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Pedagogical content knowledge of pre-service physics teachers

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ABSTRACT

This study aims to describe the content knowledge, pedagogical knowledge, and pedagogical content knowledge of students of pre-service physics teachers at Walisongo Semarang. The type of research is quantitative descriptive. The samples were Physics Pre-service teachers at Universitas Islam Negeri Walisongo Semarang. The samples were 65 pre-service physics teachers determined by the purposive sampling technique. The method of collecting data used was a test, observation, and documentation. The results showed that pre-service physics teachers' content knowledge capabilities were in three categories, namely: 35% poor, 42% sufficient, and 23% good. The pedagogical knowledge test showed that 16% of physics pre-service teachers were in a good category, 77% were in a good category, and 7% were in a very good category. The results of the pedagogical content knowledge test showed that 12% of the pre-service physics teachers were in the poor, 30% were in the moderate category, 35% were in a good category, and 23% were in the very good category. Pre-service physics teachers had the lowest ability in determining other factors that influence teaching concepts, and the highest ability in determining important science concepts in the material to be taught. This research implies that remediation is needed to improve physics pre-service teachers' Pedagogical Content knowledge capabilities, which can be applied in the Plan of Learning course.

INTRODUCTION

Teachers in the 21st-century are not only demanded to master the correct concept but also demanded to be able to deliver the concept properly to be understood comprehensively by students (Dare et al., 2018; Putra et al., 2018). Optimal learning may be achieved when teachers can formulate learning purposes, create learning objectives, create evaluative instruments, select relevant materials and evaluative learning instruments, design learning, and make students master the materials (Rahmadhani et al., 2016).

Based on an interview with four teachers and five physics lecturers in Semarang, heretofore, learning has only been emphasized on conceptual mastery, specifically within the cognitive aspect. Most educators, both teachers, and lecturers are seldom to assess affective and psychomotor aspects. The main cause is learning limitations, so that assessment may only be done twice or three times a semester from the midterm and final semester tests. It causes of pre-service teachers tend only to emphasize conceptual material and consider pedagogical aspects as less important. Proper educators do not only master materials but

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also pedagogical aspects to make their students understand the delivered materials (Nugraheni, 2015). Ball stated incapability to understand certain materials of teachers would not have properly needed the knowledge to facilitate students in mastering the material (Hansen-Thomas et al., 2016), because to the only master, the material would not be sufficient to teach (Suh & Park, 2017; Supriyono, 2018).

Teachers will not succeed in educating students when they only master a certain concept or pedagogy (Banyumin, 2016; Häkkinen et al., 2017). Both capabilities must be mastered and integrated to be implemented. Teachers who master the material without mastering the pedagogical aspect will not be able to make their students understand. In contrast, teachers who master pedagogical concepts without mastering the material will not be able to deliver the material (Maryono, 2016; Putra et al., 2017). Therefore, both capabilities must be synergic and integrated, known as Pedagogical Content Knowledge. Teachers need to create meaningful learning (Maryono, 2016).

Pedagogical Content Knowledge (PCK) is defined as the portray of a teacher to teach a subject in understanding the content material, skill, related curriculum to the material, and appropriate method to teach accurately (Rollnick, 2016). PCK covers main activities, starting from teaching, learning, curriculum, assessment, and report to support learning. It is also related to curriculum, assessment, and pedagogy (Mishra & Koehler, 2009).

PCK is a factor that allows the possibility to improve teacher's effectiveness (Williams & Lockley, 2012). It can be done by combining both pedagogical knowledge and content knowledge. PCK is a capability to motivate and sustainably develop through teaching experiences and prior content material mastery by using a certain method to make students being able to achieve a certain degree of understanding (John Loughran et al., 2012).

Pedagogical Content Knowledge (PCK) influences the teacher's professionalism in teaching. Development of a teacher's personality covers ways of teachers learning, learning to teach, and transforming their capabilities to any good practices for their students' development (Avalos, 2011). Teachers are considered professionals when they can learn materials properly, master ways of teaching, and deliver the knowledge appropriately to students' conditions (Banyumin, 2016; Shernoff et al., 2017).

Findings from Anwar et al. (2014) show that teachers with less than 10-year teaching experiences tended to teach without considering students' characteristics. Teachers should master all materials and design learning materials to facilitate students in understanding them by considering their characteristics. It is stated on Permendikbud No. 22 Tahun 2016 stating that characteristics of a certain learning process must be adjusted to competence and students' development level characteristics.

