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Pedagogical Content Knowledge Analysis of Mathematics Teachers in Developing Lesson Plans on Ratio Topic

Ahmad Badawi [1]*, Tatang Herman [2], Dadang Juandi [3]
[1,2,3] Departemen Pendidikan Matematika Universitas Pendidikan Indonesia, Indonesia
* Corresponding Author. E-mail: alwibadawi@upi.edu
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Abstract

In preparing a Lesson Plan, a mathematics teacher should pay attention to pedagogical principles, including general and mathematical pedagogy. Teacher knowledge related to these two pedagogies is called Pedagogical Content Knowledge (PCK). This study aims to analyze the PCK of a mathematics teacher at a junior high school in Kebumen when preparing lesson plans and carrying out learning activities on Ratio Topics. This study used a qualitative research method with a case study design. The teacher's PCK analyzed in this study was divided into two parts: general pedagogical knowledge and mathematical pedagogical knowledge. The results showed teachers' general pedagogical knowledge when learning was more complete than when compiling lesson plans. Likewise, in mathematical pedagogy, the teacher's mathematical pedagogy knowledge when carrying out education is better than when compiling lesson plans. This also indicates a mismatch between the lesson plans compiled by the teacher and the learning activities he carried out. Therefore, in compiling lesson plans, teachers are advised to pour all pedagogical content knowledge that they have so that the lesson plans are by the learning activities carried out by the teacher so that the entire learning process can be carried out more optimally.

***Keywords**: pedagogical content knowledge, lesson plan, ratio topic*

INTRODUCTION

Mathematics is one of the compulsory subjects that must be taught in schools, especially at the Junior High School (SMP) level. As in other learning, learning mathematics at the junior high school level has several competencies and scope of material that students must achieve through the learning process. In learning mathematics in the classroom, students are expected to understand the concepts of several topics in mathematics such as Numbers, Algebra, Geometry, Statistics, Chance, etc. In addition,

students are also expected to have a way to understand the concepts of several topics in mathematics. In addition, students are also expected to have a logical, critical, analytical, open, objective, etc. way of thinking. (Permendikbud Number 21 of 2016). This is in accordance with Harel's (2011) statement that mathematics consists of a way of understanding and a way of thinking.

Before implementing mathematics learning at school, a teacher should first do good learning planning. Learning planning is designed in the form of Syllabus and Learning Implementation Plan (RPP) which refers to the Content Standards that have been made by the Government. More detailed learning planning in one or more meetings is prepared in the form of lesson plans developed from the syllabus that has been made as an effort to achieve Basic Competencies (KD). In preparing this lesson plan, a teacher should pay attention to several principles, especially principles related to pedagogy. As Harel (2011) argues, a mathematics teacher has at least three basic components of knowledge that must be possessed, namely mathematical knowledge, knowledge of student learning, and pedagogical knowledge.

The term pedagogy in education can be defined as the art or science of teaching (Mortimore, 1999; Beetham & Sharpe, 2013). However, over time many experts say that the definition of pedagogy that only focuses on teaching has become less relevant. Nowadays, teaching and learning activities emphasize more on the learning process carried out by students, or student-centered learning. However, this does not mean that teaching activities carried out by teachers are not important. Therefore, Beetham and Sharpe (2013) redefine pedagogy as the process of guiding learning: learning in the context of teaching, and teaching with learning objectives. Views on pedagogy may differ from those of practitioners, researchers, and policy makers. However, this difference only lies in how each sees the complexity that exists in pedagogy and how their respective roles in taking action. Teachers as practitioners will see pedagogy in a very complex situation, with demands for action in a short time or as soon as possible.

In every lesson conducted by a teacher, there are some basic principles of pedagogy. This paper will discuss at least three basic principles of pedagogy that apply in general, not only in mathematics learning. The first basic principle of pedagogy is that there is no teaching without learning (Freire, 2000). This means that learning and teaching are two activities that are very closely interrelated and cannot be separated. In other words,

teaching activities carried out by teachers should pay attention to how learning activities will be experienced by students. The second principle is that teaching is not just a transfer of knowledge (Freire, 2000). This means that learning is not just about transferring knowledge from teachers to students. However, more than that, learning is expected to develop students' thinking process. Furthermore, learning is also expected to shape students' attitudes so that they can become better individuals. Furthermore, the third basic principle of pedagogy is learning as a humanizing activity (Freire, 2000). This means that in learning activities there is a process of guidance carried out by teachers to students, which is certainly done humanely. In addition to these three principles, the application of technology in mathematics learning also has the potential to be related to teachers' pedagogical knowledge (Bray & Tangney, 2013).

