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Analysis of Questioning Types of Two Novice Teachers in Professional Learning Community for Mathematics Instruction

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Abstract: *This study aims to analyze the questioning types posed by two novice elementary school teachers in a professional learning community for mathematics instruction, and to further investigate the timing and frequency of their use of four questioning types across different units and purposes in mathematics classroom. The participants in this study are two novice teachers who have different professional backgrounds and participate in the professional learning community for mathematics instruction. The analyses are based on interviews and video analysis of mathematics instruction. The main findings are as follows: (1) There was no significant difference in the frequency of questioning types used in mathematics instruction. However, the questioning types posed by the two novice teachers varied under different instructional goals and students' performances. (2) The professional backgrounds of the two novice teachers influence the questioning types they used in mathematics instruction. Based on these findings, this paper provides some recommendations for the development of teachers' professional knowledge in mathematics instruction and for future research.*

Keywords: Mathematics Instruction, Novice Teacher, Professional Learning Community, Questioning Types

1. Introduction

The professional competence in mathematics instruction is very important. School teachers should possess professional knowledge for teaching, which includes "subject matter knowledge" and "pedagogical content knowledge" (Ball, Thames, & Phelps, 2008). Teachers' mathematical expertise influences students' mathematical achievement (Hill, Sleep, Lewis, & Ball, 2007). Professional learning communities can help enhance teachers' professional competence. Therefore, this study aims to explore the mathematics instruction practices of two novice elementary school teachers participating in a mathematics professional learning community. Questioning is an essential professional knowledge for mathematics instruction and is part of both instruction and assessment. Novice teachers often have less teaching experience, but their use of questioning in mathematics classrooms has been less explored.

Questioning is an essential strategy for teaching assessment. Boaler (2014) highlights the importance of questioning types in mathematics education for inspiring students' thinking, deepening their understanding of mathematical concepts, and fostering problem-solving and application skills. Effective questioning also promotes active engagement in mathematics

learning, thereby enhancing their learning outcomes. Thus, the types and use of questioning by teachers in the classroom are crucial factors influencing student learning. Questioning guides learners to think about the content at different levels, and the types of questions asked significantly impact mathematics instruction. Accordingly, this study adopts the four types of metacognitive questioning strategies proposed by Mevarech and Fridkin (2006). They are comprehension questioning, connection questioning, strategic questioning, and reflection questioning. This research investigates the questioning types, frequency, and timing used by two novice teachers in their mathematics instruction. The research objectives are as follows.

i. Exploring the frequency of questioning types used by the two novice teachers in mathematics instruction.
ii. Investigating the timing of the questioning types used by the two novice teachers in mathematics instruction.
iii. Analyzing the differences in questioning types due to the professional backgrounds of the two novice teachers.

2. Literature Review

Novice Teachers and Professional Knowledge

A novice teacher refers to a teacher with limited experience and tenure in a school setting. For novice teachers, the lack of teaching and work experience often means that they realize, upon entering the educational field, that pre-service training programs are insufficiently comprehensive, focusing heavily on theoretical exploration with less emphasis on practical application. Research indicates that novice teachers face several challenges, including (1) high levels of job stress, (2) pressure in interpersonal relationships, (3) difficulties in mastering teaching and assessment strategies, (4) poor organization of teaching materials, (5) insufficient teaching resources, and (6) struggles in managing student learning outcomes. Park and Kim (2023) point out that elementary novice teachers, particularly in mathematics, lack effective teaching and assessment strategies, which significantly impacts their ongoing professional development.

Novice teachers can enhance their professional competence through the following methods (Darling-Hammond & Bransford, 2005; Marzano, 2007). The methods include (1) continuous learning and self-improvement, (2) seeking professional guidance and feedback, (3) observing and collaborating in teaching, (4) participating in professional communities, (5) ongoing reflection and improvement, and (6) adopting innovative teaching approaches.

Shulman (1987) proposed that teachers' professional knowledge primarily includes content knowledge (CK), pedagogical knowledge, and pedagogical content knowledge (PCK). Among these, pedagogical content knowledge (PCK) and content knowledge (CK) directly influence students' learning outcomes. Ball, Thames, and Phelps (2008) further divided pedagogical knowledge into two main categories: subject matter knowledge and pedagogical content knowledge, as shown in Figure 1.

