Identification of Pedagogical Content Knowledge (PCK) for Prospective Chemistry Teachers: Efforts to Build Teachers’ Professional Knowledge

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Abstract. Pedagogical content knowledge (PCK) is the basic knowledge that teachers must have to transform subject matter for students. PCK is very influential in research for teacher education, especially in science. Identification of PCK abilities needed as an effort to build teacher professional knowledge through the PCK construct. This study aims to identify the PCK ability of prospective chemistry teachers in each component. This study was descriptive with qualitative and quantitative approaches (mix-method). The instruments used in this study were the lesson plan’s review sheet based on the Magnusson’s framework and the interview sheets validated by two science education experts. The sampling technique was purposive sampling. The subjects of this study were 61 Chemistry Education students in the fourth semester. The identification results show that the PCK ability of prospective chemistry teachers in the components of the knowledge of curriculum, knowledge of students’ understanding of science, and knowledge of assessment is still in the “fair” category with the percentage of mastery of the components respectively 70.96%; 62.70%; 74.67%. Based on the research results, it is necessary to have a professional development program to enhance the PCK ability of prospective chemistry teachers.

1. Introduction

In recent years, researchers are increasingly interested in the development of professional knowledge of prospective teachers [1]–[5] to enhance prospective teachers’ competencies. Being a professional teacher requires extensive knowledge and teacher knowledge that can be directly integrated into the learning experience in a real context [6]. One of the important basic competencies that must be owned by a teacher for teaching is pedagogical content knowledge (PCK) [7]. PCK is an amalgam of content and pedagogy into an understanding of how certain topics, problems, or issues are organized, represented, and adapted to the various interests and abilities of students, and presented for learning [7]. CK is defined as knowledge of the subject matter that should be learned and taught, while PK is the knowledge about the process and practice of teaching and learning [7], [8]. Teachers should know the learning content at a more advanced level than their students[9], [10]. PK includes the strategies of classroom management and organization to achieve learning objectives [7].

PCK facilitates teachers to transform their content knowledge into a form that is pedagogically strong but adaptive to the varying abilities of students [7]. The PCK ability of prospective chemistry teachers needed to formulating learning objectives, selecting learning models/methods that are appropriate to the characteristics of the material and students, choosing the right learning
sources/media, describing subject matter to facilitate students' understanding, and determining how to assess learning processes and outcomes learned [7], [11], [12]. PCK involves the process of transforming teachers' knowledge (content knowledge, pedagogical knowledge, and knowledge of context) into learning [1] so that it can be used effectively and flexibly in the classroom learning practices. The packaging of subject matter for learning requires teachers' knowledge and skills about PCK so that teachers' content knowledge can be transformed pedagogically through learning to facilitate student understanding [7]. This knowledge guides teacher actions in practice, encompassing teacher knowledge and beliefs on various aspects such as pedagogy, subject matter, students, and curriculum [13]. Teachers' PCK abilities have a significant positive impact on teaching quality and student achievement [9]. Teachers' ability to identify students' misconceptions is a form of PCK [14] that can be used as a basis for providing a better understanding of students. In addition, teachers’ PCK also has a positive impact on cognitive outcomes and student motivation [9], [15]. Prospective chemistry teachers must have a good mastery for each PCK component and be able to integrate each component into learning coherently to provide a better learning process and outcomes. The conceptualization of PCK according to the concept of Magnusson [12] emphasizes the importance of coherence and integration between each PCK component for effective learning. If a teacher cannot coherently integrate every PCK component, and only mastering one component may not be sufficient to support the achievement of learning objectives.

Therefore, it is necessary to explore the understanding of prospective chemistry teachers in integrating PCK components in learning. This study aims to identify the PCK ability of prospective chemistry teachers in terms of the Magnusson framework [12], which makes the concept of pedagogical content knowledge (PCK) for science teaching consisting of five components, namely: (1) orientation to teaching science, (2) knowledge of the curriculum, (3) knowledge of students' understanding of certain science topics, (4) knowledge of assessment in science, and (5) knowledge of learning strategies. Through this research, the information will be obtained about the ability of prospective chemistry teachers to integrate each PCK component in chemistry learning. So that it can be seen which components are mastered well or which have not been mastered by prospective chemistry teachers. This information is needed as a basis for designing professional development to facilitate prospective chemistry teachers in improving their PCK skills.

