Facilitating pedagogical content knowledge development through professional development intervention

M E O Barut and A Wijaya

Graduate Program of Mathematics Education, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia
Mathematics Education Department, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia

E-mail: mariaevarista.2018@student.uny.ac.id, a.wijaya@uny.ac.id

Abstract Teacher has main responsibility to accommodate all students and their learning needs in dynamic classroom situations. This goal can be accomplished if teacher can organize high quality teaching practice to support student’s success. So that teachers must be equipped with wide range of knowledge about how particular mathematics topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners. Such knowledge is known as Pedagogical Content Knowledge (PCK). Many studies have proven PCK as professional knowledge that should be acquired by teacher to make effective teaching. Considering its importance, there must be systematic effort to develop pedagogical content knowledge through professional development. Teacher professional development has been used as the most effective approach to promote teacher change. Accordingly, the purpose of this paper is to explore ways to develop PCK in professional development intervention. The method used in this study is literature review. The review revealed that professional development intervention with collaborative-reflective situation such as: lesson study, analysing student’s work, analysing video of classroom practices, or construction of Content of Representation (CoRe) and Pedagogical and Professional Experience Repertoires (PapeRs) – based program, has positive impact to develop teacher’s pedagogical content knowledge.

1. Introduction

Undeniably, teaching process is considerably the great contribution for student success. Therefore, teacher as the main actor of the process, have to make sure providing the student with high-quality teaching and learning process in the classroom. Nevertheless, planning and conducting a teaching is not an easy thing to do. To do such a thing teacher must have adequate competence about the teaching and learning process. Teacher competence is a reflection of teacher quality which influences the quality of learning. In past decades, knowledge has become focus of many researches as part of cognitive aspect of competence. Teacher knowledge has been recognized as a key component of teacher competence [1] [2][3]. To be an effective mathematics teacher, the teacher must have a wide range of knowledge to teach. Many studies have been addressed two kinds of basic knowledge that must be owned by teacher namely knowledge of the mathematical content (content knowledge) and the type of knowledge of teaching strategies that are most effective to deliver the content so that it can be understandable by student (pedagogical knowledge). Integration of both of the knowledge is known as Pedagogical Content Knowledge.
The notion Pedagogical Content Knowledge later referred to as PCK, has been widely used in many studies and literatures about teacher’s knowledge. It is considered a specific professional knowledge that makes one a good teacher [4]. Initial concept of pedagogical content knowledge was introduced by Shulman in 1986. In Shulman conceptualization, Pedagogical Content Knowledge was categorized as one of the knowledge base along with seven other types of knowledge [5][6]. Among this knowledge, PCK is a special concern because it represents a distinct domain of teachers’ knowledge that considering development of teacher’s understanding, reasoning, and underpinnings about how to link content and pedagogy in meaningful ways in practice. It also is a unique kind of teacher knowledge that most likely to distinguish the understanding of mathematics specialist (mathematician) from that of the teacher.

Pedagogical Content Knowledge is an integration of knowledge about pedagogy and knowledge about content regarding on understanding about how to represent, structure, order and adapt specific topic of subject matter and consider student’s diverse abilities and characteristics [7][8]. PCK enables teacher to provide teaching situations that help student understand specific topic in mathematics [9]. Mathematics teacher need solid base of PCK [10] to guide them in making decisions or taking any action in teaching to teach mathematics effectively [11]. Other empirical studies related to teaching and learning practice has revealed PCK as useful support for teacher in organizing effective teaching. PCK enables teacher to anticipate, interpret, evaluate and respond to students’ thinking [12]. When teacher give more attention on student’s thinking, this could be a main source to guide them in prepare suitable learning environment that can support student success in classroom.

Above all that, many studies also correlate between teacher’s PCK and student’s achievement. COACTIV study of Baumert and Kunter proved that teacher’s PCK affect the quality of instruction and students’ achievement [3][12]. Indeed, the study also showed teacher PCK has more predictive power on student gains than teacher’s content knowledge. Regarding the importance of PCK, teacher has to become more responsive to the possible opportunities to develop PCK by participating in professional development program. Some studies have specifically addressed particular intervention that can be used in a professional development program. Therefore, the goal of this paper is to find some possible ways to develop pedagogical content knowledge in a professional development program.