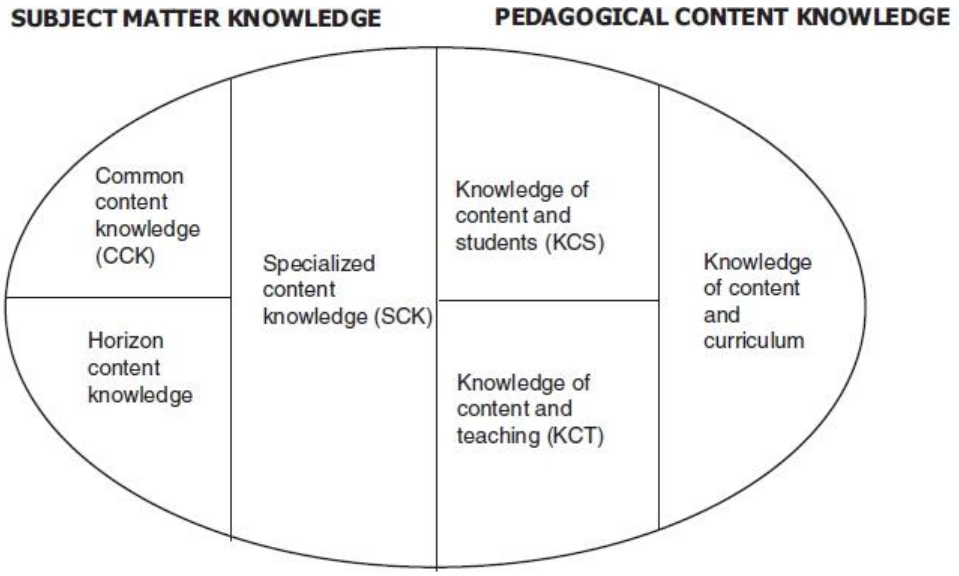

Figure 1: The Domain of Mathematical Knowledge for Teaching (Resource: Ball, Thame, & Phelps, 2008)

Teachers' knowledge in the field of mathematics is known as mathematics knowledge for teaching (MKT), which significantly impacts their professional competence in mathematics instruction. Generally, mathematics content knowledge includes knowledge related to mathematical content, while mathematical pedagogical knowledge refers to knowledge related to teaching mathematics (Ball, Thames, & Phelps, 2008). A professional learning community is an effective strategy for enhancing the professional knowledge of school teachers (Huffman & Hipp, 2003). Within a school's professional learning community, novice teachers can gain insights into their own teaching and identify areas for improvement through the community's discourse.

Relevant literature indicates that professional learning communities provide the following benefits for novice teachers (Vescio, Ross, & Adams, 2008; Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003). They are (1) Understanding the school culture and environment, (2) Promoting reflection, collaboration, and shared learning, (3) Enhancing professional development and sharing resources. Kanold (2012) suggests that schools should establish professional learning communities for mathematics teachers, with a five-step cycle in the professional learning community, as shown in Figure 2. These five steps include (1) the teacher collaborative team identifies learning goals and designs unit tasks and assessment tools, (2) teachers implement formative assessment strategies in the mathematics classroom, (3) students engage with assessment tasks and provide feedback in the mathematics classroom, (4) students experience motivation, reflection, and action through assessment activities, (5) the teacher collaborative team continuously improves instruction based on assessment feedback.

