Prospective Chemistry Teacher’s Pedagogical Content Knowledge in Chemical Application Planning

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Abstract. This research aimed to analyze the ability of PCK (Pedagogical Content Knowledge) students of prospective chemistry teachers FKIP UNS. The research method was qualitative descriptive. The study samples were all prospective chemistry teachers of FKIP UNS who took the course of Chemical Application Planning (PPK). Data was collected from the observation of student PCK competencies, including the ability to design learning, ability in material mastery, and general PCK skills of prospective chemistry teachers from Content Representation. This research instrument was an observation sheet of PCK and CoRe competency students’ prospective chemistry teachers. The percentage of students’ prospective chemistry teachers of FKIP UNS to plan learning was 75.38% for grade A and 74.34% for grade B, while for content mastery was 77.19% for class A 74.79% for grade B, where the results were included in the category enough. The results of content representation by prospective chemistry teachers in high school chemistry were also quite sufficient.

1. Introduction
Teachers represent education, so teachers must have professional preparation. In decades, educational research has provided compelling evidence that the quality of the learning opportunities created by teachers affects students’ learning and motivation [1]. The students depend on how they teach them. An effective science teacher will create an environment that supports both teachers and students as active learning agents. While students learn with learning resources, teachers also learn to understand students with different interests, abilities, and experiences to learn science. Besides, teachers know how to provide adequate support and guidance for their students [2].

The teacher competence from the early childhood education level to intermediate levels includes four competencies: professional, pedagogical, social, and individual competencies as regulated in Government Regulation No. 19 of 2005 concerning National Education Standards, in article 28 paragraph 3 [3]. The four competencies mentioned in Law No. 14 of 2005 concerning Teachers and Lecturers [4]. The regulation of Education Ministry No. 16/2007 emphasizes that science teachers must have complex academic requirements [5]. There are at least 14 requirements, including (1) understanding the theory, laws, and concepts of science and their flexible application, (2) being creative and innovative in the application and development of science. These two kinds of competencies require science teachers to have a deep mastery of science material content and teach it. Therefore, teachers must continue to improve their abilities to become professionals.
Given the importance of teacher knowledge for student progress, teacher education can be regarded as a key target and lever of educational reform. However, the understanding of how teacher education programs affect the development of professional knowledge remains limited [6]. The Teacher Competency Test (UKG) achievement can represent one of the teacher's pedagogical competencies. The purpose of the UKG is to obtain information about teacher competence, especially pedagogical competence, and professional competence with the predetermined standards. Based on the results of the competency test in 2015, the average competency score of teachers from all levels is quite alarming. Nationally, elementary-level teachers’ average value is 40.14, while junior high school teachers are 44.16 and high school teachers are 45.38. This value is still below the minimum standard set at 55. In 2016, the Ministry of Education and Culture recorded a significant increase in the average score. However, the average score was still below 70 until 2017 for all levels of education.

Thus, both in-service and pre-service science teachers need to have a vital mastery of fundamental concepts (content) and teach these concepts (pedagogy) correctly and adequately. The results showed that one of the factors for teacher teaching effectiveness was the ability of content and pedagogy [7]. A teacher needs to have a rich understanding of the concept (content) about the materials. It is essential to combine conceptual knowledge with expertise in using teaching procedures, strategies, and classroom approaches. Using and creating a mix of content knowledge and pedagogical knowledge is PCK. Shulman stated that pedagogical content knowledge serves as part of the knowledge base for teaching [8]:

“Pedagogical content knowledge represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction”

A teacher's PCK can influence how to teach and make students understand the materials [9]. Professional teachers need to have strong PCK knowledge and abilities [10]. There was some previous research carried out both inside and outside Indonesia. These studies included studies by An, Kulm, and Wu (2004), Hill et al. (2008) and Kleickmann, et al (2012). From these various studies, the results obtained indicate that Pedagogical Content Knowledge (PCK) is a professional skill that is important in developing teacher teaching skills [11,12,13].