Well, PCK of a teacher influences his ways of integrated learning by considering the materials and characteristics of students (Putra et al., 2017). However, until the present day, only a few studies have mapped Pedagogical Content knowledge of pre-service teachers, especially physics pre-service teachers. Study-related to PCK was done by Yohafrin et al. (2015) about PCK analysis of Mathematics-Science Teachers of Public SHS 11 Jambi found PCK level of the teachers were low; (Agustina, 2015)about analysis of learning simulation role in developing PCK of Biology pre-service teachers; and (Suh & Park, 2017)about the identification of general PCK patterns of three top teachers by using argumentative investigation approach.

This research is essential to figure out Pedagogical content knowledge profiles of pre-service physics teachers, so any revision may be promoted to have better professional future outcomes.

METHODS

This research was conducted on students of the Physics Department of UIN Walisongo Semarang, taken by purposive sampling from 65 students. The students had passed Basic Physics 1, Basic Physics 2, Mechanics 2, Mechanics 2, Thermodynamics, Magnetic Electricity, Optical Wave, Educational Psychology, Educational Management Principles, Learning Methodology, Learning Evaluation, JHS Physics Curriculum Review, and SHS Physics Curriculum Review.

This descriptive quantitative research used documentation, test, and observation as data collection methods. Documentation was done to get score lists of the courses as content knowledge and pedagogical knowledge data to be analyzed. The test was done to test the students' abilities in composing the PCK framework. The observation was done to assess the students' abilities in teaching. PCK framework consists of 10 question aspects: 1) scientific concepts/ideas, 2) things to be understood by students from the concept, 3) the importance of the concept mastery, 4) knowledge about unexpected concepts to be mastered by students, 5) difficulties/limitations related to teaching the concept, 6) students' thought (including misconception) influencing teaching, 7) other influential factors to teaching concept, 8) ways to deliver the concept, 9) ways to assess, and 10) teaching procedure.

The data analysis covers the validity and reliability of PCK frameworks, content knowledge analysis, pedagogical knowledge analysis, and pedagogical content knowledge analysis. Validity test of the PCK framework used content validity assessed by two experts of education evaluation. The reliability test used the Alpha Cronbach formula. CK, PK, and PCK differ in five categories based on Table 1.

Table 1. Categories of CK, PK, and PCK

Scores	Categories
$81 \leq N \leq 100$	Very Good
$61 \leq N < 81$	Good
$41 \leq N < 61$	Sufficient
$21 \leq N < 41$	Poor
$N < 21$	Very poor

(Suharsimi, 2012)

RESULTS AND DISCUSSION

Tasks of the PCK framework were tested for their validity and reliability before being used as assessment instruments. Validity ensured the tasks were reliable to use and to measure the capability of the students in composing the PCK framework. Matondang (2009) stated that influential factors to measure validity were test instruments, research subjects, and validators. The used tasks had been validated by validators. The assessment consisted of eight aspects of each task number to check each of its weaknesses. Therefore, the revision could be promoted before being tested on the subjects. A reliability test was done to check the consistency level of the tasks. The analysis result showed the PCK framework had a reliability coefficient of 0.692, which is higher than $r_{table,}$ so that it was concluded to be reliable.

Content Knowledge

Content knowledge was analyzed based on the average of pre-service teachers' scores on the aspects shown in Table 2.

Table 2. Content knowledge of pre-service teachers

Aspects of CK	Average	Category
Basics Physics 1	72	Sufficient
Basic Physics 2	73	Sufficient
Mechanics 1	69	Poor
Mechanics 2	67	Poor
Thermodynamics	69	Poor
Magnet Electricity	70	Poor
Waves	78	Good
Optics	77	Good

The data analysis showed overall content knowledge of the college students is grouped into three categories: poor, sufficient, and good with each percentage is shown in Figure 1.

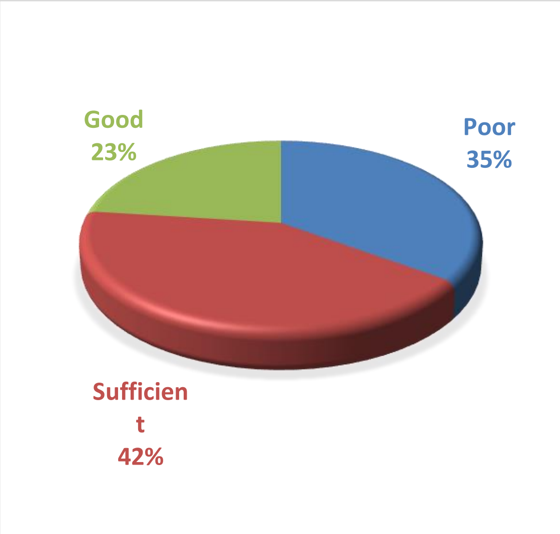

Figure 1. Content knowledge of pre-service physic teachers of UIN Walisongo Semarang

The figure shows the content knowledge of college students is still low. It was caused by several factors: educational background, major linearity to their senior high school levels, comprehension ability, and students' seriousness. Not all of the students were from favorite schools. 16.9% of them were not from science majors even they did not get psychics education. It made them having difficulties in understanding the materials, which were the continuity of the SHS level. Each of them also had a different ability to absorb the materials. Some of them were quickly able to master the materials, but the others were not although they had been given the materials' explanations. Other factors determining the materials' masteries were the students' seriousness. The serious students to study got different learning achievement to the others.