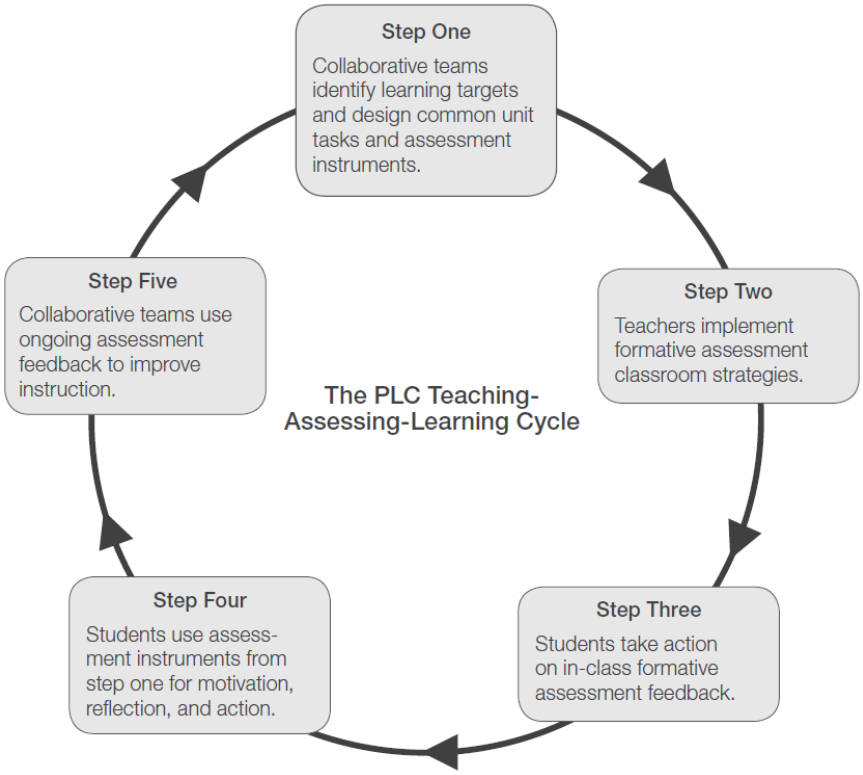

Figure 2: The Cyclical Process of Professional Learning Community for Mathematics Teachers (Resource: Kanold, 2012)

Questioning and Related Research

Questioning refers to posing problems or prompts to students to assist their understanding or guide them in applying strategies, helping them make progress in mathematics learning (Mason, 2020). Mason (2020) points out that questioning is part of the professional knowledge in mathematics instruction. Teachers must consider various aspects, such as the type of questioning to employ, the appropriate mathematical language, the timing for questioning, how to assess students' responses, and when to conduct follow-up questioning.

Elder and Paul (2007) argue that questioning promotes students' critical thinking in mathematics. According to their model of Socratic questioning, questioning can serve five functions. They are questioning clarity, precision, accuracy, relevance, and depth in students' thinking. Aizikovitsh-Udi, Clarke, and Star (2013) review related literature and note that many teachers tend to ask procedural or factual questions in mathematics classrooms, while higher-order questioning is less frequent. They emphasize that good questioning is more significant than simply asking good questions. The types of questioning used in the mathematics classroom often vary based on teachers' expertise, students' characteristics, and instructional goals.

Prommaruk (2016) suggests that questioning in mathematics instruction can incorporate real-life contexts, which not only engages students but also connects to learning objectives. Effective questioning strategies support students in learning mathematics. Mevarech and Fridkin (2006) propose the IMPROVE strategy (Introducing, Metacognitive, Practicing, Reviewing, Obtaining, Verification, Enrichment), which includes four types of questioning. They are comprehension questioning, connection questioning, strategic questioning, and reflection questioning. Mevarech and Fan (2018) also highlights that the four IMPROVE questioning strategies effectively foster self-regulated learning. Therefore, this study adopts

the four types of questioning proposed by Mevarech and Fridkin (2006) as the basis for analyzing questioning practices of two novice teachers in mathematics classrooms. The four types of questioning adopted in this study are defined as follows. (1) Comprehension questioning: This type of questioning helps students understand the meaning of the problem statement or grasp factual content, primarily involving "What" or "Who" questions. (2) Connection questioning: Through questioning, students connect new knowledge with prior concepts or life experiences, facilitating links with existing knowledge, primarily involving "When" or "Where" questions. (3) Strategic questioning: This type of questioning aids students in integrating the concepts and strategies needed for problem-solving, primarily involving "How" questions. (4) Reflection questioning: After completing a problem, questioning encourages students to reflect, review, or assess the reasonableness of their answers, primarily involving "Why" questions.

3. Methodologies

This study collected data through video analysis of mathematics instruction and interviews. The two novice teachers, referred to as Teacher A and Teacher B, are from Taiwan and participate in their school's professional learning community. The study analyzes six mathematics instruction videos for each teacher and conducts semi-structured interviews with both novice teachers.

Video Analysis of Mathematics Instruction

This study invites two experts of mathematics professor to classify the types of questioning. Table 1 presents the classification frequency results from the two experts. Rater reliability is calculated using the Kappa coefficient, with inter-rater consistency Kappa coefficients of 0.934 ($p<.001$) for Teacher A and 0.985 ($p<.001$) for Teacher B, indicating that the rater reliability in this study is acceptable.

