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Teacher professional development program to improving pedagogical content knowledge: a review of empirical research

Y F Kasi[1,2*], A Widodo[1], A Samsudin[1*], and R Riandi[1]

[1]Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung 40154, Indonesia
[2]STKIP Nusa Bunga Floresta, Jalan Mbay-Maumere Km 8, NTT 85472, Indonesia

[*]yohaneskasi@upi.edu, achmadsamsudin@upi.edu

Abstract. This study analyzed articles of the journals in Scopus database to review empirical research about the teacher professional development (TPD) program to improving science teacher pedagogical content knowledge (PCK) in the year 2008-2020. This study also explains the use opportunity of the professional development program in Indonesia. Three stages were used to analyze the article: 1) identify the articles, 2) classification based on model TPD, and 3) code and analyze all reviewed articles. Based on the above stages, 41 articles were selected for further analyze in the model of TPD program focus to improve PCK on teachers. Six models were collected are lesson study, mentoring, workshop, using CoRe and PaP-eRs, based on technology, and based on role-playing, ethnoscience. The result showed six models in an analysis of the article had a positive effect on improving the PCK on teachers and prospective teachers. However, one research explains that model workshops, not enough to improving PCK on science teachers. A case in Indonesia the combination of model TPD from this review analysis is believed to improve the PCK of science teachers. For future studies are needed to harness the resource combination of the model TPD to improving teachers' knowledge and skills.

1. Introduction

When the teachers are being regarded as intellectual actors who are known as having competences and skills bases, designs of how to prepare teachers and strategies to develop their learning are important [1][2]. Amongst these ideas for over three decades, the researcher acknowledges the importance of developing teachers knowledge and most of them opine that pedagogical content knowledge is a fundamental component of the knowledge base for teaching and learning [3][4][5]. The teachers will need to draw on not only an understanding of matter but also knowledge of specific instructional approach, technology, curriculum, and student characteristic to prepare and help students to reach the 21st-century skills that are critical thinking, collaboration, communications, and creativity. This knowledge main is commonly acknowledged as pedagogical content knowledge [6]. Pedagogical content knowledge (PCK) by Shulman [6] is a special combination of knowledge that teachers must have to make relevant content by teaching it. Therefore, teachers must know not only the content but also knowledge about how the content was taught to students. Shulman reveals "*I still speak of content knowledge here, but of the particular form of content knowledge that embodies the aspects of content most germane to its teachability*" [6]. PCK makes it possible for the transformation of knowledge content into formulas that are reachable and achievable by students. "*Pedagogical content knowledge"*

as a "special amalgam" of knowledge possessed by a teacher, one component of teachers', and knowledge base for teachers'[7]. PCK continues to draw researchers back time and time again to reconsider its position in defining that which constitutes knowledge of teaching [8]. Consequently, PCK has become an approach of comprehending the complex association between pedagogy and content through an integrated process special in classroom practice.

Pedagogical content knowledge (PCK) in science education research has attracted considerable attention ever after Shulman revealed the term. Many science education researchers conducted the research, the results of which become the idea to offer change, modifications, criticize, and complete the concept of PCK by Shulman. For example, Tamir [9] emphasized the main knowledge that must own by teachers that are; general pedagogical knowledge, pedagogical content knowledge, curriculum knowledge, student knowledge, and content knowledge. Mark [5] revealed the concept of PCK consisting of four components of that are; knowledge of the subject matter, knowledge of students' understanding, knowledge of the media, and knowledge of the teaching process. Similarly, Grossman [10] consists of four components that are; knowledge of content, knowledge of student understanding, knowledge of curriculum, and knowledge of learning strategies. Revealed somewhat different ideas, Cochran [11] used the term Pedagogical Content Knowing (PCKg) with the four knowledge basic components for teachers, namely: knowledge of pedagogy, knowledge of content, knowledge of students, and knowledge of environmental context. Loughran [12] developed an instrument *Content Representation* (CoRe) and the *Pedagogical and Professional-experience Repertoire* (PaP-eR) to capture a science teacher's PCK. Pierson [13] and Mishra & Koehler [14] proposed a new component in PCK, namely technological pedagogical content knowledge (TPACK). Finally, science education research from the meeting called "PCK Summit" agreed the latest model of PCK consists of five components of knowledge that are: knowledge of assessment, knowledge of pedagogy, knowledge of content, knowledge of students' understanding, and knowledge of curriculum [15].

To develop an understanding of PCK for teaching matters, teachers will need the support of the teacher professional development (TPD) program [16]. Teacher professional development offers the content to improve knowledge and skills teachers about teaching and their student [17][18]. Learning and teamwork teachers in TPD activities have the possibility to change their competences and skills to improve student outcomes [19]. The teacher professional development program should make chances for teachers to improve deep and flexible knowledge structures about PCK [20][21] because PCK is broadly applied to provide the theoretical basis for a strategy on teaching and learning [22]. Some studies explained the relationship teachers participate in TPD to improve PCK with their student achievement (e.g. [23][24]). Teacher professional development explaining to science teachers how to use pedagogical content knowledge activities in their teaching and thus foster their students' learning.