Loughran, et al., (2006) developed an assessment format that includes the essential aspects of understanding science and pedagogy subject matter knowledge to represent the PCK of a science teacher. There are two parts of the PCK assessment. The first part is CoRe (Content Representation) which offers a perspective on specific content when teaching a topic. The second part is PaP-eRs (Pedagogical and Professional-Experience Repertoires) which are brief but have a particular meaning. It intends to demonstrate the implementation of aspects of CoRe [14]. Based on the problems, the study needed to prepare prospective chemistry teachers to have pedagogical and content knowledge. Accordingly, chemistry students need the identification of Pedagogical Content Knowledge (PCK).

2. Method
This research collected data on the PCK abilities of prospective teacher students. The data collected are in the terms of pedagogical and professional skills. The researcher analyzed the pedagogical skills from the lesson plan study results and the CoRe filling data. Moreover, the data analysis of professional abilities was from the material matrix (content) created after the students followed the Chemistry Learning Planning course. PCK debriefing for prospective teachers focused on the Chemistry Learning Planning course and the microteaching course. The sampling of the research subjects for prospective teachers selected from the researcher's consideration of participation in PCK debriefing and microteaching. The research subjects were 61 students of the second year in Chemical Education students who took the Chemistry Learning Planning course. The research used a qualitative method by analyzing the lesson plans' results, material matrix (content), and students' CoRe results. In this study, the students did not carry out the preparation of PaP-eRs because they wrote PaP-eRs after doing the microteaching. The CoRe instrument adopted the description of Loughran et al. (2004), which was in this following Table 1 [15].
Table 1. CoRe format according to Loughran et al.

| No | Questions |
|----|-----------|
| 1. | What will you teach students about the idea/concept? |
| 2. | Why is it important for students to understand the concept? |
| 3. | What ideas have not been known by students about the concept? |
| 4. | Are there any difficulties in teaching the concept? |
| 5. | What are the common mistakes (misconceptions) in teaching the concept? |
| 6. | What factors influence the way you teach? |
| 7. | What is the teaching procedure in teaching the concept? |
| 8. | What are the ways you do to find out that students understand or are confused about the concept? |

3. Finding and Discussion

There are three parts of the results and discussion in this chapter: a description of the ability to design the learning, a description of the competency in mastering the material or content, and the PCK (Pedagogical Content Knowledge) profile of Chemistry teacher candidate students.

3.1 A Description of the Ability to Design the Learning Planning for Chemistry Teacher Candidate Students

Teachers need to master pedagogic competence, which is one type of competence. Pedagogic competence is the ability of teachers to design and manage student learning. There are five aspects related to pedagogical competence, including curriculum knowledge, understanding of students, knowledge of teaching, knowledge of evaluation, and mastery of resources [16].

The lesson plan review results conducted by the Chemistry teacher candidate students represent the ability to design the lesson. Based on Chemistry students' design analysis, the percentage of achievement in class A is 75.38% with a value distribution, as shown in Figure 1. Slightly below Class A's achievement, the percentage of achievement for class B is 74.34% with a value distribution, as in Figure 2. This percentage shows that Chemistry teacher candidate students' average ability in compiling learning designs is considered sufficient.

The first aspect relates to the prospective chemistry teachers’ knowledge about the curriculum. The curriculum is the basis for learning by preparing learning tools such as calendars, syllabus, lesson plan (RPP), and textbooks as teaching materials. In this aspect, the indicators contain learning procedures, starting from the identity and completeness of the components, learning materials, learning methods, and management of learning activities as outlined in the lesson plan. Indicators of identity and completeness of components contain three aspects. The first aspect is the completeness of identity. A
complete learning identity has subjects, education level, class, semester, time allocation, and implementation date. The second aspect includes Competency Standards (SK) or Core Competencies (KI), Basic Competencies (KD), and the formulation of indicators. The third aspect is that determining learning objectives must be formulated to the learning indicators. Because the second aspect is the teacher’s understanding of students, chemistry teacher candidate students should analyze the media and learning models with the students’ material and the learning goals. Teachers’ knowledge of students to help the learning process includes physical, intellectual, emotional, and character socio-cultural backgrounds.