In addition to general pedagogical principles, in mathematics there are also several principles that a mathematics teacher needs to know in order to better teach mathematics to his students. In other words, in teaching mathematics, a pedagogical approach is also needed so that learning is maximized and in accordance with the needs of students and the characteristics of mathematics itself. Harel (2008) said that there are at least three principles when teaching mathematics with a pedagogical approach. The three principles are Duality, Necessity, and Repeated-reasoning (DNR). Duality principle is a principle that sees mathematics as a mental act consisting of way of understanding (WoU) and way of thinking (WoT). In this duality principle, WoU and WoT are seen as two closely related concepts. Students develop their ways of thinking (WoU) through the construction of their ways of understanding (WoU), and conversely, the ways of understanding (WoU) produced by students are determined by their ways of thinking (WoT) (Harel, 2008).

In addition, mathematics as an abstract object will certainly be more useful for students, if the learning of mathematics can help students acquire the abilities and skills they need to live in the midst of society or their community. For this reason, a critical approach to mathematics education also seems important, because it can help students see the world with mathematics (Tutak et al., 2011). The goal of the critical approach in mathematics education is to equip students with the knowledge, skills, and dispositions needed to create democratic communities that uphold social justice both inside and outside of school (Tutak et al., 2011). In this critical perspective, there are several principles of conceptual duality in mathematics learning (Vithal, 2003). The principle of

concept duality is a view that sees pairs of concepts that seem to contradict each other, but at the same time also complement each other. Conceptual duality includes several pairs of concepts in mathematics learning such as structure and freedom, authority and democracy, mathematics and context, differentiation and equity, and actuality and potentiality (Vithal, 2003).

Seeing the importance and number of pedagogical approaches that must be understood by mathematics teachers, a teacher should be able to utilize the preparation of lesson plans to design pedagogical approaches that will be used when teaching mathematics. However, from the author's observations and experiences, most mathematics teachers rarely pay attention to pedagogical approaches when preparing lesson plans. Most teachers prefer to use lesson plan formats that have been provided by other teachers through the internet or the Mathematics Subject Teacher Conference (MGMP). This is in accordance with research conducted by (Nasution & Amalia, 2020) which found that 60% of the teachers studied did not make original lesson plans by themselves. This can certainly make the learning carried out by teachers less than optimal, because the process of preparing lesson plans does not pay attention to the pedagogical approach needed and in accordance with the conditions of each class. In fact, according to the Primary and Secondary Education Process Standards, there are principles that should be considered by teachers when preparing lesson plans, such as paying attention to individual differences, providing feedback, follow-up, etc. (Permendikbud Number 22 of 2016). Moreover, according to Nasution and Amalia (2020) there are still mathematics teachers who have not implemented learning in accordance with the lesson plans they made.

One of the Mathematics materials at the junior high school level that is considered difficult by students is comparison material. From the author's observations, students have difficulty in comparison material because they often do not understand the concept of comparison, especially in distinguishing equal and inverse value comparisons. Susiaty and Haryadi (2019) in their research showed that students still make many mistakes in understanding comparison material, especially in the indicators of defining concepts and representing problems in other forms.

Based on the above background, the author feels the need to conduct research related to the pedagogical content knowledge of mathematics teachers when conducting

mathematics learning, especially on comparison materials. Pedagogical content knowledge (PCK) is the transformation of at least two domains of knowledge, namely general pedagogical knowledge, and subject matter knowledge (mathematics) of a teacher (Newsome & Lederman, 1999). Thus, this study aims to analyze the PCK of Mathematics Teachers in one of the junior high schools in Kebumen in preparing lesson plans and implementing learning activities on comparison materials.

METHODS

This research is a qualitative research with a case study design (Borg, 2014). The research subject was a Mathematics Teacher in one of the junior high schools in Kebumen. The teacher chosen as the research subject is a Mathematics Teacher who has a minimum teaching experience of five years and has taken Teacher Professional Education. This was done to make the assumption that the research subject was a professional mathematics teacher. The data collection techniques used were documentation and interviews. The documentation technique was carried out by collecting learning tools used by teachers, especially lesson plans, to be analyzed. Meanwhile, the interview technique was carried out to validate the results of the document analysis carried out and to explore deeper information from the research subject. Furthermore, the data were analyzed through several stages, namely collecting and processing data for analysis, reducing data into themes through coding, and presenting data in the discussion (Creswell, 2013).

