ISSN 2964-4291
https://proceeding.unnes.ac.id/index.php/iset

How Does The Ability of Pedagogical Content Knowledge Preservice Teacher Students in Mathematics Learning?

Dedi Muhtadi[1,2], YL Sukestiyarno[3], Isti Hidayah[4], Amin Suyitno[5]

[1]Universitas Siliwangi, Jl. Siliwangi No.24, Tasikmalaya 46115, Jawa Barat, Indonesia

[1,2,3,4,5]Universitas Negeri Semarang, Jl. Kelud Utara III Semarang 50237, Jawa Tengah, Indonesia
*Corresponding Author: dedimuhtadi@unsil.ac.id

Abstract. The purpose of this study was to determine how the ability of Pedagogical Content Knowledge (PCK) of prospective teacher students in learning mathematics. The research method uses a qualitative approach with case studies. The data analyzed came from three groups of prospective mathematics teacher students with very good, good, and sufficient levels through concept understanding tests, vignettes, and interviews. The results showed that students with excellent and good academic abilities had relatively the same content, teaching, and student knowledge. Content knowledge is at level 1, teaching knowledge is at level 2, and knowledge about students is at level 1. At the same time, students with sufficient academic ability are at level 0 for content knowledge.

Keywords: Pedagogical Content Knowledge (PCK); student-teacher candidates; mathematics learning.

How to Cite: Muhtadi, D., Sukestiyarno, YL., Hidayah, I., & Suyitno, A. (2022). How Does The Ability of Pedagogical Content Knowledge Preservice Teacher Students in Mathematics Learning? *ISET: International Conference on Science, Education, and Technology* (2022), 550-556.

INTRODUCTION

Teachers play an essential role in the development of education and are the spearhead of determining the quality of educational outcomes because teachers are the most influential component in the process and outcomes of education (Sunhaji, 2014). In addition, teacher competence also plays an essential role in achieving student academic achievement (Ramdhani et al., 2012). So, a teacher's ability will determine student academic achievement and future education quality.

One of the efforts to improve the quality of teachers is to improve the quality of prospective teacher students. This is to the statement of Clarke and Hollingtown (2002) that the professional development of teachers begins when they are prospective teacher students during their education. Universities should prepare learning programs for student-teacher candidates to become well-qualified educators and acquire professional knowledge before teaching in the classroom (König et al., 2017; 2021).

The professional competencies of teachers and prospective mathematics teachers have been investigated in detail (TEDS-M study by Blömeke et al., 2014; COACTIV study by Kunter et al., 2013). Several critical similarities in the concept of professional competence developed from the COACTIV and TEDS-M studies. In particular, the two concepts of professional competence assume that professional knowledge consists of content knowledge, pedagogical content knowledge, and pedagogical/psychological knowledge. In addition to this cognitive-oriented knowledge dimension, both approaches consider professional competence to include affective/value-oriented aspects.

A mathematics education study program under the auspices of higher educational institutions is a study program that is expected to produce graduates who are professional mathematics teacher candidates. To produce professional teacher candidates, students who are prospective mathematics teachers are required to have good pedagogic skills in addition to mastering mathematics. Pedagogic knowledge is knowledge about learners, learning, assessment, and goals in education. While content knowledge is knowledge about specific subjects related to the content the teacher must teach (König et al., 2017; 2021). When the two bits of knowledge are combined in the form of teaching, it will produce new pedagogical content knowledge (PCK) knowledge.

Shulman first proposed the term PCK in 1986 in an article entitled "Those Who Understands: Knowledge Growth for Teaching," published in the journal Educational Researcher. PCK is an essential dimension of professional knowledge and must be possessed by teachers and

prospective teachers (Shulman, 1986; Evens et al., 2015). PCK consists of pedagogical and material knowledge or can be understood as knowledge of the material and how to teach it. PCK ability is not a self-taught ability but must be trained and developed. Shulman (1987) explains that PCK abilities can be developed when they become student teacher candidates. Develop teacher candidates' pedagogical content knowledge as part of their professional ability to teach mathematical modeling (Greefrath et al., 2021). Because teaching is a profession with an expertise base, teacher educators play an essential role in providing opportunities for teachers to develop this knowledge (Phelps et al., 2019).

