Systematic Review on Pedagogical Content Knowledge for Preservice Science Teachers

Susilowati Susilowati[1, 2], Suciati Suciati[1], Sulistyo Saputro[1], Muzzazinah Muzzazinah[1]

[1] Sebelas Maret University, Indonesia
[2] Universitas Negeri Yogyakarta, Indonesia
susilowati@uny.ac.id

Abstract. This systematic study aims to identify research trends regarding the development of Pedagogical Content Knowledge (PCK) for preservice science teachers in science learning. The method used Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA). The parameters used in this study use the PICOS design. An article search was carried out using the keyword "pedagogical content knowledge in science teaching" with the criteria of articles from international journals from 2010 to 2020. The next step is the process of selecting articles. The data for the study was acquired from wiley on library, google scholar, and sagepub. Based on searches using the keywords, 205 articles were obtained and acquired 15 articles that appropriate with inclusion criteria. The article reviewed as a whole from the full paper and resulted in 14 articles. Articles that met the eligibility criteria were used for synthetic materials in a systematic review. Based on the results of the review, a synthesis was obtained regarding the model for the professional development of science teachers. To produce professional science teachers, several important aspects are needed, including belief or self-efficacy, inquiry-based teaching, socio-scientific issues, explaining skills, and metacognitive awareness.

Keywords: Systematic Review, Pedagogical Content Knowledge, Preservice Science Teachers.

1 Introduction

Science teachers must have four competencies, namely pedagogical, professional, personality and social competencies. The specific competencies of science teachers are also contained in the NSTA (National Science Teaching Association) which recommends the Standards for Science Teacher Preparation. This standard contains a number of standards that must be possessed by science teachers including content standards, nature of science, inquiry, issues, general skills of teaching, curriculum, science in the community, assessment, safety and welfare, professional growth. These standards are consistent with the vision of the NSES (National Science Education Standards). Science teachers in primary and secondary schools must have interdisciplinary science skills [1].

Preservice science teachers must have the ability to teach science according to their nature. Science teachers must master the content being taught and how to teach. This ability is related to pedagogic and content knowledge, which is referred to as PCK (Pedagogical Content Knowledge). Mastering material content alone is not enough to teach science well. This is also in line with the statement that professional science teacher preparation programs should place more emphasis on "how to teach certain

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topics" rather than "how to teach subjects" [2]. Science teachers are faced with the challenge of mastering pedagogic knowledge and content knowledge in the rapidly changing times [3].

PCK is one of the seven categories of knowledge as a teacher. The other categories are subject matter knowledge, general pedagogical knowledge, curriculum knowledge, knowledge of learners and their characteristics, knowledge of educational context. education), knowledge of educational ends, purposes and values (knowledge of educational goals and values) [4]. Effective teachers need PCK rather than just material knowledge) [4]. It is important to explore models that can develop the pedagogical and content abilities of prospective science teacher students.

Teacher professionalism is determined by mastery of components in PCK. There are five components of PCK that are important in teaching effective science, namely orientation towards science teaching, knowledge and beliefs about the science curriculum, knowledge and beliefs about students' understanding of specific topics, knowledge and beliefs about assessment in science, and knowledge and beliefs about learning strategies in teaching science [5]. In science education, PCK is conceptualized as consisting of four components consist of science curriculum knowledge, knowledge students' understanding in science, knowledge of instructional strategies, and knowledge of scientific literacy assessment. Each of these four components is affected by science teacher teaching orientation [6]. The category of preservice teacher knowledge includes student knowledge, knowledge about educational context, subject matter knowledge and general pedagogical knowledge [7]. PCK is the teacher's knowledge that describes the pedagogic and content of the material. In line with its function, PCK is a tool to make topics more understandable, relevant, and interesting for students [8]. Teacher education plays a role fundamental role in supporting preservice teacher PCK development [9].

In this systematic study, a critical analysis was carried out regarding the components of teacher knowledge in teaching or pedagogical content knowledge (PCK), especially science teacher professional development programs through the empowerment of PCK components. The purpose of this review is to analyze the professional development model for preservice science teachers through PCK development. This systematic study answers the question "what are the PCK development models for preservice science teachers?".

1.1 Definitions of PCK

Knowing science is a necessary but not sufficient condition for teaching. Science teachers must also have knowledge about science learners, curriculum, instructional strategies, and assessments through which they transform their science knowledge into effective teaching and learning [10]. Pre-service science teacher is necessary have good scientific literacy in order to be able to produce students who are scientifically literate [11].