The third aspect is knowledge about teaching. Chemistry teacher candidate students can analyze learning strategies, use of learning resources, and use information communication technology (IT) to benefit learning so that students are more motivated to increase creativity in every learning activity. The learning method or model used refers to the scientific approach that required students to solve problems with teacher assistance. The learning steps must also be in line with the method used. There are three main steps in learning activities. The first step is to open learning activities that begin with a clear and correct apperception design. Then, there is a way to motivate students. The second activity is the main activity in learning. It collaborates with the flow of KD achievement stages, and the learning stages provide opportunities for students to interact with friends, teaching materials, teachers, or the learning environment. The last step is the activity of closing learning.

The fourth aspect is knowledge about evaluation. The evaluation aims to see the achievement of learning objectives by students. Student performance assessment is from the elements of knowledge, attitudes, written and spoken skills, and observation. Chemistry teacher candidate students have analyzed the lesson plan reviews according to their competence by reflecting the assessment instrument with basic competence. The assessment instrument used includes a written posttest, attitude assessment questionnaire when students conduct discussion and presentation. The fifth aspect is resources include learning media, teaching aids, learning resources, and information technology used in learning. Based on the lesson plan study results, student chemistry teacher candidates have analyzed the use of instructional media such as the use of images, videos, and websites. Moreover, they can explain the advantages of using these media in learning certain chemical materials and teachers’ roles in using these media.

3.2 A Description of competence in the content mastery of Chemistry teacher candidates on Learning Planning

![Figure 3. Score Distribution of Content/ Material Mastery in Class A](image)

![Figure 4. Score Distribution of Content/ Material Mastery in Class B](image)

The content mastery of prospective teachers is professional competence, which is the primary competence of a teacher. Teachers must have the professional competence to master their field. For Chemistry prospective teachers, the assessment of the mastery of chemical concepts is from the chemical matrix. The first indicator is the correctness of the idea of learning materials in a theoretical
explanation. The second indicator is the formulation of basic competencies according to content standards.

The development of learning materials must relate to the basic competencies and the learning materials. Moreover, it should be both conceptually or theoretically correct. This matrix assessment used the matrix assessment rubric made by the Chemistry prospective teachers. Based on the subjects’ performance analysis, the percentage of achievement was 77.19% for class A with the distribution of values in Figure 3. On the other hand, the percentage of achievement for class B is below class A, which is 74.79% with the distribution of values in Figure 4. The percentage indicates that the content mastery of chemistry teacher candidates is insufficient criteria.

3.3 PCK Profiles of Chemistry Prospective Teachers

The PCK ability of prospective teacher students in planning learning through CoRe represents the ability of the CoRe component. The results of the analysis show that the students' PCK ability in planning learning through CoRe is still simple. It is possible due to the lack of experience in delivering chemistry material in class. In another opinion, PCK is an integrated collection of knowledge, concepts, beliefs, and values that teachers develop in teaching situations [17]. Thus preservis or novice teachers usually have minimal PCK compared to experienced teachers [18]. Moreover, the results will show that the teacher is dominant in one aspect of both procedural, concept, or teaching representation.

The following is an example of a description of the CoRe document's preparation written by prospective chemistry teacher students.

3.3.1. What materials will you teach about these ideas/concepts to the students?

Determining concepts is essential. It begins with how the teacher decides the learning objectives in various ways. The number of big ideas written by chemistry teacher candidates is quite different from one another. For example, student A focused on colligative traits, but student B wrote about molality and mole fraction. Even though the ideas are different from one another, they still seem coherent. For example, teachers A and B explain the definition of the colligative properties of a solution. They chronologically presented the others, such as molality, molarity, mole fraction, decrease in vapor pressure, increase in the solution's boiling point, decrease in the freezing point of the solution, and osmotic pressure, and colligative properties of electrolyte compounds.