Improving the quality of education in the future is determined by the successful preparation of teacher candidates. Therefore, students majoring in mathematics education are prospective teachers who, from an early age, must prepare themselves as professional teacher candidates. Teaching mathematics requires a variety of knowledge, including knowledge specific to the teaching profession. It is essential to emphasize professional preparation because knowledge of content is a specialized form of knowledge(Phelps et al., 2019). This research begins by analyzing their PCK, hoping the results can be considered to improve the higher education curriculum, especially the mathematics education department.

Several opinions present a framework for analyzing the characteristics of teachers' PCK based on certain levels. For example, Thompson (1992) mentions that there are three levels in PCK, namely: Level 0, Level 1, and Level 2; Lindgren (1996) also mentions that there are three levels in PCK, namely: Level 0: Rules and Routine (RR), Level 1: Discussion and Game (DG), level 2: Open Approach (OA); and Karahasan (2010) mention that there are three levels of PCK, namely: Level 0 (inadequate), Level 1 (good), Level 2 (strong).

This study uses Karahasan's theory (2010) to analyze the characteristics of teachers' PCK, combining and refining previous theories, namely Thompson's theory and Lindgren's theory. Karahasan (2010) explains that there are three components at each level: the component of teaching knowledge, the component of knowledge of content, and the component of students.

In the teaching knowledge component, the characteristics are (1) Level 0: as a provider and demonstrator of knowledge for students, introduces procedures after concepts, dominates information, has problems ordering topics and questions during learning or in designing learning, difficulty controlling the class so that a learning environment is created democratic ones; (2) Level 1: not only provides sufficient rules and procedures but also helps students build meaning and understanding, views their role as mentors, assessors, and reminders, still dominate information, only has problems with the order of questions during learning or in designing lessons, occasionally controlling the class to create a democratic learning environment, and (3) Level 2: facilitating and guiding students rather than providing answers and explanations,

For the content knowledge component, the characteristics are (1) Level 0: unable to state the definition correctly, unable to use notation correctly, only using declarative or procedural questions, unable to interpret and use different representations easily, difficulty seeing connections between different topics/subunits; (2) Level 1: stating the definition correctly, using appropriate notation, still using declarative or procedural questions, interpreting and using graphical and non-graphical representations, seeing connections between different topics/subunits; and (3) Level 2: stating the definition correctly, using appropriate notation, using all types of questions (declarative, procedural, and conditional) in the correct position.

As for the knowledge component about students, the characteristics are described as follows: (1) Level 0: has difficulty diagnosing student errors, views responding to student misconceptions as an opportunity to tell students actual rules or procedures, has difficulty in realizing students' needs in understanding; (2) Level 1: diagnosing some student errors although if they show them, they focus on the surface of the error only, solve numerical examples of similar, practical problems, and appreciate the importance of discussion, from time to time aware of students' needs in understanding; and (3) Level 2: quickly diagnose student errors and point out student difficulties, guide and facilitate students rather than providing answers and explanations, aware of students' needs in understanding. Therefore, it becomes easy to create a good learning environment.

Based on what has been described, this research describes the Pedagogical Content

Knowledge (PCK) ability of prospective teacher students in learning mathematics with quadratic equations material.

METHODS

The characteristics of PCK as tacit knowledge require student teacher candidates to have deep insight into what is on their minds in learning mathematics, so this research was conducted through a qualitative approach with case studies. This is so that an overview of how the PCK abilities of prospective mathematics teacher students can be obtained in more detail. The research subjects came from three groups of prospective mathematics teacher students, 6th semester who were ready to practice teaching in schools, from a university in Tasikmalaya, West Java, Indonesia, based on their academic abilities with very good, suitable, and sufficient levels.