According to toÖzden (2008), content knowledge influenced teaching practices. The teacher who does not master the materials properly will have difficulties in delivering the materials. Other possible problems to emerge due to poor mastery are incomplete and not comprehensive material delivery, which causes a misconception. It occurs because students do not have complete knowledge, so they construct their concept inappropriately to the agreed concept by scientists (Fariyani et al., 2015).

Therefore, analyze misconceptions was important to identify the students' understandings.

Pedagogical Knowledge

A good teacher does not mean he must master learning material without considering the students' rights. The teacher should accommodate the needs of his students (Saito & Atencio, 2015). Pedagogical knowledge was analyzed based on the average of pre-service teachers' scores on the aspects shown in Table 3.

Table 3. Pedagogical knowledge pre-service teachers

Aspects of PK	Average	Category
Educational Psychology	74	Sufficient
Educational Management Principles	79	Good
Learning Methodology	76	Good
Learning Evaluation	79	Good
JHS Physics Curriculum Review	76	Good
SHS Physics Curriculum Review.	76	Good

Pedagogical knowledge of the college students, based on the overall analysis result, could be categorized into three categories: sufficient, good, and very good. Most of them had well pedagogical competence. The percentage of each category is shown in Figure 2.

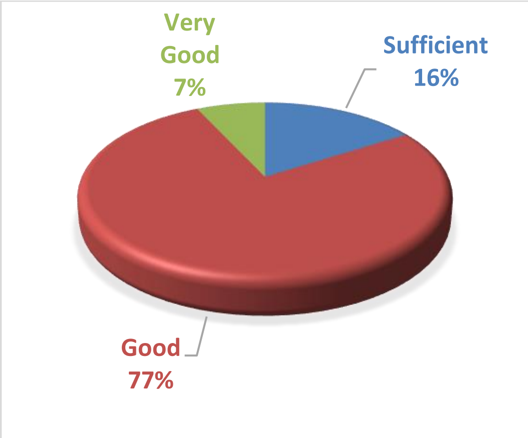

Figure 2. Pedagogical Knowledge of Pre-service Physics Teachers of UIN Walisongo Semarang

Most of the students had good pedagogical competence. But there were some of them categorized sufficient. It was due to not all of them had an interest in teaching. Even, the interview revealed that some of them had mistakenly chosen their major and did not want to be a teacher.

One teacher's task is to develop mediating and facilitating skills in learning materials (Kansanen, 2018). It is needed to mediate various abilities of the students in receiving materials, both given by teachers and learned independently. Teachers with good material mastery and the ability to utilize pedagogical capability in teaching the materials will make students learning optimally.

Pedagogical Content Knowledge

Pedagogical Content Knowledge (PCK) assessment was gained from the PCK framework and its implementation through teaching practices. PCK framework was presented in the form of a table consisting of 10 question aspects to answer. The purposes of creating this framework were to find out the students' concept masteries and how they planned to learn. The recapitulation of the framework is presented in Table 4.

Table 4. The formulating PCK framework ability

No.	Aspects of Pedagogical Content knowledge Framework	Average (%)
1.	Concepts/important science ideas on the materials	69.3
2.	Things to be understood by students from the concept	64
3.	The importance of mastering the materials	56
4.	The unexpected knowledge of the students dealing with the concept	60.7
5.	Difficulties or limitation dealing with teaching the concept	47.3
6.	Students' thoughts (included misconception) influencing teaching	60
7.	Other influential factors in teaching the concept	32
8.	Ways to deliver the concepts	41.3
9.	Ways to assess	50
10.	Teaching procedures	62

The table shows the pre-service teachers had the best ability to formulate the concepts/science ideas. This aspect demanded them to formulate the main materials to teach. One main point consisted of several concepts to be delivered. The pre-service teachers had to refer to the syllabus to develop anything to teach. However, there were still some of them who had poor ability to elaborate on the main points. They would be able to express things to be delivered to a certain point when they did not understand the materials comprehensively. The pre-service teachers whose poor understanding could only write the basic competence of the main discussion when they were asked to formulate the important concepts.

The pre-service teachers had the lowest ability in formulating other factors affecting concept teaching. They had to understand students' conditions properly to determine the factors. The influential factors in teaching the concept could be internal and external. Internal factors are from students, such as understanding level and their learning patterns. External factors may be such as facility and infrastructure or environment.