3.3.2. Why is it essential for students to understand this concept?

Regarding the importance of chemical concepts to be studied by students, prospective chemistry teachers answered that the basic concepts were essential to learning the next material. Moreover, they stated the concepts related to daily life and the emergence of material in national exams. There are no prospective teachers who have written about the benefits of learning the idea of the material. If a teacher explains the benefits of studying the materials, there is a link to the preliminary activities, including orientation and perception. The lesson plan analysis results wrote down their orientations and perceptions on the preliminary activities to motivate students. Still, there is no information on how to motivate students.

3.3.3. What ideas have not been known by students about the concept?

This question relates to prospective teacher students' ability to decide what materials the students need and have never learned yet. It will affect the depth and breadth of the materials. Some students wrote too in-depth materials that were too in-depth, but some students had not determined the depth of the chemical material conveyed to students. The prospective teachers have not yet reached the limit of materials as backup materials related to the main ideas.
3.3.4. Are there any difficulties in teaching this concept?

The difficulty of prospective teacher students in teaching important concepts is different from one another. Some review the limitations of tools and chemicals in carrying out practicum or demonstrations, prerequisite materials, mathematical formulas used, and too abstract material. They stated that the focus was on the material. The students had not analyzed the difficulties that might arise while implementing the learning method.

3.3.5. What are the common mistakes (misconceptions) in teaching the concept?

This question is about how prospective teacher students analyze the students' knowledge and predict students' ability to absorb the materials. Based on the answers, they had almost the same problem, which was on how to convey the concept of material to understand it.

3.3.6. What factors influenced the way you taught?

Each student has specific considerations in designing the teaching materials. The considerations are from the number of students, limited tools and materials, and time allocation due to different learning environments and conditions. This identification requires deep thinking and the ability to relate concepts to various things.

3.3.7. What is the teaching procedure in teaching the concept?

Prospective teachers must determine the teaching media and learning flow so that the learning process can be useful, efficient, and pleasant. There are many varieties of different methods and media to teach an important concept. Implementation of classroom learning designed activates students through practicum and group discussions—additionally, the learning methods adapted from the learning material.

3.3.8 What are the ways you do to find out that students understand or are confused about the concept?

This question is about the assessment prepared for each indicator in a particular basic competence. Moreover, it allows the teacher to design follow-ups to improve the learning process. The CoRe results represent the readiness of prospective teachers in developing evaluation tools. The students had not shown how to assess the students, so they still needed more evaluation ideas. The method of assessment expressed by prospective teachers is still traditional, such as by carrying out tests.

Based on the study results, four CoRe components have not demonstrated the ability of prospective teachers to integrate content knowledge and pedagogy. The four components include material boundaries, the difficulty of teaching main ideas, students' prior knowledge that affects learning, and how to assess students' abilities.

4. Conclusion

Based on the analysis and discussion results, the conclusion is that the percentage of Chemistry teacher candidate students' pedagogical and professional abilities is sufficient criteria. The analysis results were from the lesson plans, material matrix, and CoRe data filling. The PCK ability of prospective teacher students in planning learning through CoRe still has not shown an integration between pedagogical knowledge and content. Moreover, four CoRe components have not shown the ability of students to integrate content knowledge and pedagogy. The four elements are material boundaries, the difficulty of teaching main ideas, students' prior knowledge that affects learning, and the assessment of students’ ability components.

The prospective teacher students cannot obtain the PCK ability in a short time. Moreover, students’ field experience programs do not guarantee teaching expertise. Therefore, it would be better if there is a continuous program carried out, so that prospective teacher students’ teaching ability is more honed, especially in lectures. The PCK competence of a teacher can increase if there are various supporting aspects of learning, including teachers, students, facilities, and teacher preparation. It is in line with
Cochran (1993), who also said that teachers learned from content knowledge learning, innovative development, and substantive learning. Thus, various parties should participate in evaluating continuously [19].

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