2. Methods
This study is descriptive with qualitative and quantitative approaches. This study aims to identify the ability of prospective chemistry teachers to each component of the PCK. The subjects in this study were 61 Chemistry Education students in semester IV of the 2019/2020 academic year who took the chemistry learning planning course. The subjects were predominantly female with 55 people (90.16%) versus 6 (9.84%) male. In the chemistry lesson planning course, it can be seen how prospective chemistry teachers implement their knowledge in planning and designing an instruction. The sampling technique was carried out by purposive sampling, which is taking research samples based on certain considerations that aim to make the data obtained more representative.

Data collection techniques were documentation and interview. The data were obtained from the identification of the PCK abilities of prospective chemistry teachers for each component. Identification of the PCK ability of prospective teachers was carried out using an instrument lesson plan's review sheet and structured interviews which were validated by two science education experts.

The lesson plan’s review sheet was developed based on the Magnusson concept [12], regarding PCK components that are integrated into RPP components. The PCK components identified include; (1) orientation to teaching science, (2) knowledge of curriculum, (3) knowledge of students' understanding of certain science topics, (4) knowledge and beliefs about assessment in science, and (5) knowledge of learning strategies [12].

The collected data tabulated then interpret the score. The data analyzed quantitatively by calculating the mean (M) to determine the mean score of mastery on each item of the PCK component, then categorized according to Table 1. Qualitative analysis was carried out by converting the scores.
obtained into percentages, then described qualitatively. The results of the interviews were analyzed in a descriptive qualitative to deepen information about the PCK abilities of prospective chemistry teachers for each component.

**Table 1. Score Category.**

| Interval               | Criteria      |
|------------------------|---------------|
| 3.60 < \( \bar{X} \) ≤ 4.00 | Very Good    |
| 3.00 < \( \bar{X} \) ≤ 3.60  | Good          |
| 2.40 < \( \bar{X} \) ≤ 3.00  | Fair          |
| 1.80 < \( \bar{X} \) ≤ 2.40  | Poor          |
| 1.00 < \( \bar{X} \) ≤ 1.80  | Very Poor     |

3. **Results and discussion**

The identification results PCK ability prospective chemistry teachers at every component summarized in Table 2.

**Table 2. Percentage of the PCK ability of prospective chemistry teachers for each component.**

| PCK components                             | Mastery of Each Indicator (%) | Category |
|--------------------------------------------|-------------------------------|----------|
| Orientation to teaching science             | 88.36                         | Good     |
| Knowledge of curriculum                     | 70.96                         | Fair     |
| Knowledge of students' understanding of a science | 62.70                       | Fair     |
| Knowledge of assessment in science          | 74.67                         | Fair     |
| Knowledge of instructional strategies       | 84.83                         | Good     |

Analysis of PCK ability of prospective chemistry teachers was carried out using lesson plan’s review sheets developed based on PCK components according to Magnusson [12], namely: (1) orientation to teaching science, (2) knowledge of the curriculum, (3) knowledge of students' understanding of science, (4) knowledge and beliefs about assessment, and (5) knowledge about instructional strategies.

Each PCK component has several indicators that are used to identify the PCK abilities of prospective chemistry teachers through the lesson plan's review. The results of identification PCK abilities of prospective chemistry teachers for each indicator in each component described as follows:

3.1. **Orientation to teaching science**

The PCK ability of prospective chemistry teachers in the orientation to teaching science describe in Table 3. Table 3. shows that the PCK ability of prospective chemistry teachers in the component of orientation to teaching science is generally categorized as "good". The average percentage of indicator mastery was 88.36% (Table 2.). Prospective chemistry teachers can provide appropriate orientation to designed learning because each learning model/method has characteristics with a certain orientation [12]. Learning orientation has two important elements: the goals of teaching science and the characteristics of instruction with a particular orientation [12].