2. Method
This study is a literature review that attempts to collect information from several pieces of literature about the kind of professional intervention suitable for facilitating development of teacher PCK. To obtain proper literature, the author searched through google scholar, that is one of electronic literature database for academic article journal, book and document. There were specific terms used in the searching process such as pedagogical content knowledge, teacher, mathematics, and professional development (all written between quotation mark). These search terms resulted a total number of 29,500 pieces of literature.

Furthermore, the author narrowed the literature number down using some additional criteria. First, the pieces of literature had to be published in the past 10 years between 2010-2019 considering update and credible standard for academic literature [13]. Secondly, pieces of literature must be written in English. The criteria were chosen in order to get a wider perspective from international literature. Third, the articles had to explicitly cope with pedagogical content knowledge topic. In order to do so, author excluded pieces of literature related to technological pedagogical content knowledge (TPCK), technological pedagogical and content knowledge (TPACK), curriculum knowledge, context knowledge, content knowledge, or general pedagogical knowledge. From this process the number of results reduced to 91 articles.

After the careful examination on these pieces of literature, the author found out some irrelevant pieces of literature or less related with the topic. For example, an article reported a study about measurement on teachers’ PCK or article related to teacher educator. Eventually, author decide to review 42 literatures in this study. Classification of literature will present below:
Table 1. Classification of Literatures

| Literature Category                                      | Amount |
|----------------------------------------------------------|--------|
| Pedagogical Content Knowledge Aspect                     | 5      |
| Teacher professional development                          | 11     |
| Kind of professional development program intervention to enhance teachers’ PCK | 32     |
| **Total**                                                | **42** |

*aThere are articles that can be included in more than one category

3. Result

3.1 Aspect of Pedagogical Content Knowledge

In Shulman initial conceptualization, he described PCK as “knowledge of representations of the specific content and instructional strategies, on the one hand an understanding of learning difficulties and students’ conceptions of specific content on the other”. On this Shulman origin conceptualization, PCK consist of two main components that is knowledge of the most useful forms of representation for the topics in one’s subject area and knowledge about student’s understanding of what makes the topics easy or difficult to learn [6][2]. In mathematics education context, PCK framework was expanded by team of researcher, Ball and her team. Based on Shulman’s seminal work, Ball and her colleagues developed a framework of teacher’s knowledge known as Mathematical Knowledge for Teaching (MKT). In this model teacher knowledge subdivided into subject matter knowledge (SMK) and Pedagogical Content Knowledge (PCK) each with its own subdomains. Further, MKT has been used in many studies as a tool to distinguish distinct teacher knowledge needed for effective teaching [5][14][15][16].

In this model, PCK consist of three domains that is knowledge of content and students (KCS), knowledge of content and teaching (KCT), and knowledge of content and curriculum (KCC) [14][17]. Knowledge of Content and Student (KCS) is about teacher’s understandings on how student learn a mathematic content, include knowledge about student conceptions and misconception over particular mathematics topics, for instance, knowledge about student difficulties and error in accomplishing a mathematical task. Knowledge of Content and Teaching (KCT) is teacher knowledge about instructional strategies, methods, activities or manipulatives for teaching particular mathematical content include knowledge of representations to build student understanding of particular mathematics content. Knowledge of Curriculum (KCC) is teacher’s knowledge about how content is arranged within mathematics curriculum which include knowledge about mathematic content at specific grade levels.

3.2 Teacher Professional Development

In the last few years, many experts have begun focusing on teacher-related variable to understand more about process in a classroom that may help increase student’s learning level [18]. The teacher has been recognized as professional occupation with ultimate responsibility to teach, educate, guide direct, train, and evaluating students. As a professional it is important to maintain the quality of the teacher through a professional development programs, especially to prepare new standards and challenges as a result of global changes. The term professional development defined by Guskey as any processes and activities intended to increase teacher’s professional knowledge, skills and attitudes than further bring positive impacts on student’s learning [19]. Another term commonly used is continuous professional development (CPD), which is a term used to differentiate between kind of teacher professional development within professional work as a teacher with professional development during teacher education and induction phases [20].

Professional development for teacher can take many forms such as in-service education and training, workshops, mentoring, etc. According to Harris et al and Lumpe (cited in Kafyulilo), any one-shot workshop, short workshops and seminars are not sufficient to transform teachers’ teaching practices [21][22]. Therefore, educational practitioner has been trying to explore the characteristics of effective
professional development. Some literature has been trying addressed the core component of effective teacher professional development [23][24][25][26][27]. The ongoing professional development like CPD viewed as the most effective approach to improve the teacher instructional practices after they enter workforce [28]. From those literature, one of the most agreed-on features of effective professional development is focused on teacher knowledge base development, particularly pedagogical content knowledge [29][26][30][24][31]. It is no wonder that PCK has been central focus on implementation of professional development program around the world.