Because PCK is a personal construct, the paradigm of interpretivism is guided by data collection and analysis of findings. The subjects in this study were deliberately identified, and each student-teacher was treated as a case study to ensure the transferability of the findings. Data collection is carried out through (1) Subject Worksheets in the form of (a) knowledge survey of quadratic equations, (b) concept maps and essays from concept maps, and (c) a vignette, a scenario (fictional material), which contains stories/cases/conversations that occurred in the classroom written on sheets of paper as a basis for assessment (Huebner, 1991; Poulou, 2001; Angelides & Gibbs, 2006); and (2) interviews.

RESULTS AND DISCUSSION

Student Prospective Mathematics Teacher 1 (SPMT1)

Content knowledge of prospective teacher students with excellent academic ability is at level 1, and some are at level 2 and level 0. This means that this excellent academic ability does not guarantee that one's content knowledge is at the highest level. According to Talbert-Johnson (2006), content knowledge is not the only measure to justify a highly qualified teacher. Major & Palmer (2006) assert that teachers learn through learning by doing and reflecting, collaborating with other teachers, observing student teacher candidates and their work, and sharing what they see.

The characteristics of content knowledge at level 1 are: stating the definition correctly, using notation correctly, using declarative or procedural questions, interpreting and using graphical and non-graphical representations, and seeing connections between different topics/subunits (Karahasan, 2010). This can be seen from the results of interviews with students with excellent academic abilities as follows:

R : *What is the relationship between quadratic equations and quadratic functions?*

SPMT1 : *Quadratic equations and quadratic inequalities are two related materials. Quadratic inequalities are an extension of quadratic equations. In solving quadratic inequalities apply the principle of quadratic equations.*

R : What is the relationship between the quadratic equation and the function square?

SPMT1 : *The quadratic equation is part of the quadratic function.*

R : *What is the general form of a quadratic equation?*

SPMT1 : *(write the general form of the quadratic equation, y = ax2 + bx + c)*

R : *What is the general form of a quadratic function?*

SPMT1 : *f(x) = ax2 + bx + c*

R : Then what is the difference? Doesn't y represent f(x)? So if the general form of a quadratic equation should be ax2 + bx + c = 0, that is, from the quadratic function f(x) = y = 0.

From the interview excerpt, it can be seen that the subject is still confused about distinguishing quadratic equations from quadratic functions. So it can be concluded that the subject content knowledge is at level 0.

The teaching knowledge of prospective teacher students in this group is at level 2 based on vignette analysis. The characteristics of teaching knowledge at level 2 are facilitating and guiding students in providing answers and explanations, assessing students' understanding, extending that understanding with further mathematical knowledge questions, assessing student-student interactions, appreciating and encouraging students to construct mathematical knowledge through inquiry, sequencing topics, and questions in the right way, and control the class to create a democratic learning environment (Karahasan, 2010).

Knowledge Content Teaching (KCT) is the fourth domain of mathematical knowledge for teaching. This domain combines knowledge of teaching and mathematics. Ball et al. (2008) further explain that the order in which content is taught and decides whether content representation is valid are all parts of this domain.

As for knowledge about students, it turns out that most of them are still at level 1. Many cases requiring the subject to fix students' misconceptions have not been responded to perfectly; however, the subject has tried with the experience and knowledge obtained. Characteristics of knowledge about students are at level 1, namely diagnosing some students' mistakes even if they show these errors, they focus on the surface of the error only, solve numerical examples of similar, practical problems, and appreciate the importance of discussion, from time to time realize the need students in understanding (Karahasan, 2010).

The subject of SPMT1 argues that algebra can be derived into equations, where equations are divided into several types according to the highest power of the variable, for example, linear equations (to the power of one), quadratic equations (to the power of two), and equations to the third power. However, in this concept map, the focus is on linear equations and quadratic equations. The following are excerpts of interviews with subjects that corroborate the above.