The studies to analyze the effect of the teacher professional development program for science teachers have grown in recent decades because teacher professional development to improve teachers has become the emphasis of educational reform. Furthermore, the finding that the TPD program to improving the PCK component is important and has repeatedly been interested. Nevertheless, there has been no analysis study to exploring what the effectivities of the teacher professional development model in science education study for teachers from the aspects of pedagogical content knowledge component. Prearranged the appearances of TPD studies for improving the PCK of science teachers and the result past of these studies is essential to understand its overall conclusion. This analyze empirical could be shed more light on how to exactly contrivance the TPD studies to improving PCK at the teachers' and prospective science teachers' level as well as changing their insufficiencies. Henceforth, this research would suggest an occasion for researchers, program developers, and policymakers to specify the most effective model of TPD.

2. Methods

The purpose of this study to analyze empirical research about the teacher professional development (PD) program to improve science teacher pedagogical content knowledge (PCK). This study also explains the

use opportunity of the professional development program in Indonesia based on the analysis which collected from 2008 to 2020.

2.1 data collection

This study explored articles records to verve finished the professional development program to improving PCK. We searched for the target articles in the Scopus list using the keywords "professional development" and then used ' pedagogical content knowledge' or "PCK", to refine the search results. We also added science, teachers, prospective teachers, and all the relevant combinations of these terms in the topics of the articles within the list that served as the primary sources for the relevant literature.

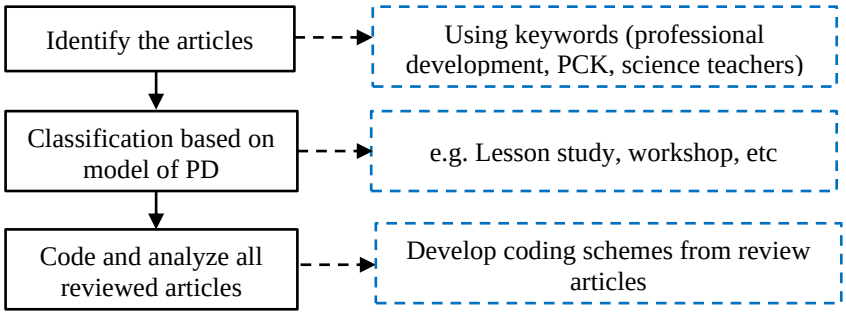

Figure 1. The methodology of this research

This search identified the articles related to the teacher professional development program for improving PCK published between 2008–2020 in eleven target journals (see table 1). After selection, the keywords, title, abstract, and careful reading a full text of the articles in the first phase, articles that did not that do not fit the topic was discarded.

Table 1. Overview of the reviewed articles

Name of the Journal	Number of the articles	Year
International Journal of Science Education	7	2015, 2015, 2016, 2016, 2016, 2016, 2017
Indonesia Journal of Science Education	1	2019
Journal of Educational Computing Research	2	2018, 2018
Journal of Science Teacher Education	18	2008, 2009, 2012, 2013, 2013, 2014, 2015, 2015, 2016, 2016, 2017, 2017, 2017, 2018, 2018, 2018, 2019, 2019
Universal Journal of Educational Research	2	2020, 2020
Professional Development in Education	7	2012, 2013, 2013, 2015, 2018, 2018, 2019,
European Journal of Teacher Education	1	2018
Journal of In-service Education	1	2008
Journal of Research on Technology in Education	1	2017
Asian Social Science	1	2014

2.2 data analysis

From the analyze of articles, a few more models of the teacher professional development program to improving PCK were found including workshop, lesson study, using technology, mentoring, CoRe and PaP-eRs, and based on reality-experienced, and role-playing. These models were added to the coding scheme and other coded for each article. These codes of data analysis variables were: model of TPD, characteristics of TPD, participant, and the result of these articles.

In an article screening, we read all the abstracts of the articles, noted their definition of the TPD program, and furthermore made a judgment that the TPD program was a feature of the research article. Moreover, our criteria for article selection included: science teachers were clearly engaged in the TPD

program which focused on improving their PCK. After careful analysis, followed by further negotiation and arriving at purpose, from 62 articles resulted in 41 articles that met the criteria for inclusion in this literature review.

3. Result and Discussion

Reliable with our review of the teacher professional development program for improving PCK, we explained the results based on the purposes of the study. Appropriate specifics about each article are showed for a strong understanding of the studies and the effect that TPD program for PCK, students outcomes, and in each appropriate context. Based on the identify, classify, coding, and analyze the articles in this study we found six model professional development to improving PCK (see Table 2). These articles focus on PD programs to improving PCK and dominated science teachers' and some prospective teachers are a participant of the program in articles.