3.3 Type of Professional Development Intervention to Enhance PCK Development
Kunter et al categories in depth PCK as one of characteristic of teacher’s professional competence [32]. As professional competence, PCK deserve professional treatment. Meaning to say that its growth must be fostering through engagement and learning experiences in communities of practices relevant to teacher work, for example, through the professional development program. Professional development is considered as key strategy to help teachers develop their pedagogical content knowledge [33]. Promoting pedagogical content knowledge in professional development usually involved some particular intervention. Furthermore, what and how the kind of intervention works in professional development will be explained below.

3.3.1 Lesson study
Lesson study first was originated in Japan as a systematic teacher professional development model based on school setting which involves several activities such as determining objectives teaching, planning a learning lesson, implementing the plan and evaluating the lesson to see whether the plan has solved problems [34][35]. Through lesson study, teacher is provided with rich opportunity to reflect deeply on their own practice through discourse with other teacher and observation on classroom practices. On reflection and collaborating processes, teacher focus on students' thoughts of a particular topic as well as choosing effective ways to teach the topic [36]. During lesson study, teachers work together with their colleagues to learn about subject matter, pedagogy, and student thinking and then apply what they learned by developing a lesson plan. Teacher continuous participation in this process empowered teacher obtain to rich knowledge about characteristics of student needs and ways of facilitating those needs to achieve success in learning. This kind of knowledge is form of PCK, so it is possible to foster development of PCK through lesson study.

There are many studies has involved lesson study as main intervention to enhance teacher’s PCK. Shuilleabhain in 2016 implemented lesson study as an intervention to develop PCK of 12 post primary mathematics teachers [37]. At the beginning of lesson study process not all teacher’s discussion related to plan and reflect on a research lesson. However, after continuous participating in successive cycles of lesson study, teachers became more focused to anticipation and reflection on students’ mathematical strategies (KCS), explicitly structured the sequences of learning activity for students (KCT) and develop contextualised content related to students’ prior knowledge (KCS and KCT). This study show teachers engagement in lesson study practice promoted PCK development, especially in two of PCK aspect which are KCS and KCT.

Another variant of lesson study had been developed in Hongkong called learning study. Even though it took lesson study spirit, learning study own its uniqueness regarding the application of variation theory as guiding principles for the teachers when they designing, analysis and evaluate the lesson [38]. Variation theory is kind of learning theory that assuming learning could occur if student experience discernment through variation of critical aspect of the object of learning [39][38]. Basically, on the variation theory learning is the result of student’s awareness of variance in the object of learning. According to Pang and Ling [38], variation can be the ways student seeing the object of learning (V1), the ways teacher seeing and dealing with the object of learning (V2), pedagogical design (V3). Attention to learning study leads to growth of research both related to student academic attainment and teacher professional development.
Alike lesson study, learning study also support growth of PCK. Learning study enables teacher to discuss and collaborate with other teacher to support motivation for instructional improvement and this could bring influence on pedagogical practices and positive student achievement. In learning study, the theory of variation enables the teacher to reflect on their teaching, to structure lessons better, and to accommodate individual differences in learning mathematics[35]. Teacher also have opportunity to identify of students’ misconceptions, which enables teacher to understand teaching from students’ perspective. All this kind of situation helps teachers to develop their pedagogical content knowledge.

3.3.2 Analysing of Classroom Artefacts
Integration of classroom artefacts such as classroom teaching recordings and student’s work has been proved as useful tool in professional development program. In many studies related to development of teacher quality, the artefact can be used collectively [27][40][41][42][29][30][43][44][45][25][46][41][47] or separately that is only employ classroom teaching recording [48][49][31][16][33] or student’s work[50][51]. As a product of learning process, those artefacts can be used to bring classroom situation as learning resource to evoke teacher change, include change in teacher knowledge. Providing recordings of one’s self or colleagues classroom practices holds a great deal of potential to develop teachers’ pedagogical content knowledge. According to Shanahan, analysing video gives teachers the opportunity to observe the complexity of classroom practice and learn from another perspective as well as explicit strategy instruction to teach specific content, student, and particular situation for new action in the classroom [49]. Video on professional development recording usually used as tool to engage teacher on reflective discussion about mathematical content of a lesson, students’ mathematical work, and pedagogical decisions and practices [47][27]. Meanwhile, examining student work also can be an essential activity on professional development because student work products is a medium for teacher to reflect on their lesson through student’s perspective. [51]. Through student’s work, teacher can evaluate whether or not process on classroom practice has enhanced student’s understanding. Further, findings from analysing student’s work like misconception or error student likely do in their work help teacher to select proper approach or strategies on teaching. This situation analogues with Park Olive opinion (cited in Saito) development of PCK largely depends on how well teachers understand students’ misconceptions [7].

