an explicit focus on the work of mathematics instruction. Mathematics instruction includes interpreting the work of students and analyzing errors students make. Mathematics teacher must be able to choose the mathematical representation for a given situation so as to help students understand mathematics concepts (Hill, Rowan, & Ball, 2005). Therefore, Ball, Thames, and Phelps (2008) proposed a diagram as to domains of mathematical knowledge for teaching (See Figure 1).

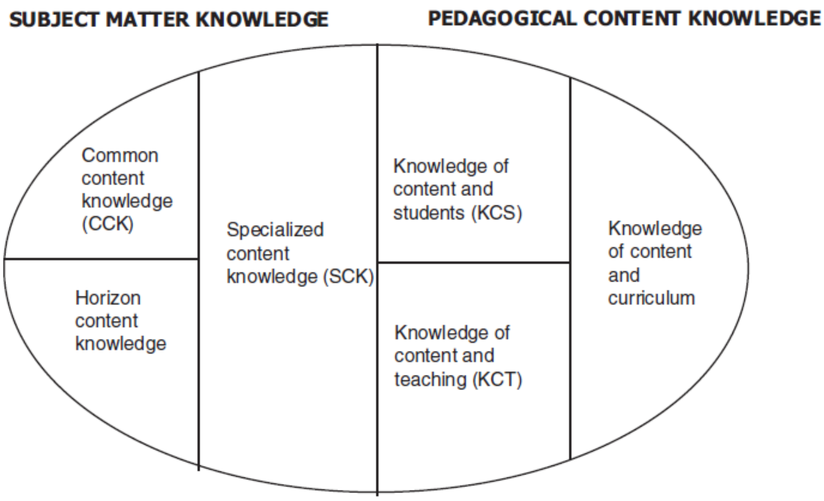

Figure 1: Domain Map for Mathematical Knowledge for Teaching (Adapted from "Content Knowledge for Teaching: What Makes It Special?" by Ball, Thames, and Phelps, 2008, p. 403.)

Knowledge of the subject matter of mathematics refers to one's depth and breadth of understanding of mathematical concepts and processes. Moreover, teacher's pedagogical content knowledge is directly related to the ways of taking subject matter and making it accessible to students (Ball, Thames, & Phelps, 2008). NCTM (2000) also shows that teachers need several different kinds of mathematical knowledge. These knowledges is the whole domain which include (1) deep, flexible knowledge about curriculum goals and about the important ideas that are central to their grade level; (2) knowledge about the challenges students are likely to encounter in learning these ideas; (3) knowledge about how the ideas can be represented to teach them effectively and (4) knowledge about how students' understanding can be assessed (NCTM, 2000, p. 17). In addition, Schoenfeld and Kilpatrick (2008) also establish a framework that distinguished between two kinds of mathematics content-specific knowledge, which are mathematics content knowledge (MCK) and mathematics pedagogical content knowledge (MPCK). MCK is the mathematics about definitions, concepts, algorithms, and procedures and MPCK is the complex interactions between knowledge of the discipline of mathematics and the principles of mathematics specific pedagogy (Kwong et. al, 2007). Senk et al. (2012) suggest the MCK and MPCK of are important for pre-service and in-service teachers.

Many researches give evidence to show that mathematics teachers require more MCK and MPCK. Ball, Lubienski, and Mewborn (2001) find that many teachers do not possess a fundamental understanding of MCK. Ma (1999) introduces profound understanding of fundamental mathematics (PUFM) and claims this conceptualization of pedagogical content knowledge could be used to analyze teacher's construction of knowledge about teaching mathematics. Ma (1999) further explains that a mathematics classroom should have the following four characteristics: (1) connectedness: a teacher with profound understanding has a general intention to make connections among mathematical concepts and procedures; (2) multiple perspectives: those who have achieved profound understanding appreciate and can provide mathematical explanations for different facts of an idea and various approaches to a solution, as well as their advantages and disadvantages; (3) basic ideas: teachers with profound understanding revisit and reinforce 'simple but powerful basic concepts and principles of mathematics, and (4) longitudinal coherence: teachers with profound understanding are ready at any time to exploit an opportunity to review crucial concepts that students have studied previously and are able to take opportunities to lay the proper foundation for what students will study later. The best pre-service and in-service teacher education programs can prepare teachers to be learners who will learn and develop throughout their teaching careers.