In the lesson plan, it was found that prospective chemistry teachers who use the discovery learning model were able to describe active learning that was centered on students to explore learning materials to find patterns and concepts by themself. Prospective chemistry teachers who choose problem-based learning, the design learning centered on problem-solving. Prospective teachers who choose inquiry-based learning use experimental methods to investigate problems. It was appropriate with the orientation to teaching science described by Magnusson [12], learning orientation inquiry has characteristics investigations-centered, teachers support students in defining and investigating the problem, draw conclusions, and assess the validity of their conclusions.
Table 3. PCK ability on each indicator component of the orientation to teaching science.

| Indicator                                                      | Mean | Criteria   |
|---------------------------------------------------------------|------|------------|
| Subject matter identity                                      | 4.00 | Very good  |
| Formulate learning objectives appropriate with the Audience, Behavior, Condition, and Degree aspects | 3.24 | Good       |
| Formulate learning objectives according to measured competencies | 3.34 | Good       |
| Choose a method appropriate with the learning objectives      | 3.54 | Good       |
| Choose a model or learning method with a relevant approach    | 3.54 | Good       |

3.2. Knowledge about the curriculum

The PCK abilities of prospective chemistry teachers in the knowledge of the curriculum described in Table 4. Magnusson states that knowledge of the curriculum includes knowledge of the goals and objectives in the subject they are teaching, and also knowledge of specific curricular programs [12]. The knowledge component of the curriculum shows that the average percentage of indicator mastery is 70.96% with the "fair" category (Table. 2).

Table 4. PCK ability on each indicator of the knowledge component of the curriculum.

| Indicator                                                      | Mean | Criteria   |
|---------------------------------------------------------------|------|------------|
| Formulate learning objectives according to the curriculum     | 3.49 | Good       |
| Arrange teaching materials appropriate with the scope of material in the curriculum | 3.13 | Good       |
| Arrange teaching materials appropriate with the learning objectives | 2.95 | Fair       |
| The correctness of the composition of teaching materials      | 2.18 | Poor       |
| Describing the subject matter into teaching materials         | 1.68 | Very Poor  |

Based on the PCK identification results of prospective chemistry teachers from the lesson plan’s review and interviews, the ability of prospective chemistry teachers is still quite low in mastering certain curriculum programs and materials that are relevant to teaching a particular domain of science.

The results of interviews with prospective chemistry teacher respondents regarding knowledge of the curriculum are in line with the identification of PCK based on a review of the lesson plan. Following are the interviews conducted:

Interviewer : "What aspects need to be considered in formulating learning goals and objectives?"

Prospective teachers A: “Students, curriculum and evaluation. Besides that, there are also cognitive aspects, skills, and attitudes to be achieved."

Prospective teachers B: "Formulating learning objectives needs to consider students, learning activities, the conditions before and after learning to be achieved."

Prospective teachers C: “Things that must be considered are the characteristics and abilities of students, curriculum, and evaluation."

Based on interviews with prospective chemistry teachers with "good" PCK skills, they already have an understanding of the learning goals and objectives that should be adjusted to the curriculum. Table 4. shows that the PCK ability to knowledge of the curriculum is the lowest on the indicator of
transforming materials into teaching materials with an average mastery score of 1.68 (very poor). This result is supported by the results of interviews with prospective chemistry teachers who still feel that they can’t transform subject matter into teaching materials. The following is a summary of the interviews conducted:

- **Interviewer**: "Are you able to transform the material into teaching materials?"
- **Prospective teachers D**: "No, I don't understand the scope of the material as it is good for teaching materials. Apart from that, I've never done it in person."
- **Prospective teachers E**: "I don't think I have it. Because, in my opinion, I am still lacking in knowledge so I am very afraid of misconceptions."
- **Prospective teacher F**: "Not really, because in my opinion, to be able to compile teaching materials, you must have an understanding of the organization of the subject matter properly."

Based on interviews prospective chemistry teachers can’t describe the material into teaching materials. It relates to the understanding of prospective chemistry teachers about the scope of material in the curriculum, the suitability of the material with learning objectives, and the correctness of the subject matter.