Applying classroom artefacts for professional development program presented in study of Bell et al [25] On the program called Development of Mathematics Ideas (DMI), both of analysis of student work and video of classroom practice had been used to facilitate development of teachers' knowledge of mathematics children's ideas about mathematics and instructional approaches that could engage and support student reasoning. After some DMI sessions teacher was tested on their Mathematical Content of a lesson, students' mathematical work, and video of classroom practice had enhanced teacher PCK largely depends on how well teachers understand students’ misconceptions [7].

3.3.3 Constructing CoRe and PaPers
Content of Representation (CoRe) is blank table with two-dimensional matrix format which contains two main section that is “Big Ideas” at the top of each column and “CoRe’s questions/prompts” placed down at the left-hand side of column. Big ideas are the major ideas and concepts within the particular topic that are important for developing a robust of student understanding [52][40]. Meanwhile “CoRe’s Question” is eight prompt questions which must be answered for every Big Ideas. It is used to examine deeper understanding of the content about how it might be taught also how it might (or might not) be learned [53]. CoRe is suitable to accommodate teacher PCK development, because it forces teacher explicitly to reflect on their teaching by asking through CoRe’s question about how approach the teaching of particular topic and the reasons for that approach as well as what, why and how the specific topic is taught. In other words, it is used to reveal the teachers’ reasoning behind pedagogical choices.
or activities, knowledge of their students (such as alternative conceptions, difficulties, and points of confusion) and ways of assessing student understanding [54]. Unlike CoRe structure, Professional Experience Repertoires (PapeRs) was designed as short narratives based on teacher account of teaching a specific topic. This narrative gives in-depth description and reflection on teacher’s reasoning and thinking about one particular lesson based on a particular part of the content from the CoRe already planned before [54]. It could take form as a journal, a flow chart, or a reflective essay. Meanwhile the PaPers has caused self-evaluation and self-reflection on teacher. Then, the reflection increases teacher awareness about their understanding about what happens in teaching.

Initially CoRe and PaPers were developed as framework to concretize PCK of experience teacher in teaching practices. Recently, whether used together or apart, CoRe and PaPers is used as powerful tool to build teacher Pedagogical Content Knowledge. For instance, Betram and Loghran used both CoRe and PaPers as intervention instruments on their 2 years ethnographic study to help teacher develop their Pedagogical Content Knowledge [52]. In this research teachers were asked to create CoRe for a particular topic they would be teaching. For PaPers, teachers were asked to describe as much information as they could on teaching process of the topic from the CoRe that already planned before. Based on the interview, teacher claimed that CoRe essentially encouraged them to carefully choose the best way to present the topic for the student, recognize effective teaching approach, also in particular enable them to structure and plan teaching especially in teaching new or unfamiliar topic. Meanwhile PaPers generated meaningful consideration of their practice, helped them to recognise their students better and how to support their needs, and helped them to recognise strengths and weaknesses and areas that could be improved. In summary that their PCK developed because CoRes and PaPeRs offered a structured way to reflect in a meaningful and purposeful manner.

4. Conclusion
Since the idea of pedagogical content knowledge was introduced decades ago, many attempts have been trying to examine PCK on teaching practices as well as encourage teacher’s proficiency on PCK. Pedagogical Content Knowledge has been acknowledged as the essential knowledge that must be owned by teacher to conduct effective teaching. Regarding its importance, there must be systematic effort to promote development of teacher PCK that is through professional development program. Many experts have addressed on their studies that it is very possible to develop PCK through professional development program.