The PCK thinking concept provides an understanding that to teach science it is not enough to only understand the content of science material (knowing science) but also how to teach (how to teach). Science teachers must have knowledge about science students, curriculum, instructional strategies, assessments so they can transform science knowledge.

a PCK model for teaching science teachers include curricular knowledge, knowledge of teacher's understanding of science and science teaching, knowledge of assessment, knowledge of instructional strategic [12].

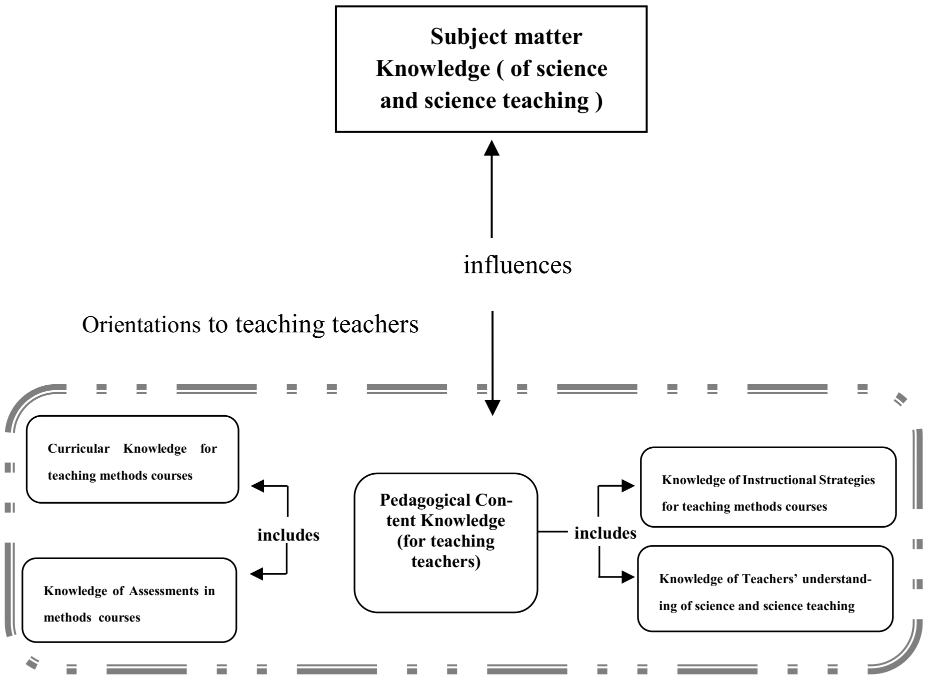

Fig.1. Model of PCK for teaching science teachers (adapted from Grossman 1990 and Magnusson et al. 1999).

2. Methodology

This research is a systematic review (systematic review).The method used Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA). The procedure for this systematic review consists of several steps, namely 1) compiling the background and purpose, 2) research questions, 3) searching for the literature 4) selection Criteria 5) practical Screen 6) quality checklist and procedures 6) data extraction strategy, 7) data synthesis strategy [13].

The parameters used in this study use the PICOS design. This design contains considerations for defining research questions, establishing inclusion and exclusion criteria and providing an overview of the steps in the investigation. The parameters used are presented in Table 1.

Table 1. Inclusion and Exclusion Criteria

PICOS Components	Considerations in Research
Population (populasi)	Preservive science teachers
Intervention	Pedagogycal Content Knowledge (PCK) in science learning
Comparison	Improving the quality of non-PCK teachers
Outcomes	Improved PCK components
Study design	All research designs (survey, development, experiment)

An article search was carried out using the keyword "pedagogical content knowledge in science teaching" with the criteria of articles from international journals from 2010 to 2020. The next step is the process of selecting articles.

3. Result and Discussion

Based on searches using the keywords above, 205 articles were obtained consisting of 154 articles from scimajojr, 23 from google scholar, 25 from JSTOR and 3 from sagepub.