### 3.3. Knowledge of students' understanding of science

PCK includes an understanding of what makes learning a particular topic easy or difficult. It is related to the conceptions and preconceptions that are brought by students of various ages and backgrounds into learning. If the student's preconceptions are misconceptions, the teacher needs knowledge of effective strategies in reorganizing students’ understanding of particular concepts [7]. This component includes knowledge about the requirements for learning and knowledge about the difficulties of students, including teachers' knowledge of concepts or material topics that difficult for the students [12]. The illustrations provided by Magnusson is to provide a variety of different representations to help the self-understanding of chemical phenomena at the level of molecular [12]. In addition, this component also includes knowledge of student difficulty areas which refers to the teacher's knowledge of science concepts or topics that make students feel difficult. Some topics are considered difficult because the concept is very abstract and/or they do not have a connection to students’ real experience [12].

The PCK ability of prospective chemistry teachers about knowledge of students' understanding of a science topic-specific described in Table 5.

**Table 5.** PCK ability on each indicator of the knowledge of students' understanding of science.

| Indicator                                                                 | Mean | Criteria |
|---------------------------------------------------------------------------|------|----------|
| Identify the depth of the material according to the level of development of students | 2.16 | Poor     |
| Interpret and use different representations (macroscopic, sub-microscopic, symbolic) | 1.59 | Very poor|
| Presenting facts/phenomena in the real-world related to subject matter     | 1.86 | Poor     |
| Choose learning sources/media that are appropriate with the characteristics of students | 3.06 | Good     |
| Choosing learning methods that are appropriate with the characteristics of students | 3.45 | Good     |
| Gives apprehension, motivation, and delivery of learning objectives to prepare students' initial knowledge | 2.90 | Fair     |

The knowledge of the students' understanding of science topics was in the "fair" category with an average percentage of indicator mastery of 62.70% (Table. 2). Based on the identification results in
Table 5, it shows that the lowest indicators’ mastery is interpreting and using different representations (macroscopic, sub-microscopic, symbolic) with an average mastery score of 1.59 (very poor). The ability of prospective chemistry teachers is still quite low in representing certain content and presenting facts/phenomena in daily life related to certain topics to be more easily understood by students. The representation used is still at the macroscopic or symbolic level, while the sub-micro level has not been used, especially to explain the material that is abstract and unfamiliar to students. This is consistent with the results of the interview prospective chemistry teachers do not yet understand how to implement macroscopic, sub-microscopic, and symbolic representations in explaining a topic to facilitate students’ understanding.

In addition, prospective chemistry teachers rarely present facts/phenomena in the real world related to learning materials. Important for teachers to know about the real-world experience they need to understand new problems, it can help students more easily understand the relationship between the material learned and the real situation, so that students do not just imagine abstract concepts that make it difficult for students to understand. This knowledge directs the teachers in finding solutions to overcome students' difficulties in understanding certain concepts.

3.4. Knowledge of assessment in science,

The PCK abilities of prospective chemistry teachers on the component of knowledge of assessment in science are described in Table 6. This component includes knowledge of the aspects of science learning that are important to assess, and knowledge of the methods of assessment used [16]. Teacher's knowledge of methods of assessment includes knowledge of specific instruments or procedures, approaches or activities that could be used to assess dimensions of science learning, and the use of tools or assessment techniques specific [12].

Table 6. PCK ability on component about knowledge of assessment in science.

| Indicator                                                      | Mean | Criteria |
|----------------------------------------------------------------|------|----------|
| Provide conclusions, reflection, assessment, feedback, and follow-up on closing activities | 3.01 | Good     |
| Using techniques and forms of instruments appropriate with learning objectives | 3.16 | Good     |
| Formulate question indicators appropriate with learning objectives | 2.83 | Good     |
| Assessment to measure aspects of cognitive, affective, and psychomotor | 3.60 | Good     |
| Establish clear assessment procedures                           | 2.32 | Poor     |