There are some specific interventions that have been proved as the appropriate intervention to develop teacher PCK. Result of literature review above shown that such intervention like lesson study, analysing classroom artefacts, and constructing CoRe and PaPer have been useful support in professional development in order to develop teacher PCK. These activities provide teacher with collaborative-reflection experience, so that teacher has deeper understanding on student thinking in learning process as well as variation on instructional strategies that can be used to support student’s learning. Supporting PCK development through collaborative-reflective experience analogous with Kleickmann et al statements “several studies suggest that teaching experience needs to be coupled with thoughtful reflection on instructional practice, with nonformal learning through interactions with colleagues, and with deliberative formal learning opportunities” [1]. This means that teacher’s PCK is highly dependent with teacher experience, but it must be followed with participation in collaborative-reflective activities through professional development.
From Figure 2 above, two of three of PCK aspect (KCT and KCS) get greater influence from all interventions. Although development of Knowledge of Content and Curriculum (KCC) does not appear in these interventions, but KCC has been known as one of the aspects that integrate with two other aspects (KCS and KCT). That means development of KCT and KCS aspects also bring changes on KCC.

In the other hand, considering the importance of teacher’s PCK, Indonesian government or any authorized institution that related with teacher’s quality development could consider to use these kind of interventions (lesson study, analysing classroom artefacts, and constructing CoRe and PaPer) as the part of professional development practice in Indonesia.

5. References

[1] Kleickmann T Richter D Kunter M Elsner J Besser M Krauss S and Baumert J 2013 J. Teach. Educ. 64 pp. 90-106.
[2] Depaepe F Torbeys J Vermeersch N Janssens D Janssen R Kelchtermans G Verschaffel L and Dooren W V 2015 Teach. Teach. Educ. 47 pp. 82-92.
[3] Baumert J Kunter M 2013 Cogn. Act. Math. Classr. Prof. Competence Teach. Results from COACTIV Proj Vol 8, ed Kunter et al (New York : Springer) chapter 2 pp. 1–378.
[4] Fernandez C 2014 Probl. Educ. 21st century 60 pp. 79–100.
[5] Depaepe F Verschaffel L and Kelchtermans G 2013 Teach. Teach. Educ. 34 pp. 12–25.
[6] Evens M Elen J and Depaepe F 2015 Educ. Res. Int. 2015 pp. 1–23.
[7] Saito E and Atencio M 2016 Pedagog. Cult. Soc. 24 pp. 101–121.
[8] Setyaningrum W Mahmudi A and Murdanu 2018 J. Phys. Conf. Ser. 1097.
[9] Loughran J Milroy P Berry A Gunstone R and Mulhall P 2001 Res. Sci. Educ. 31 pp. 289–307.
[10] Olfós R Goldrine T and Estrella S 2014 Rev. Bras. Educ. 19 pp. 913–944.
[11] Atay D Kaslioglu O and Kurt G 2010 Procedia - Soc. Behav. Sci. 2 pp. 1421–1425.
[12] Goos M 2013 Int. J. Math. Educ. Sci. Technol. 44 pp. 972–983.
[13] Kemenristekdikti 2011 Peraturan Direktur Jendral Pendidikan Tinggi Kementerian Pendidikan Nasional Republik Indonesia No. 49/DIKTI/Kep/2011 Tentang Pedoman Akreditasi Terbitan Berkala Ilmiah (Jakarta : Kemenristekdikti).
[14] Matthews M E 2013 J. Educ. 193 pp. 29–37.
[15] Chapman O 2013 J Math Teach. Educ. 16 pp. 237–243.
[16] Borko H Koellner K and Jacobs J 2014 *J. Math. Behav.* **33** pp. 149–167.
[17] Appova A and Taylor C E 2019 *J. Math. Teach. Educ.* **22** pp. 179–204.
[18] Cueto S León J Sorto M A and Miranda A 2017 *Educat. Stud. Math.* **94** pp. 329–345.
[19] McMeeking L B S Orsi R and Cobb R B 2012 *J. Res. Math. Educ.* **43** pp. 159–181.
[20] Wernke W 2011 *Prof. Dev. Educ.* **37** pp. 665–683.
[21] Kafyulilo J L C and W W F and – M F and – S 2013 *E A L E and – J Q and J. McCray*, vol. 16, no. 1, pp. 936–226.
[22] Burton E P 2013 *Teach. Teach. Educ.* **29** pp. 156–166.
[23] Bertram A and Loughran J 2012 *Res. Sci. Educ.* **42** pp. 1027–1047.
[24] Cooper R Loughran J J and Berry A 2015 *Re-examining Pedagogical Content Knowledge in Science Education* (New York : Routledge) pp. 60–74.
[25] Bertram A 2014 *Educ. Quim.* **25** pp. 292–303.