Table 1: The frequencies of the two raters for Teacher A and Teacher B

Novice Teacher	Rater	Questioning Types				Sum
		Comprehension Questioning	Connection Questioning	Strategic Questioning	Reflection Questioning	
Teacher A	Expert 1	85	21	Teacher A	Expert 1	85
	Expert 2	88	19		Expert 2	88
Teacher B	Expert 1	73	13	Teacher B	Expert 1	73
	Expert 2	73	13		Expert 2	73

Interview Instrument

The interview instrument in this study includes four questions, as shown in Table 2.

Table 2: Descriptions of Interview Questions

Questions Number	Descriptions
1	For the following teaching objectives, which types of questioning would you use? Please provide examples. (1) Conceptual understanding (2) Procedural execution (3) Problem-solving and reasoning
2	Which types of questioning do you use to stimulate motivation at the beginning of each unit?
3	What types of questioning do you use when students exhibit misconceptions?
4	Which aspects of your professional background or experiences before becoming a teacher (e.g., major, clubs, attending lectures, participating in competitions, etc.) have helped you understand or influenced your perception of the importance of questioning in mathematics instruction?

4. Analysis and Discussion

The main findings based on the analysis of the mathematics instruction videos and interviews with the two novice teachers are as follows.

The Frequency of Questioning Types Used by the Two Novice Teacher

As shown in Table 3, the comparison of the four types of questioning used by the two novice teachers in mathematics instruction reveals a contingency coefficient of .074 ($p > .05$). Thus, there is no significant difference in the use of the four questioning types between the two novice teachers in their mathematics instruction.

Table 3: Frequency of Four Questioning Types in Mathematics Instruction by Two Novice Teachers

Novice Teacher	Questioning Types				Sum
	Comprehension Questioning	Connection Questioning	Strategic Questioning	Reflection Questioning	
Teacher A	85(68%)	21(17%)	5(4%)	14(11%)	125(100%)
Teacher B	73(60%)	13(11%)	9(8%)	25(21%)	120(100%)

The Timing of Questioning Types Used by the Two Novice Teachers

When students have misconceptions, teacher A often uses comprehension questioning or reflection questioning, while teacher B often uses reflection questioning. In teaching algorithm and calculation, teacher A often uses reflection questioning, while teacher B often employs all four types of questioning. Examples of video analysis mathematics instruction and interview analysis is shown in Table 4.

Table 4: Examples of the Timing of Questioning Types Used by Two novice teachers

Novice Teacher	Resources	Examples
Teacher A	mathematics instruction	Item: Use rounding to approximate to the third decimal place. 5.08019≈ ( ) Teacher A: 5.080, are you sure? (Reflection questioning) Student: I'm not confident. Teacher: Let's have someone help you feel more confident. Number 12. Student: 5.080. Teacher: Correct. 5.080. So… should we omit that last 0? **(Comprehension questioning)** Student: No. Teacher: Why? What decimal place are we rounding to? **(Comprehension questioning)** Student: The third place.
Teacher A	interview	Interviewer: What types of questioning do you use when students exhibit misconceptions? Teacher A : Reflection questioning is when you ask them back, "Do you think this is reasonable?" or "Do you think this is correct?" Or when a student completes a calculation on the board, we'll discuss as a class, "Do you think their calculation is acceptable? Was there an error anywhere?" Sometimes, I don't even need to say anything—the students will point it out themselves, saying, "They made a mistake there."
Teacher B	mathematics instruction	Teacher B: Multiply 4/5 by 2 to get 8/10. What's next? How did you get 16/20? **(Strategic questioning)** Student: Writes the equation on the board Teacher B: Okay. Multiplying 8/10 by 2 gives us 16/20; no problem there. Good. What's next? How did you get 24/30? **(Strategic questioning)** Student B: I multiplied 5 by 6 to get 30, and then 4 by 6 to get 24. Teacher B: How did you know to multiply by 6 at the beginning? (Reflection questioning)

		Student: I divided 24 by 4 to get 6. Then I multiplied 4 by 6 to get 30 Teacher B: Yesterday, some students continued smoothly by multiplying by 2 each time until they got stuck here and wrote 40 as the denominator. Let me ask, does multiplying 16 by 2 give 24?**(Comprehension questioning)** Student: No. Teacher B: So, they continued with 16 times 2, but for some reason, they just wrote 40 as the denominator without knowing why.
Teacher B	interview	Interviewer: What types of questioning do you use when students exhibit misconceptions? Teacher B: All types of questioning should be used. In mathematics instruction, comprehension questioning is essential. I have to make sure they all understand the definitions! I ask them about the definitions, and once I'm sure, I can move forward! **(All kinds of Questioning)** Teacher B: I ask students about what they have learned, so I'll ask, "What is this question about?" **(Connection questioning)**

The Differences in Questioning Types due to the Professional Backgrounds

The professional backgrounds of the two novice teachers influence the development of their mathematics instruction activities. In these activities, Teacher A use connection questioning and reflection questioning, while Teacher B use comprehension questioning, showing a difference in the types of questioning employed.