The average percentage of prospective chemistry teachers PCK abilities in the knowledge of the assessment was 74.67% with the "fair" category. Based on the identification results in Table 6 shows that the PCK ability about the knowledge of assessment in science is the lowest on the indicator of clearly compiling assessment procedures with an average mastery score of 2.32 (poor), prospective chemistry teachers are can’t arrange assessment procedures both in the grid and the assessment rubric. The indicator was highest is the suitability of assessment to assess aspects of cognitive, affective, and skills with an average score of 3.60 (good). Most of the prospective chemistry teachers already have good skills in choosing techniques and forms of assessment instruments that are tailored to the aspects that want to be assessed and the learning objectives. For example, affective aspects are assessed through observations of students' attitudes during the learning process. Students' conceptual understanding can be assessed by written tests whereas their understanding of scientific investigation requires assessment through practical laboratory examinations [17]. In addition, it can also use a form of performance-based assessment and portfolio [18], [19] whether evaluated at the end of learning activities or during learning activities.
3.5. Knowledge of instructional strategies

The PCK ability of prospective chemistry teachers in the component knowledge of instructional strategies is described in table 7.

| Indicator                                                                 | Mean | Criteria |
|---------------------------------------------------------------------------|------|----------|
| Supports competency achievement and active learning                       | 3.47 | Good     |
| Using learning resources/learning media including printed, electronic,    | 3.40 | Good     |
| natural, and other learning resources                                       |      |          |
| Choose learning resources/learning media that are appropriate with the    | 3.24 | Good     |
| learning objectives                                                        |      |          |
| Choosing learning resources/learning media that are appropriate with the   | 3.22 | Good     |
| learning material                                                          |      |          |
| Arrange complete learning steps                                            | 3.70 | Very good|
| Arrange learning steps according to the learning model/method used         | 3.31 | Good     |
| Describe a communicative and interactive learning process                  | 3.63 | Very good|
| Develops learning steps tailored to the allocation of time                 | 3.13 | Good     |

The teacher's knowledge about the components of instructional strategies consists of two categories: knowledge of subject-specific strategies, and knowledge of topics-specific strategies [12]. Knowledge of subject-specific strategies includes general approaches or overall schemes for enacting science instruction. Knowledge of topic-specific strategies refers to the teacher's knowledge of specific strategies that are useful to help students understand specific concepts [12]. This category includes topics-specific representation and activities.

The PCK ability of prospective chemistry teachers in the component of knowledge about instructional strategies has an average percentage of 84.98% with the "good" category. Prospective chemistry teachers are generally able to develop strategies that include learning approaches/methods and describe the stages of learning according to the learning model used. Prospective chemistry teachers have also been good at implementing knowledge about topic-specific strategies. For example, to explain the topic of the effect of temperature on reactions, prospective teachers give an example of an illustration that dissolving sugar or salt in boiling water will dissolve faster than using cold water. Prospective chemistry teachers could create representations to help students develop an understanding of certain concepts. Representations that can be used to aid student understanding can be in the form of illustrations, examples, models, or analogies [12], [13].

In the learning strategies designed in the lesson plans, most of the prospective chemistry teachers have provided learning activities that support students' understanding of certain topics. Based on interviews with several prospective chemistry teachers, the results are consistent with the results of the PCK identification based on the lesson plan's review. For example, to ask what activities can be used to help students understand certain topics. Overall, prospective chemistry teachers gave answers which included presenting practice questions, using the questions and answers method, quizzes, discussions, presentations, experiments, and making concept maps. This is supported by the opinion of [12] Magnusson that activities that can be used to help students understand certain concepts or relationships can be in the form of examples, problems, simulations, demonstrations, or experiments [12].
4. Conclusion
The conceptualization of PCK according to the concept of Magnusson [12] emphasizes the importance of coherence and integration between each PCK component for effective learning. If a teacher cannot coherently integrate every PCK component, and only mastering one component may not be sufficient to support the achievement of learning objectives. Based on the results of this study, the PCK of prospective chemistry teachers in several components was still in the “fair” category. It means that each PCK component has not been mastered properly by prospective chemistry teachers. The problems faced by prospective chemistry teachers are difficulties in packaging chemistry materials appropriately for high school level and how to properly teach these materials. In general, prospective chemistry teachers also do not understand the knowledge of students' understanding of chemistry so that prospective teachers only preparing teaching materials without thinking about what actions to take when there are students who have difficulty understanding the material or when there are misconceptions in students. On average, chemistry teacher candidates do not know how to make appropriate assessment procedures for the dimensions of chemistry learning that are important to assess.