In this teacher PCK analysis, we will explore how the teacher's pedagogical content knowledge consists of general pedagogical knowledge and mathematical pedagogy. The pedagogical knowledge in question is knowledge related to the principles of general pedagogy and mathematical pedagogy. Mathematical pedagogy itself is seen through two perspectives, namely the DNR perspective and the critical perspective. The principles of general pedagogy and mathematical pedagogy discussed in this study are contained in Table 1.

Table 1. Principles of General Pedagogy and Mathematical Pedagogy

Types of Pedagogy	Principle
General Pedagogy	1. There is no teaching without learning. 2. Teaching is not just a transfer of knowledge. 3. Learning as a humanizing activity. 4. Application of technology in learning.
Mathematical Pedagogy	DNR perspective: 1. Principle of Duality (WoU and WoT) 2. Principle of Necessity 3. Principle of Recurrent Reasoning Critical Perspective: 1. Duality of the Concepts of Structure and Freedom 2. Duality of the Concepts of Authority and Democracy 3. Duality of the Concept of Mathematics and Context 4. Duality of the Concepts of Difference and Justice 5. Duality of the Concept of Actuality and Potentiality

RESULTS AND DISCUSSION

General Pedagogical Knowledge

Based on the lesson plans prepared by the teachers, the researchers analyzed whether or not the general pedagogical principles appeared in the learning activities planned by the teachers. The analysis is the result of the researcher's interpretation of the learning activities designed by teachers that are considered to contain general pedagogical principles, either explicitly or implicitly. The results of the analysis are presented in Table 2.

In the lesson plan prepared by the teacher, the teacher has planned the activities that will be carried out by the teacher and students during learning. That is, in addition to planning the teaching activities that will be carried out by the teacher himself, the teacher also plans what kind of learning activities will be carried out by students. In addition, from the interview results, the teacher also prepares materials, learning instruments, and supporting media to ensure that students learn well when learning. This means that the teacher has implemented the principle that there are no teaching activities without learning activities. In addition, from the interview results, it is known that teachers also actively develop themselves through mathematics teacher professional competence development activities that are carried out in a focused and continuous manner. These self-development activities carried out by teachers indicate that as teachers, teachers also

continue to learn. This is a form of interpreting the principle that there is no teaching without learning, which means that a teacher must keep learning in order to teach well. Moreover, self-development activities carried out by teachers are also felt to have an effect on teachers' teaching practices. This is in accordance with the results of Copur-Gencturk and Papakonstantinou's (2016) research which shows that mathematics teachers' professional development programs have a sustainable influence on teachers' teaching practices in the classroom.

Table 2: Analysis of General Pedagogical Principles in Teacher's Lesson Plans

General Pedagogical Principles	Occurrence in the lesson plan	Description
1. There is no teaching without learning.	Available	The activities in the lesson plan have described the learning activities that students will do, but at the beginning of learning, the teacher does not explicitly convey the learning objectives to students.
2. Teaching is not just knowledge transfer.	Available	There are learning activities that direct students to be able to think critically, and not just receive knowledge directly from the teacher. However, there are no learning activities that can improve students' non-knowledge aspects, such as students' attitudes and skills.
3. Learning as a humanizing activity.	Available	There are learning activities where the teacher guides and dialogues with students according to the understanding and difficulties experienced by each student in the learning group.
4. Application of technology in learning.	None	The use of technology appears in the contents of the media used by teachers, but does not appear in the learning activities.

Based on the lesson plans, the teacher has planned the learning activities so that the teacher does not merely transfer knowledge to the students. One of the activities is that the teacher asks students to formulate questions so that students can practice their critical thinking skills. In addition, based on the results of the interview, in teaching the teacher also conducts activities to shape students' character. However, this activity has not been seen in the lesson plan prepared by the teacher. In this case, this study shows the same results as the research of Pertiwi and Marsigit (2017) which shows that the value of implementing character education in public junior high schools in Yogyakarta is higher than the value of planning.

In the teacher's activity plan written in the lesson plan, the teacher has also planned activities that build dialog between the teacher and students. Based on the interview results, the teacher also said that in her teaching activities, the teacher tries to build positive interactions with students in order to build students' self-development. This shows that the teacher is fully aware of teaching activities as human activities that humanize people. Because the dialogical climate between teachers and students can build students' critical awareness to liberate themselves as complete human beings (Shih, 2018).

Based on the lesson plan analysis, the teacher does not make an activity plan that applies technology in learning. However, based on the results of the interview, the teacher utilizes technology when implementing learning, namely using the Quipper School and Quizizz applications. According to the teacher, the use of technology in learning has an effect on increasing students' enthusiasm and interest in learning. This is in accordance with the research of Nugroho (2014) which shows that the use of technology in learning can increase students' interest in learning mathematics by 20.57%.