Teacher A majored in chemistry in college and incorporates skills learned from club activities into mathematics instruction. For example, in a lesson on building water rockets, he uses a PPT to introduce rockets, explaining their structure and parts. He employs connection questioning to ask students about rocket shapes they have seen and to link this with the mathematical concept of "angles" learned in third grade. Reflection questioning is then used to guide students in thinking about the direction of their designs. Teacher B majored in history in college, where his courses emphasize text analysis and the use of questioning for guidance. As a result, she believes that mathematics instruction should focus on reinforcing students' mathematical concepts. She frequently uses comprehension questioning to repeatedly ask students about the concepts conveyed in a given problem. Her college coursework has influenced his approach to mathematics instruction. Examples of interview analysis is depicted in Table 5.

Table 5: Examples of Questioning Types due to the Professional Backgrounds of Two Novice Teachers

Novice Teacher	Resources	Examples
Teacher A	interview	Interviewer: Which aspects of your professional background or experiences before becoming a teacher (e.g., major, clubs, attending lectures, participating in competitions, etc.) have helped you understand or influenced your perception of the importance of questioning in mathematics instruction? Teacher A: So we might find some pictures and say, "Look at the rocket's tail, what do you see? Do you see a large part here? What is it?" We could ask them to design a triangle and try it out. Oh, what kind of triangle would fit on top or in the design? Then students can start to look for the ones they like or the patterns they prefer. Teacher A: If I'm not in a rush to finish the lesson, I can do other related activities. But if I am in a rush, I'll just quickly finish the lesson. So, if we want to ask questions, we should use connected questioning. When there's a practical activity, there might be reflective questions. For example, we can ask them, "What kind of triangle do you like to use as a tail fin? Why?" Then students might say, "I want to use a right-angled triangle so that it can be straight and stand firmly. Because the bottom of the bottle is flat, if we make a right-angled triangle, it can stand very steady. Maybe it can be more stable when we launch it." I don't tell them the correct answer because I won't know until we actually launch it. I just let them explain why.

		Interviewer: Which aspects of your professional background or experiences before becoming a teacher (e.g., major, clubs, attending lectures, participating in competitions, etc.) have helped you understand or influenced your perception of the importance of questioning in mathematics instruction? Teacher B: Because I majored in history, the economics teacher would choose different historical periods for us to study, like German history, European history, or Chinese economic history. Then the teacher would ask questions based on historical documents, and we would have to discuss why certain situations occurred.
Teacher B	interview	Teacher B: If you're teaching a class, you definitely need to ask comprehension questions. You have to make sure they understand the definitions. Otherwise, how can I continue teaching? So, when teaching definitions, I would always ask them comprehension questions. I would ask them what the definitions mean, and then I can move on to the next topic after confirming their understanding. Teacher B: If I were tutoring students based on previous lessons, I would assume that they should already know the material since they've learned it from their teacher. So I would ask, "What is this question about? What is it asking you?" If they still don't understand, I would say, "Okay, let's look at the question slowly. Let's circle the keywords." Then I would emphasize, "So what is the question asking?"

5. Conclusions

This study finds no significant difference in the frequency of questioning between two novice teachers. However, the questioning types varies depending on the teaching objectives and student performance. Based on the findings, this research proposes the following recommendations. The first recommendation is to support novice teachers in participating in mathematics professional learning communities. Novice teachers may have difficulty understanding the importance of questioning in mathematics instruction. Therefore, it is recommended to encourage novice teachers to participate in mathematics instruction professional learning communities to learn from the experiences of other teachers and engage in reflection. In professional learning communities, novice teachers can also enhance their subject knowledge by reading relevant mathematics education literature or participating in professional development activities. The second recommendation is that future research could analyze more novice teachers. This study only observes two novice teachers with different professional backgrounds, and the analysis of questioning types are based on instruction video and interviews. Generalizing the findings of this study to other novice teachers requires further research. Therefore, it is recommended that future researchers analyze more novice teachers with different professional backgrounds.

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