R : What would you teach first among the keywords given if you became a math teacher?
SPMT1 : *Sir, does the term have to be on the list?*
R : It can be added if needed. What do you have added?
SPMT1 : If mine starts with algebra, sir, in the algebra later, there will be an equation that must contain, uh, not for sure but usually *loads variables and constants like that, sir. After that, the equation is divided into several terms according to the power of the variable.*
R : *What do you think about algebra?*
SPMT1 : *Algebra must give rise to the unknown.*
R : *What do you mean?*
SPMT1 : *This means that everything is made of symbols or symbols.*
R : *For example, what is the symbol?*
SPMT1 : *For example, x, y, and so on.*
R : *What are the symbols called in mathematics?*
SPMT1 : *Variable, sir.*

Student Prospective Mathematics Teacher 2 (SPMT2)

As for the subject of student-teacher candidates with good academic abilities, knowledge of the content is the same as that of prospective teacher students with excellent abilities, which is at level 1. For example, in problem three, the subject still cannot find the difference between equations and quadratic functions correctly; the subject mentions that a quadratic function is a quadratic equation in the form of a function. Of course, this requires further clarification. The following is an excerpt from an interview with SPMT2.

R : *What is the relationship between quadratic equations and quadratic functions?*
SPMT2 : *When viewed from the definition of a quadratic function, a quadratic function is a function whose highest variable power is 2. It contains an equation with a quadratic equation, both of which have the same degree of two, only that the quadratic function is a quadratic equation in the form of a function.*
R : The two are constants but look at their position to tell the difference. Okay, next, What does the quadratic equation do with quadratic functions?
SPMT2 : *A quadratic function is a quadratic equation in the form of a function.*
R : If so, you still do not see the difference. Try more *what is next? Can the quadratic function be graphed?*
SPMT2 : *Can.*
R : *Okay for example f(x) = x2, what kind of picture?*
SPMT2 : *This is possible, sir (shows a straight graph drawing sketch)*
R : Is the picture a straight line? Please check again! A straight-line graph is a linear equation. How about?
SPMT2 : *Oh yes, like an arch, sir.*
R : *What exactly is it like?*
SPMT2 : *Parabola sir.*

From the interview excerpts, it can be seen that, at first, the subject was still confused about the difference between equations and quadratic functions, and even the subject was still wrong in interpreting the graph of the quadratic function (considered as a straight line). However, after being guided by several questions, the subject finally realized that the quadratic function of the graph was a parabola. From this description, it can be concluded that the knowledge of subject content in problem 3 is at level 1.

This confirms that academic ability is not the main thing in developing content knowledge, but there are other factors such as experience and training. This follows Martin's (2008) opinion that a degree in the field of study helps prospective teachers in the classroom. This study shows that content knowledge of one major is not the only thing needed to teach students.

As for the teaching knowledge in this group, it is at level 2 as the group of prospective teacher students with excellent academic abilities. Experience is another way to accumulate pedagogical knowledge. A qualitative study by Gatbonton (2008) stated that the pedagogical knowledge of novice teachers (teachers with less than two years of experience) and experienced teachers of pedagogical knowledge was the same. However, the experienced teacher group seemed to have more detailed pedagogical knowledge, especially in acknowledging attitudes. And student behavior. This study shows that college programs are very helpful in developing teachers' pedagogical knowledge, but the previous experience of these teachers will help build knowledge to be more specific and valuable (Gatbonton, 2008).

Meanwhile, knowledge about students is also dominant at level 1. It shows that between groups of student-teacher candidates with excellent and good academic abilities, there is no significant difference in knowledge of pedagogical content. The following are the results of interviews with MCGM 2 related to teaching knowledge and student knowledge:

R : What would you teach first among the keywords given if you became a math teacher?

SPMT2 : *I think it is a linear equation because there are terms, constants, and variables in a linear equation. After that, we take it to quadratic equations and inequalities, then to discriminants. From the discriminant later, the term value D = 0 means that the line intersects or touches only after the graphic image.*

Student Prospective Mathematics Teacher 3 (SPMT3)

As for the subject of student-teacher candidates with sufficient academic ability, it was found that the content knowledge of prospective teacher students who became the subject was mostly at level 0, although some were categorized as level 1 and 2. Characteristics of knowledge at level 0 were: unable to state the definition correctly, using proper notation, only using declarative or procedural questions, unable to interpret and use different representations easily, and difficulty seeing connections between different topics/subunits (Karahasan, 2010). Following is an interview to explore content knowledge with SPMT 3.