Mathematical Pedagogy Knowledge

In the analysis of mathematical pedagogical knowledge, the lesson plans made by the teachers were also examined based on whether or not the principles of mathematical pedagogy appeared in the designed learning activities. The mathematical pedagogical knowledge here is seen through the DNR perspective and the critical perspective. The results of the analysis of mathematical pedagogy principles in the lesson plans prepared by the teachers are presented in Table 3.

Based on the analysis of the lesson plans prepared by teachers, from the DNR perspective, teachers have come up with activities that indicate the application of the WoU and WoT duality principles. This can be seen from the learning materials listed in the lesson plan as shown in Figure 1.

Materi Pembelajaran	*Membedakan perbandingan senilai dan berbalik nilai dengan menggunakan tabel data, grafik, dan persamaan*

Figure 1. Learning materials arranged by teachers in lesson plans

Table 3. Analysis of Mathematical Pedagogy Principles in Teacher's Lesson Plans

Principles of Mathematical Pedagogy	Occurrence in the lesson plan	Description
DNR Perspective		
1. Principle of Duality (WoU and WoT)	Available	In the lesson plan, the WoU that emerged was differentiating equal and inverse value comparisons. Meanwhile, the WoT is the strategy used, which is using data tables, graphs, and equations.
2. Principle of Necessity	None	There are no activities that try to convey the benefits of learning to raise students' intellectual needs for the material presented.
3. Principle of Recurrent Reasoning	None	There are no activities that facilitate students to be able to do repeated reasoning related to the material studied.
Critical Perspective		
1. Duality of the Concept of Structure and Freedom	Available	The teacher gives students the freedom to use various sources to collect data related to the material studied, but still directs students so that activities and materials remain structured.
2. Duality of the Concepts of Authority and Democracy	None	The teacher creates authoritarian activities when dividing students into groups. However, there are no activities that encourage students' democracy in the classroom.
3. Duality of Mathematical Concepts and Context	None	There are no activities that relate the material learned to the context that students already know.
4. Duality of the Concepts of Difference and Justice	None	There are no activities that facilitate student differences and no actions taken to promote equity in learning.
5. Duality of the Concept of Actuality and Potentiality	None	There are no activities that accommodate the students' self-actualization process, but there are activities that facilitate students to be able to interact with their environment as a form of potentialization.

Based on Figure 1, the researcher interpreted the results of differentiating equal and opposite value comparisons as a way of understanding (WoU) that students will get. As according to Harel and Sowder (2005), WoU can refer to students' interpretation or meaning of a concept or problem. In this case, the concept or problem in question is the difference in value and inverse value comparisons. While the way of thinking (WoT) of students in this material is in the form of strategies used to distinguish valued and inverse value comparisons, namely by using data tables, graphs, and equations. This refers to the

statement of Harel and Sowder (2005) which says that one form of student WoT is the approach used in solving problems. However, based on the interview results, it was found that the teacher did not understand the concept of WoU and WoT itself. So it can be concluded that WoU and WoT that will be obtained by students are not planned by the teacher directly.

Based on Table 3, we can also see that the principle of repeated needs and reasoning has not been fulfilled by the teacher through the activities she planned in the lesson plan. However, this result is different from the interview with the teacher regarding her lesson implementation. From the interview, the teacher said that she emphasized the importance of mathematics as the main subject that underlies other subjects. This shows that the teacher tries to apply the principle of necessity in her learning. As stated by Harel (2008), students who are learning mathematics must have a need for the material taught by the teacher, where the need in question is an intellectual need. In addition, based on the interview results, the teacher also stated that she also designed activities so that students can do repetitive reasoning. Repeated reasoning is done so that the expected WoU and WoT can be internalized into students (Harel, 2008).

Based on Table 3, we can see the results of the analysis of teachers' mathematical pedagogy knowledge from a critical perspective. From the analysis, it is shown that from the five principles of conceptual duality, only the principles of structural duality and freedom are indicated to appear in the lesson plans prepared by the teachers. However, the results of interviews conducted with teachers showed different conclusions. In the duality of the concept of authority and democracy, in addition to applying authority in the form of the division of student groups by the teacher himself, it turns out that the teacher also gives students the opportunity to choose their own leaders democratically. Furthermore, on the duality of the concept of mathematics and context, the teacher said that she used real stories around the students as context when presenting the material to the students. This context in mathematics learning is used to make learning effective (Sulianto, 2011). Next, in the duality of difference and fairness, the teacher said that she addresses the differences that exist in each student by forming groups that bring together different students in one group. This implies that the teacher values the differences that exist in each student, and then takes action as an effort to implement justice in the classroom. With this perspective, it means that the teacher sees the diversity in the

classroom with an inclusive approach (Vithal, 2002). Finally, in addition to facilitating students to be able to develop their potential through their interactions with the environment, the teacher also said that she provided opportunities for each student to be able to self-actualize by giving problems to work on individually.