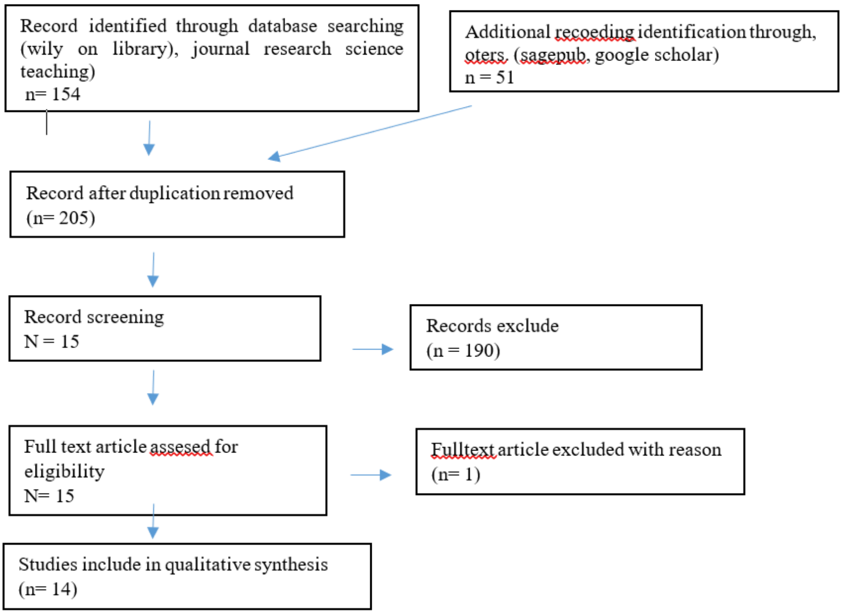

Fig. 2. Article selection stage

The article screening process was carried out according to the criteria set out in the PICOS and also the general criteria, namely articles from international journals from 2010 to 2020. Of the 15 full papers assessed, 1 article was excluded because the article was a journal in book form, not a separate journal article. Based on the results of reviewing 14 full paper articles that fit the criteria, there are 7 journal articles on PCK for preservice teachers, 6 PCK journal articles for inservice science teachers and 1 PCK journal article for preservice and inservice science teachers.

Based on a review of articles, findings were obtained regarding the model for developing PCK science teachers, as follows:

Table 2. Article Review Results

PCK Development Model	Review Results
Teaching with dialogic soci-oscientific issues	• PCK development with SSI (Socio Scientific Issues) teaching can achieve the components of subject matter knowledge, knowledge of the

	nature of SSI (Socio Scientific Issues), knowledge of classroom management strategies, knowledge of dialogic delivery discourse), the ability to conduct strategic arguments, (knowledge of argumentation strategies), knowledge to understand the material (knowledge of student learning, and knowledge of the teacher's role.
Development of explaining skills during field practice	• There is a link between professional knowledge prior to field practice and the development of explaining skills during field practice in schools, which involves a process of reflection on the teaching process. • Prospective teacher education program, the most important first stage is professional knowledge before practicing skills.
Professional development with self-efficacy with inquiry-based learning practices	• There is a positive correlation between self-efficacy and inquiry-based instructional practice • High self-efficacy has an impact on the achievement of student learning outcomes • Insufficient knowledge of science content leads to low self-efficacy
Beginner science teacher development	• Provide evidence that specially designed courses support the development of PCK through scientific inquiry. • Development of teacher PCK with scientific inquiry which emphasizes the presentation of evidence and explanations.
Development of metacognitive awareness	• Teacher developers who pay attention to alternative conceptions with metacognitive. • Metacognitive as a key prerequisite for conceptual change
Improving the quality of teaching in the skills or performance of explaining "explaining performance".	• Practical experience is not correlated with good explaining performance, because there is no reflection.

	• With practical experience helping student teacher candidates become aware of how difficult it is to be a good explainer. • Both Content knowledge (CK) and Pedagogic Content Knowledge (PCK) are important to improve the quality of explaining. PCK acts as an intermediary between content knowledge and performance in explaining. • Teacher training program, not only focusing on developing content knowledge but also pedagogic content knowledge. • Confidence or "belief" plays an important role in explaining better performance.

Based on the results of the review, a synthesis was obtained regarding the model for the professional development of science teachers. To produce professional science teachers, several important aspects are needed, including belief or self-efficacy, inquiry-based teaching, socio-scientific issues, explaining skills, and metacognitive awareness.

3.1 Self Efficacy

Self-efficacy is essentially a belief in one's ability to be successful in performing a particular task. Self-efficacy is defined as a belief in the ability to organize and carry out actions or activities in subjects or subjects needed to produce achievement [14]. In the development of teacher professionalism programs, design and implementation are carried out on an ongoing basis. In increasing self-efficacy and encouraging the implementation of performance or performance in teaching in the classroom, it can be done by considering the factors that influence teacher self-efficacy as a basis for consideration in designing teacher professional development programs [14]. Self-efficacy increases due to the achievement of comfort due to the repetition of the implementation of new learning methods. The main benefit of material content knowledge is the deeper understanding of science material, the main benefit achieved in its role in professionalism learning in groups is increased self-efficacy [14]. Based on Bandura's social cognitive theory that self-efficacy can be increased through individual mastery of experience, with representation of experience, affective statements and persuasion. In addition to factors for the development of adequate PCK: teacher's CK, teaching experience, and beliefs.