Professional Learning Community for Mathematics Instruction

Many literatures show that one feature of successful professional development models is the ability to create community (Cobb, McClain, Lamberg, & Dean, 2003; Franke & Kazemi, 2001; Grossman, Wineburg, & Woolworth, 2001). Chapman (2014) considered a shift from within-school, to between- school and beyond- school to improve educational systems is needed. This shift aims at making schools become better place for students, teachers, and is definitely complicated by the challenge of working across organizational, geographical and professional boundaries. Sprinthall, Reiman, and Thies-Sprinthall (1996) classified teacher professional development into craft, expert, and interactive models in which the interactive model describes that teachers' knowledge grows when external sources of information lead to new experiences in the classroom, thus enhancing professional development. Here, an external source of information, which could be the consequence of participation in a network or community (Macià & García, 2016). A professional community provides an opportunity for teachers to do reflection that has been considered as an essential component of teacher professional learning (Chamoso & Cáceres, 2009; Clarke & Hollingsworth, 2002; Schön, 1987).

National Council of Teachers of Mathematics (NCTM) addressed that the usage of technology in mathematics lessons is a necessity and that technology must be adapted to the teaching-learning process (NTCM, 2000). Li (2003) pointed that face-to-face and online learning in a professional development program is able to complement each other. An asynchronous learning community is relevantly more suitable for PLC since the participant teachers are often busy and located in different schools. Asynchronous learning has been widely used in in-service training programs (Asensio-Pérez et al., 2017; Khine, Yeap, & Lok, 2003; Li, 2003; Loving, Schroeder, Kang, Shimek, & Herbert, 2007; Maor, 2003). An asynchronous learning environment is beneficial for busy teachers to get helpful perspectives shared from others. Loving et al. (2007) utilized blogs to help launch a science and mathematics teacher professional development platform for sharing resources and ideas for teachers. Their research revealed that blogs seemed to benefit teachers in terms of integrating technology into their teaching practices. Also, they found face-to-face and online learning can complement each other, and the findings are agreed with those of Li (2003).

Our project invited in-service teachers from remote area, rural and urban primary schools in Taiwan. In addition to face-to-face meetings, we accordingly built a platform for collecting teaching materials and ideas from teachers in different schools in Taiwan. Importantly, the analyzed test data of each examination of each participant teacher and some teaching videos taped from some participants are put in the platform as practice materials for increasing the opportunity of reflecting their own teaching practice.

Research Design

Teachers of the PLC

This study is an action research to investigate the effects of mathematics PLC. There are 74 teachers from 5 five primary schools participating in the team of PLC. In terms of these primary school teachers, there are 16 male and 58 females. There are also five mathematics teacher educators, who are university teachers in the department of mathematics education, in this study. The PLC framework and design is depicted as Figure 2.