R : *What do you think is a quadratic equation?*

SPMT3 : *A quadratic equation is an equation of the form*
f(x) = ax2 + bx + c, where the largest exponent is two and a 0. If the largest exponent is one, it is not a quadratic but an ordinary equation.

R : What would you teach first among the keywords given if you became a math teacher?

SPMT3 : I think it is a linear equation because quadratic equations' big theme in the concept map. In linear equations, there are variables and constants. In comparison, quadratic equations are similar to linear equations.

R : *What is similar?*

SPMT3 : *Both have variables, and there is a "=" relation.*

R : *So what distinguishes the two?*

SPMT3 : The highest rank, sir, the quadratic equation of the highest power is 2, *while the highest power linear equation is one.*

R : Okay, now what is the relationship between quadratic equations and functions
square?

SPMT3 : The form, sir, means that the quadratic function has the form f(x) =

ax2 + bx + c, while the quadratic equation ax2 + bx + c = 0.

R : So, what is the conclusion?

SPMT3 : Quadratic equation is a quadratic function with a value of f(x) = 0

As for teaching knowledge, the subject is at level 1. From the cases given, many of the responses were not as expected. This follows the general characteristics of Karahasan (2010), which states that the subject does not only provide good rules and procedures at this level. However, it also helps students build meaning and understanding, sees their role as guides, assessors, and reminders still dominate information, and have problems with the order of questions during learning or in designing learning, occasionally controlling the class to create a democratic learning environment.

Likewise, for students' knowledge, the subject is at level 1. Hill (2007) said this category includes predicting errors and questions. Ball et al. (2008) provide several examples from this domain, including choosing to motivate and compelling examples for students, anticipating students will think about what assignments are given and how they will handle them, and predicting what students think and think. Students think confusingly about a particular topic.

CONCLUSION

The results of this study can be concluded as follows: (1) The group of student-teacher candidates with excellent academic ability and the group of student-teacher candidates with good academic ability have content knowledge, teaching knowledge, and student knowledge that is relatively the same. Content knowledge is mostly at level 1, teaching knowledge is at level 2, and student knowledge is at level 1; (2) In the group of prospective teacher students with sufficient academic ability, it can be concluded that content knowledge is at level 0, teaching knowledge is at level 1, and student knowledge is at level 1; And (3) a person's knowledge of pedagogical content is not only influenced by his academic ability.

REFERENCES

Angelides, P, & Gibbs, P. (2006). Supporting the Continued Professional Development of Teachers through the Use of Vignettes. *Teacher Education Quarterly*, Fall 2006.

Ball, D., Thames, M., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education, 59* (5), 389-407. doi:10.1177/0022487108324554.

Blömeke, S., Hsieh, F.-J., Kaiser, G., & Schmidt, W. H. (2014). International Perspectives on Teacher Knowledge, Beliefs and Opportunities to Learn. TEDS-M Results. Dordrecht, the Netherlands: Springer Netherlands. https://doi.org/10.1007/978-94-007-6437-8

Clarke, D. J., & Hollingsworth, H. (2002). Elaborating a model of teacher professional growth. *Teaching and Teacher Education*, 18(8), 947–967.

Evens, M., Elen, J. & Depaepe, F. (2015). Developing Pedagogical Content Knowledge: Lessons Learned from Intervention Studies. *Education Research International*. Hindawi, 2015, Pp. 1–23. Doi: 10.1155/2015/790417.