Appropriateness of lesson plans and implementation

Table 4. Comparison of Lesson Plan Analysis Results and Implemented Learning

Principles of Pedagogy	Occurrence in the lesson plan	Occurrence in Learning
General Pedagogy		
1. There is no teaching without learning.	Available	Available
2. Mengajar bukan hanya transfer pengetahuan	Available	Available
3. Learning as a humanizing activity.	Available	Available
4. Application of technology in learning.	None	Available
Mathematical Pedagogy		
DNR perspective:		
Principle of Duality (WoU and WoT)	Available	None
Principle of Necessity	None	Available
Principle of Recurrent Reasoning	None	Available
Critical Perspective:		
Duality of the Concept of Structure and Freedom	Available	Available
Duality of the Concepts of Authority and Democracy	None	Available
Duality of Mathematical Concepts and Context	None	Available
Duality of the Concepts of Difference and Justice	None	Available
Duality of the Concept of Actuality and Potentiality	None	Available

To see the suitability between the lesson plan and the implementation of learning, the researcher conducted an interview with the teacher regarding the implementation of learning by the teacher on this comparison material. Based on the results of the interview, it was concluded that the teacher did not use the lesson plan that had been prepared as a reference for implementing learning. This resulted in a mismatch between the activities planned in the lesson plan and the activities carried out in learning. This corroborates research (Nasution & Amalia, 2020) which found that the level of conformity between lesson plans and the learning carried out has not reached 100%, which means that there are still discrepancies between the lesson plans and the learning carried out.

This discrepancy is what causes some of the results of the lesson plan analysis to be different from the results of the interviews. For this reason, the information related to teachers' pedagogical content knowledge obtained from the analysis of lesson plans and

the results of interviews conducted with teachers will be compared again. The comparison is presented in Table 4.

Based on Table 4, we can see that based on the interview results, teachers almost implement all content pedagogical principles. Only one principle is not implemented by teachers, which is the principle of duality in the DNR perspective. This is because teachers do not understand the concept of WoU and WoT in DNR perspective.

CONCLUSION

Based on the analysis of lesson plans and interviews with teachers related to learning on comparison materials, the results show that the teacher's general pedagogical knowledge when implementing learning activities is better than when preparing lesson plans. When implementing learning, the teacher has implemented all general pedagogical principles, while when preparing the lesson plan the teacher did not bring up the principle of applying technology in learning through the activities planned in the lesson plan. Furthermore, teachers' mathematical pedagogy knowledge when implementing lessons is also better than when preparing lesson plans. This can be seen from the implementation of almost all mathematical pedagogy principles when the teacher implemented the lesson. There was only one principle that was not implemented by the teacher, namely the principle of duality of way of understanding (WoU) and way of thinking (WoT). Whereas in the lesson plan, there were only two principles that appeared in the activities planned by the teacher, namely the principle of duality of WoU and WoT and the principle of duality of structure and freedom. In addition, there is a discrepancy between the lesson plans prepared by the teachers and the learning activities implemented. This discrepancy is because the teacher does not use the lesson plan as a reference when implementing learning. This is also reinforced by the different results of the pedagogical content knowlwdge analysis of teachers when preparing lesson plans and when implementing learning.

From the results of the research and the conclusions made, the researchers tried to provide advice to mathematics teachers related to pedagogical content knowledge, so that they can pour all their pedagogical knowledge when preparing the Learning Implementation Plan (RPP) so that there is a match between the RPP and the learning activities carried out. This can be useful, because all learning activities carried out are well documented since they are planned, so that they provide complete information to

teachers or other parties. In addition, it is recommended for mathematics teachers to be able to understand the concepts of way of understanding (WoU) and way of thinking (WoT), so that they can apply the duality principles of WoU and WoT when preparing and implementing mathematics learning with students.

In this study there are several limitations, such as the scope of research and the depth of research conducted. Therefore, researchers try to provide suggestions for future research on the same theme in order to expand the scope of research by involving more research subjects with different characteristics and conducting more in-depth studies for themes that may be more specific.

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