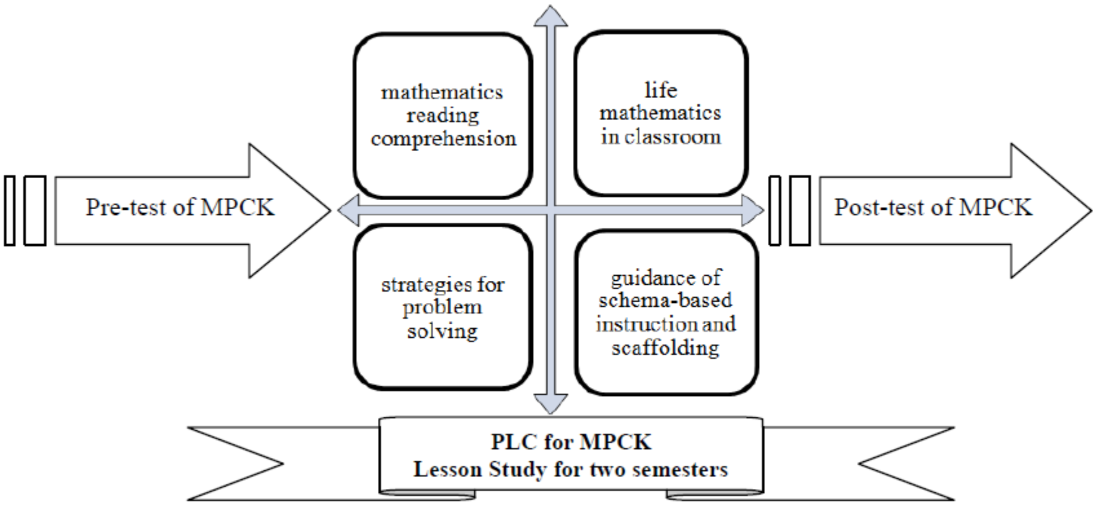

Figure 2: PLC Framework and Design

As shown in Figure 2, the PLC is operated for one year in which there are two semesters. Based on the theoretical foundation of mathematics instruction and survey of teachers' need, there are four components as to improve mathematical pedagogical content knowledge (MPCK). They are life mathematics in classroom, strategies for problem solving and mathematics reading comprehension, guidance of schema-based instruction and scaffolding. All the theoretical foundation and practical examples were scheduled in the workshops. From August 2014 to 2015 July, these teachers in PLC for mathematics instruction participate in two joint workshops for lesson study. As to each joint workshop, it is totally three days. In addition, there were two workshops in each primary school during each semester. In the workshop, the teacher educators introduce the theoretical foundations and practical case studies as to the four components to improve mathematical pedagogical content knowledge. These primary school teachers also do lesson study together so as to share the knowledge and experiences of mathematics instruction.

Questionnaire of MPCK

In the beginning, these primary school teachers take the MPCK questionnaire. When they participate in the PLC for one year, they take the same MPCK questionnaire. The repeated measure of MPCK is adopted to evaluate the effects of PLC on teachers' MPCK. The questionnaire of mathematical pedagogical content knowledge (MPCK) consists of six dimensions according to the related literatures of mathematics teaching knowledge. The questionnaire is four-point Likert scale. The coding and linguistic variables are 1 = strongly disagree 2 = disagree 3 = agree and 4 = strongly agree. These dimensions are mathematics content knowledge (MCK), students' cognition knowledge (SCK), mathematics instruction knowledge (MIK), mathematics instruction practice (MIP), mathematics assessment knowledge (MAK) and teacher professional responsibility (TPR). The validity has been confirmed based factor analysis and experts. The Cronbach reliability, which is one of internal consistency indices, with respect to each dimension is between 0.81 and 0.90. It reveals the acceptance of validity and reliability.

Results

Mean comparisons among dimensions of MPCK

Based on the purpose of this study, mean comparisons in accordance with the Pre-test and Post-test of MPCK questionnaire is analyzed. As shown in Table 1 and Figure 2, t-test for mean comparisons with respective to each dimension reveal there are significant differences between mean of pre-test and post-test. Moreover, means of post-test are higher than those of pre-test. It indicates the professional activities for mathematics instruction in the PLC could promote teachers' perception of MPCK.