Considering the results of this study, a design is needed to develop the ability of prospective chemistry teachers to integrate PCK components in learning. It is necessary to facilitate the education of prospective teachers with knowledge and skills about PCK by considering the coherence and integration of each component in learning. We recommend further research to develop the PCK abilities of prospective chemistry teachers, referring to enhance understanding of how teachers change subject matter knowledge for student learning and the application of this understanding in the context of prospective teachers’ education.

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References
[1] Abell S K, Rogers M A P, Hanuscin D L, Lee M H and Gagnon M J 2009 Preparing the next generation of science teacher educators: A model for developing PCK for teaching science teachers J. Sci. Teacher Educ. 20 77–93
[2] Van Driel J H, De Jong O and Verloop N 2002 The development of preservice chemistry teachers’ pedagogical content knowledge Sci. Educ. 86 572–590
[3] Evens M, Elen J, Larmuseau C and Depaepe F 2018 Promoting the development of teacher professional knowledge: Integrating content and pedagogy in teacher education Teach. Teach. Educ. 75 244–258
[4] Kartal T, Ozturk N and Ekici G 2012 Developing pedagogical content knowledge in preservice science teachers through microteaching lesson study Procedia - Soc. Behav. Sci. 46 2753–58
[5] Meschede N, Fiebranz A, Möller K and Steffensky M 2017 Teachers’ professional vision, pedagogical content knowledge and beliefs: On its relation and differences between preservice and in-service teachers Teach. Teach. Educ. 66 158–170
[6] Darling-Hammond L and Bransford J 2005 Preparing teachers design of teacher education programs (San Francisco: Jossey-Bass)
[7] Shulman L 1987 Knowledge and teaching: Foundations of the new reform Harv. Educ. Rev. 57 1–23
[8] Mishra P and Koehler M J 2006 Technological pedagogical content knowledge: A framework for teacher knowledge Teach. Coll. Rec. 108 1017–54
[9] Baumert J et al. 2010 Teachers’ mathematical knowledge, cognitive activation in the classroom, and student progress Am. Educ. Res. J. 47 133–180
[10] Kleickmann T et al. 2013 Teachers’ content knowledge and pedagogical content knowledge: the role of structural differences in teacher education J. Teach. Educ. 64 90-106

[11] Park S and Oliver J S 2008 Revisiting the conceptualization of pedagogical content knowledge (PCK): PCK as a conceptual tool to understand teachers as professionals Res. Sci. Educ. 38 261–284

[12] Magnusson S, Krajik J and Borko H 1999 Nature, sources, and development of pedagogical content knowledge for science teaching. In Gess-Newsome J and Lederman N G (Eds.) (Boston: Kluwer Press) pp. 95–132

[13] Van Driel J H, Verloop N and De Vos W 1998 Developing science teachers’ pedagogical content knowledge J. Res. Sci. Teach. 35 673–695

[14] Sadler P M and Sonnert G 2016 Understanding misconceptions teaching and learning in middle school physical science Am. Educ. Spring 40 26–32

[15] Kunter M, Klusmann U and Richter D 2013 Professional competence of teachers: effects on instructional quality and student development 105 805–820

[16] Tamir P 1988 Subject matter and related pedagogical in teacher education Teac Teach Educ. 04 99-110

[17] Tamir P 1974 An inquiry oriented laboratory examination J. Educ. Meas 11 25–33

[18] Duschl R A and Gitomer D H 1991 Epistemological perspectives on conceptual change: Implications for educational practice J. Res. Sci. Teach. 28 839–858

[19] Kulm G and Malcom S M 1991 Science Assessment in The Service of Reform (Washington D.C : American Association for The Advancement of Science)