3.2. Inquiry Based Teaching

Producing a quality generation requires the right method for children born in different contexts, the diversity of learning roots in the complexities that are now challenging 21st century learning.The development of important teacher professionalism courses is designed to develop Inquiry-based PCK. The inquiry stage includes (a) Generating hypotheses about a posed question. (b) Designing and conducting scientific investigations to respond to the question. (c) Using appropriate tools and instruments when collecting scientific data. (d) Analyzing and interpreting data to construct evidence-based explanations. (e) Representing data and explanations through various means, such as drawings and tables. (f) Communicating investigations and explanations orally and in writing [15],[16]. The implementation of inquiry learning practices is influenced by both intrinsic and extrinsic factors. These factors include teaching efficacy, professional science knowledge, professional attitude and interest, resource adequacy, time, professional support, school ethos. From the research it is proved that there is a correlation between factors [16]. Inquiry has been proven to be effective and can be applied to stimulate thinking skills. prepare science teacher candidates for implementing inquiry-based learning is more challenging as science teacher candidates have difficulty creating an inquiry-based classroom environment [17]. Teaching inquiry is included in the realm of inductive approach which starts with asking questions for investigation, then gathers data through scientific procedures and finally interprets data to arrive at conclusions that explain the results [18]. Inquiry, which engages students in scientific practice, is not the only approach to teaching science but important because it is based on current educational theory and aligned with how we think about learning [19].

3.3. Socio Scientific Issues

PCK with SSI (Socio Scientific Issues) based teaching can develop subject matter knowledge, knowledge of the nature of SSI, knowledge of classroom management strategies, knowledge of dialogic discourse, knowledge of argumentation strategies, knowledge of student learning, and knowledge of the teacher's role [20]. Teaching based on socioscientific issues can develop people who think at a higher level, have discussion skills, scientific argumentation, inquiry-based learning and understand the essence of science [21]. All topics regarding SSI having components that lead to risk, such as a potential hazard to human health or environment, human rights, or other aspects of man [22].

3.4. Explaining Skill

Professional learning opportunities play an important role in how teachers design or adapt teaching materials to meet the needs of students [23].Explaining skills is a core activity in teaching practice (The profile of future science teachers is expected to be proficient in mastering the delivery of material using information technology tools, especially in online learning [24]. Empirical evidence shows that the skill of explaining material is a skill that can be learned. Preservice teachers experience difficulties in presenting and explaining the content of the lesson properly. Explaining is considered a content-specific skill that cannot be directly transferred from one content to another [25]. Components that need to be emphasized in explaining skills include:content, student-teacher interaction, process structure, representation, and language. in learning science, teachers need to direct students to make connections between cause and effect are articulated through data analysis and evidence-based explanations [26].

3.5 Metacognitive Awareness

Metacognition means thinking about own thoughts. Some metacognitive skills that can be followed:a). Knowing your limits - knowing someone's limits own memory for a specific task; b). Self-monitoring – one's learning strategy like concept mapping, and then adapting strategy if not effective; c). Modification – watching to see if someone understands something and then modifying it; d). Skimming – choose to skim; e). Practice – repeatedly practice the skill for acquire skills; f). Self-test – periodically self-test to see how well [27]. There are three types of metacognitive knowledge, among others: a). Awareness of knowledge- it involves understanding what one knows, what one does not know, and what one wants to know; b). Awareness of thinking- understanding cognitive tasks and the nature of what is required to complete them; c). Awareness of thinking strategies- understanding approaches to direct learning.

In the preservice teacher education program, an important first phase is professional knowledge before action practice. There is a relationship between professional knowledge prior to field practice and the development of explaining skills during field practice, which then involves the reflection process of the teaching process [28]. During innovative teaching and learning, the teacher's beliefs lead to three levels of practice, namely normative, discursive and actual. Normative is what is thought and will be done, discursive describes what will be said and done, and actual is what they are doing. Metacognition means the human ability to reflect our own perceptions, thoughts, and actions [29]. The important role of metacognitive awareness in science teaching and learning, namely the extent to which the participants obtain benefits from MR (Multi-representation) learning and their subsequent involvement in concept change to reduce misconceptions [30].

4. Conclusion

Science teacher development emphasizes PCK mastery. PCK components include curricular knowledge, knowledge of teacher's understanding of science and science teaching, knowledge of assessment, knowledge of instructional strategy. The development pattern of Pedagogical Content Knowledge (PCK) leads to an emphasis on aspects of self-efficacy, inquiry based teaching, and socio scientific issues.

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