Table 1: Mean Test on MPCK between Pre-test and Post-test

Dimensions	Mean of Pre-test	Mean of Post-test	t-test
MCK	2.9817	2.9985	2.732**
SCK	2.7774	2.7993	6.175***
MIK	2.9009	2.9332	9.267***
MIP	2.9474	2.9798	5.217***
MAK	2.9223	2.9339	3.792***
TPR	3.1434	3.1526	2.862**

**p<.01 ***p<.001

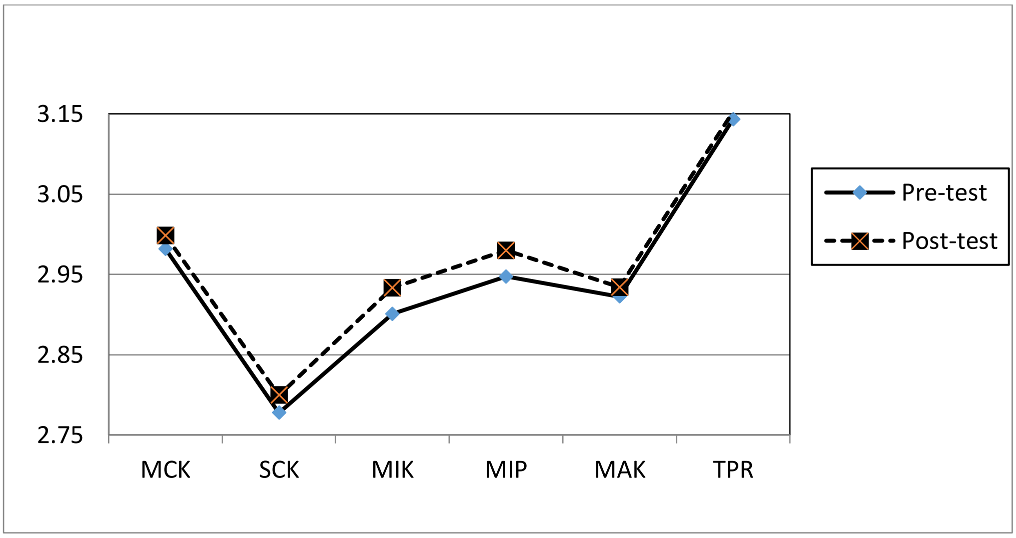

Figure 2: Line Chart for Mean Score of MPCK

Clustering on increment score of MPCK

Since the above results show that there are significant differences between pre-test and post-test as to the six dimensions of MPCK, advanced investigation on the clustering based on the increment score (post-test -pre-test) of MPCK is feasible. The dendrogram of hierarchical clustering shows the proper cluster number is six. Therefore, the k-means clustering is adopted to analyze the clustering.

Table 2: k-means clustering based on the increment score of MPCK

Cluster (number)	Mean of increment score within cluster					
	MCK	**SCK**	**MIK**	**MIP**	**MAK**	**TPR**
I (n=24)	-.0123	.0158	.0290	-.0047	.0053	.0190
II (n=2)	-.0217	-.0026	.0506	.0505	-.0387	-.0486
III (n=18)	.0448	.0459	.0153	.0486	.0066	.0076
IV (n=7)	.0909	.0373	.0262	-.0607	.0326	-.0035
V (n=5)	.1044	.0242	.0232	.0512	.0184	.0079
VI (n=18)	-.0174	.0165	.0212	.0898	.0209	.0067
Total (n=74)	.0167	.0219	.0237	.0325	.0114	.0087

As shown in Table 2, it shows all the primary school teachers could be properly classified into six clusters based on the increment score of MPCK. It also reveals the mean of increment score with respective to dimensions of MPCK. Each cluster has distinct increment score of MPCK and it means the influence of PLC on teachers' MPCK may vary. Besides, the cluster I, III, VI have more teachers and the other clusters own few teachers. All this finding could provide references for practical PLC of mathematics instruction.

Discussions

Professional learning community nowadays is the core for teachers' professional development. The professional learning community for mathematics instruction help foster collaborative learning among colleagues within the environment to improve knowledge of mathematics instruction. Little is known about the PLC effects as to the collaboration of teacher educators and primary school teachers. This study shows the positive effects of PLC, which is organized by teacher educators, on the MPCK perception for primary school teachers. Each cluster has features on the increment score of MPCK and the influence of PLC on teachers' MPCK may vary. Further research could investigate PLC effects on practical instruction and analyze students' mathematics achievement.

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