Table 2. Descriptive information related to the reviewed articles

Model of PD/ Total analysed	Participant	Characteristics of PD	Result
Lesson study/7	Teachers and Prospective teachers	Teamwork (3-5 person), discussion curriculum update, collaboration to lesson planning, teaching, and observation (the focus of students), reflection.	An important element in each stage of the Lesson study model is effective in improving PCK on science teachers.
Mentoring/10	Teachers and Prospective teachers	Mentoring (scientist-teacher or novice-expert teacher), discussion about teaching experience, sharing ideas, collaboration to choosing and using methods and teaching materials, collaboration to implementation and evaluation teaching.	The mentoring process (scientist and expert teacher) is effective for improving PCK on science teachers and also their social competence.
Workshop/13	Teachers and Prospective teachers	Workshop, sharing topic, discussion about learning and teaching concepts.	Components PCK on science teachers increase after participating in the program, but there are journals that explained that the course program is not effective in giving teachers an understanding of PCK
Using Core and PaP-eRs/5	Teachers and Prospective teachers	Discuss science teachers' understanding about content, lesson planning, teaching practice, and reflection.	Effective to improve PCK on science teachers
Based on technology/4	Teachers and Prospective teachers	Online discussion, mentoring	TPACK on science teachers increased after join in PD based online
Based on role playing, ethnoscience, realitiy-experienced/2	Teachers and Prospective teachers	Discuss about teaching material, peer-teaching.	Effective to improve PCK on science teachers

3.1. the effect of the teacher professional development program to improving PCK

This section explains the first purpose in this study about the teacher professional development (TPD) program to improve science teacher pedagogical content knowledge (PCK). Based on the total review analysis of the article in this study, the TPD most widely used program in enhancing PCK is with a

workshop (13 articles, 32%), a Lesson Study (10 articles, 17%), using Core and PaP-eRs (5 articles, 12%), and then (4 articles, 10%) for TPD based on technology and (2 articles, 5%) on role-playing, ethnoscience, realitiy-comparison. Our findings from an analysis of the entire article show that the six models in an analysis of the article had a positive effect on improving the PCK on teachers and prospective teachers. However, one research explains that model workshops, not enough to improving PCK on science teachers. [25]. It is possible because most of the characteristics in the workshop program have on only passive activity such as discussion about learning and teaching concepts, peer teaching, and sharing topics.

The force in the characteristics TPD for a model lesson study and mentoring is that teachers can collaborate directly together to enhance their PCK. Start from designing learning, implementation of learning, evaluation, and also reflect learning (e.g. [26][27]). Furthermore, the online collaboration of participants (based on technology) participants offering new offers can also have a positive effect on increased PCK as well as on teacher technology knowledge [28][29]. Future developments in the educational dimension can use technology together or meaningfully to enhance learning activities for students such as planning, classroom management, and assessment [13][30]. The offer is in accordance with educational reforms that are aimed at the use of technology in learning as well as current occupational Covid-19 circumstances. In addition, using technology can sustain programs because teachers can do online discussions and learning sharing. The use of CoRe instruments and PaP-eRs for teachers in TPD is because they can measure the extent of a PCK increase on them. Moreover, CoRe and PaP-eRs instruments can be to determine the category of PCK on teachers (pre PCK, growing PCK, maturing PCK) [31]. The result explains while they are not reliable across all articles under review, that there are noticeable improve PCK on science teachers' as well as students' achievement when the teachers participate in the TPD program. In addition, the model of TPD can also increase creativity and collaboration skills in teachers.

3.2. opportuniti of PD in Indonesia

TPD program in Indonesia still lacks a collaboration strategy between a teacher and another experienced teacher, using technology as a means to preserve program sustainability and ethnoscience approach which links cultural activity in a region to the concept of science [32][33]. Furthermore, program sustainability from TPD in Indonesia is not maximal yet because what teachers who are involved in PD can't implement the program material into the classroom. The characteristics of the PD program are dominated by lesson study, PPG, dual-model, short time duration, and directionless sustainability (e.g. [34][35][36]). Therefore, the recommendation on future studies in Indonesia for using the resource combination of the model professional development from this review analysis is believed to improving the PCK of science teachers.

4. Conclusion

This study exploring the models and trends of teacher professional development program to improving pedagogical content knowledge on teachers and prospective teachers from a review of 2008–2020 articles. From our analysis, all models of teacher professional development program related to science can improve PCK teachers and prospective teachers. We expected more of the model chosen for inclusion in the professional development program to have positive associations with teachers' competence and student learning. For the future studies are needed to harness the resource combination of the model professional development to improve teachers' knowledge and skills.

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