After composing the PCK framework, the pre-service teachers were asked to practice it. Any weakness found during the practicing session were: less confident during teaching, being over nervous – causing hindered speech, poor classroom management – included to put students while discussing, poor time management, a limited variant of teaching method, lack of motivating the students to be actively involved, lack of learning media utilization, poor learning presentation – not systematic, and poor ability to instill Unity of Science into learning. Sukaesih et al. (2017) stated that difficulties of pre-service teachers in learning were on teacher personal readiness aspect, readiness to promote learning, time management, media utilization, and learning strategy. It showed that the pre-service teachers needed more time to learn and train in promoting learning.

Pedagogical content knowledge was analyzed based on the average of pre-service teachers scores on the aspects shown in Table 5.

Generally, the pre-service teachers' abilities in composing the PCK framework were in line with their teaching practicing. They could compose the framework well but could not deliver it properly. It indicated that to deliver the material properly, an educator needs to master pedagogical content knowledge attached to the PCK framework.

Table 5. Pedagogical content knowledge of pre-service teachers

Aspects	Average	Category
PCK Framework	77	Good
Teaching practice (Observer 1)	76	Good
Teaching practice (Observer 2)	76	Good

Physics teaching needs complex learning source management, including teacher's PCK (Hauk et al., 2014). The basic components of PCK are teaching orientation, knowledge of science teachers as science learners and its teaching, knowledge about curriculum, knowledge about teaching strategy, and knowledge about assessment (Demirdöğen et al., 2015). Overall PCK analysis result showed the ability of the pre-service teachers was poor, sufficient, good, and very good, as shown in Figure 3.

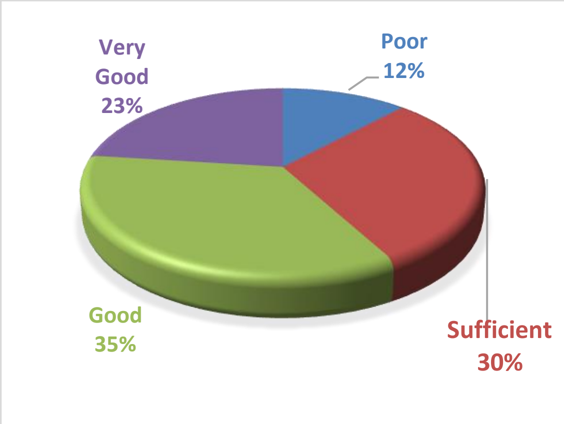

Figure 3. Pedagogical content knowledge of the pre-service teachers

Content knowledge and pedagogical knowledge are a unity to master by a teacher. Van Driel et al. (1998) stated that comprehensive and coherence understandings were requirements before developing PCK. A teacher will be able to develop PCK properly when he masters material and pedagogical aspects comprehensively and completely. When one aspect could not be fulfilled, it would hinder the teacher from developing PCK. It would cause ineffective teaching and learning. It is in line with Eames et al. (2011), stating that one of the supportive effectiveness of teacher's performance is PCK skill, integration of material, and pedagogical masteries in which have been developed time by time. It does not only cover teacher skills in promoting learning but also to reflect the learning (Taylan & da Ponte, 2016).

Pedagogical content knowledge (PCK) is a skill required by educators. It influences the teacher to deliver materials. Teachers with proper PCK mastery could simply deliver complex physics materials and understandable for the students.

PCK of the pre-service teachers could be improved through learning emphasizing content knowledge and pedagogical knowledge integration. One of them is by having a Learning Planning course. This course demands the college students plan and simulate the physics teaching of JHS and SHS levels. They were asked to create learning instruments, scenarios, and evaluation, as well as to simulate the learning in class. Through this course, the lecturer could train them to integrate content and pedagogical knowledge to have better pedagogical content knowledge (PCK).

CONCLUSION AND SUGGESTION

Content knowledge is the ability to master materials and how to develop the materials. The ability of the pre-service teachers could be categorized as 35% poor, 42% sufficient, and 23% good. Pedagogical Knowledge is the ability to master pedagogical aspects related to teaching skills. Pedagogical knowledge of the pre-service teachers was 16% sufficient, 77% good, and 7% very good. Integrated content knowledge and pedagogical knowledge is called pedagogical content knowledge (PCK). The pre-service teachers had categories of PCK started from 12% poor, 30% sufficient, 35% good, and 23% very good. The pre-service teachers had the highest ability in determining concepts/important science ideas on the taught materials. Meanwhile, the lowest ability was in determining other influential factors to concept teaching.

AUTHOR CONTRIBUTIONS

QF collected and analysed data. FK and QF writing result and discussion, SM reviewing literature. FS prepared research design. All authors contributed to the writing of the manuscript.

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