Gatbonton, E. (2008). Looking beyond teachers' classroom behavior: Novice and experienced ESL teachers' pedagogical knowledge. *Language Teaching Research*, 12(2), 161-182. DOI: 10.1177/1362168807086286

Greefrath, G., Siller, H-S., Klock, H., & Wess, R. (2021). Preservice secondary teachers' pedagogical content knowledge for the teaching of mathematical modeling. *Educational Studies in Mathematics*, https://doi.org/10.1007/s10649-021-10038-z

Hill, H. (2007). Mathematical knowledge of middle school teachers: Implications for the no child left behind policy initiative. *Educational Evaluation and Policy Analysis*, 29(2), 95-114.

Huebner, S. (1991). Bias in special education decisions: The contribution of analogue research. *School Psychology Quarterly*, 6(1), 50-65.

Karahasan, B. (2010). *Preservice secondary mathematics teachers' pedagogical content knowledge of composite and inverse functions*. (Unpublished dissertation). Turki: Secondary Science and Mathematics Education Department, Middle East TechnicalUniversity.

König, J., Ligtvoeta, R., Klemenza, S., & Rothland, M. (2017). Studies In Educational Evaluation E Ff Acts of Opportunities To Learn In Teacher Preparation On Future Teachers" General Pedagogical Knowledge: Analyzing Program Characteristics And

Outcomes. *Studies In Educational Evaluation*. Elsevier, 53 (March), Pp. 122–133. Doi:10.1016/J.Stueduc.2017.03.001

König, J., Blömeke, S., Jentsch, A., Schlesinger, L., Nehls, C. F., Musekamp, F., & Kaiser, G. (2021) The links between pedagogical competence, instructional quality, and mathematics achievement in the lower secondary classroom. *Educational Studies in Mathematics*, 107:189–212. https://doi.org/10.1007/s10649-020-10021-0

Kunter, M., Baumert, J., Blum, W., Klusmann, U., Krauss, S., & Neubrand, M. (Eds.). (2013). Cognitive activation in the mathematics classroom and professional competence of teachers. *Results from the COACTIV Project*. Boston, MA: Springer US. https://doi.org/10.1007/978-1-4614-5149-5

Major, C. & Palmer, B. (2006). Reshaping teaching and learning: The transformation of faculty pedagogical content knowledge. *Higher Education*, 5, 619-647.

Martin, F. (2008). Knowledge bases for effective teaching: Beginning teachers' development as teachers of primary geography. *International Research in Geographical and Environmental Education*, 17(1), 13-39.

Lindgren, S. (1996). Thompson's levels and views about mathematics. An analysis of Finnish preservice teachers' beliefs, *Zentralblatt für Didaktik der Mathematik*, 28, 113–117.

Phelps, G., Howell, H., & Liu, Sh. (2019). Exploring differences in mathematical knowledge for teaching for prospective and practicing teachers. ZDM. https://doi.org/10.1007/s11858-019-01097-x

Poulou, M. (2001). The role of vignettes in the research of emotional and behavioral difficulties. *Emotional and Behavioural Difficulties*, 6(1), 50-62.

Ramdhani, N., Djamaludin Ancok, Dj., Swasono, Y., & Suryanto, P. (2012). Teacher Quality Improvement Program: Empowering Teachers To Increase A Quality of Indonesian "S Education," *Procedia - Social And Behavioral Sciences*. Elsevier B.V., 69 (Iceepsy), Pp. 1836–1841. Doi:10.1016/J.Sbspro.2012.12.134.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15(2), 4-14. doi:10.2307/1175860

Shulman, L. S. (1987). Knowledge and Teaching: Foundations of the New Reform. *Harvard Educational Review*, 57(1), 1–21.

Sunhaji (2014). Kualitas Sumber Daya Manusia (Kualifikasi, Kompetensi dan Sertifikasi Guru). *Jurnal Kependidikan*, II(1), 142–160.

Thompson, A. G. (1992). Teachers' beliefs and conceptions: A synthesis of the research. *In D. A. Grouws (Ed.), Handbook of Research on Mathematics Teaching and Learning*, (pp. 127-146). New York: Macmillan Publishing Company.

Talbert-Johnson, C. (2006). Preparing highly qualified teacher candidates for urban school: The important of dispositions. *Education and Urban Society*, 39(1), 147-160.