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Investigating development of pre-service elementary mathematics teachers' pedagogical content knowledge through a school practicum course

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Abstract

This study investigates pre-service elementary mathematics teachers' development of pedagogical content knowledge (PCK) through a school practicum course. Four components of PCK were determined and used for the design of the school practicum course. A case study was designed to investigate two pre-service teachers' PCK development with regard to number patterns. Data indicated that observations in real classroom settings and discussions of these observations resulted in considerable improvement in pre-service teachers' PCK especially with regard to the knowledge of student difficulties.

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1. Introduction

In teacher education research, the notion of pedagogical content knowledge (PCK) was proposed by Shulman (1986) as a new domain of teacher knowledge and it has been a useful framework for exploring what teachers need to know or to develop for an effective teaching of a particular content. Shulman (1986) defined PCK as a blend of content and pedagogy and further explained it as

the most useful forms of [content] representation . . . the most powerful analogies, illustrations, examples, explanation, and demonstrations—in a word, the ways of representing and formulating the subject that makes it comprehensible to others (p. 9).

Recently, there has been a growing literature on PCK in science and mathematics education (Even, 1993; Kinach, 2002; Magnusson et al., 1999). In mathematics teacher education research, these studies focused on PCK of various concepts of mathematics such as functions (Even, 1993; Wilson, 1994) and slope (Stump, 2001). In other words, these studies bring the content dimension of PCK into play.

Research on PCK focused on different components of it (see Park and Oliver, 2008, for a detailed list of components used by different researchers). Grossman (1990) offers four components of PCK: (i) knowledge of strategies and representations for teaching particular topics; (ii) knowledge of students' understanding, conceptions,

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and misconceptions of these topics; (iii) knowledge and beliefs about the purposes for teaching particular topics; and (iv) knowledge of curriculum materials available for teaching. Extending Grossman's (1990) components, Magnusson et al. (1999) added the 'knowledge of assessment of scientific literacy' component to PCK framework.

Although there has been a growing literature on PCK, use of this framework for the course design especially for school practicum courses has received less attention from the research community. Recently, there has been research on the development of PCK in methods courses. Kinach (2002) investigated pre-service teachers' instructional explanations within the domain of integer subtraction and used a cognitive strategy called IACTS to develop PCK. Similarly, Bingölbalı, Özmantar & Akkoç (2008) designed a teaching methods course using PCK framework with its various components and investigated how pre-service mathematics teachers' PCK developed throughout the course. On the other hand, there are studies on how pre-service teachers learned from their fieldwork experience (Lowery, 2002; Ebby, 2000). Among these studies, Ebby (2000) investigated how field experiences affected pre-service teachers' PCK. However, her study investigated PCK in a quantitative manner using "The Content Knowledge for Teaching Mathematics measure (CKTM)" which included 27 multiple-choice items integrating pure content knowledge, content knowledge situated in teaching, and knowledge of students' thinking. In other words, this study focused on PCK in a more general sense rather than bringing the content dimension into play.

In an attempt to contribute to this growing literature on PCK development through field experiences, this study investigates pre-service elementary mathematics teachers' development of PCK through a school practicum course. In our investigation, we use components of PCK which was proposed by Grossman (1990) and Magnusson et al. (1999): knowledge of students' difficulties and misconceptions for a particular topic; knowledge of instructional strategies and methods; knowledge of curricula; knowledge of assessment.

This study brings the content dimension into play and focuses on PCK in the context of number patterns. Pattern is emphasized as an important topic in mathematics by many mathematicians and mathematics educators (Reys et al., 1984). Structure of mathematics can be observed by searching for patterns and relationships. Therefore, generalizing about patterns is thought to be particularly important (Hargreaves et. al., 1998). Learning about patterns gives students the opportunity to make the transition from arithmetic to algebra (English & Warren, 1998). Research indicates various difficulties encountered by students such as difficulties with finding rules of patterns (MacGregor & Stacey, 1995; English & Warren, 1998; Orton ve Orton, 1999). Main source of this difficulty is students' tendency to find the next term of a pattern from the previous one rather than focusing on the general structure of the pattern (e.g. for the pattern 1, 3, 5,... focusing on the differences which is 2 and guessing the next term as 7 instead of exploring the general term which is $2n-1$).

The concept of pattern has been newly introduced in Turkish national curriculum since 2005. Therefore, participants of this study learnt about patterns during the teacher education program for the first time. In schools, patterns are introduced to students in Year 1 when they are six or seven years old. In the first five years they are taught to find the relationship of a pattern given in pictorial context, to complete the number or pictorial pattern with missing terms, to extend a given pattern, to construct a pattern and to explain the numerical relationship verbally in a given pattern. In Year six and seven, when they are 12-13 years old, students are taught to use letters to stand for generalized numbers in the context of writing formulas for number patterns.

2. Methodology

A case study was designed to investigate two pre-service elementary mathematics teachers' PCK development with regard to number patterns. Pre-service teachers were enrolled in a four-year teacher training program in a university in İzmir, Turkey. The data of this study was collected during the university component of 'School Practicum II' course during which pre-service teachers make observations and do activities in the classrooms e.g. preparing and implementing worksheets, planning and conducting group work and assessment activities. During the university component of the course, pre-service teachers reflect on their experiences in schools and plan activities for the next school visit with their university tutor.

For this study, we focus on pre-service teachers' observations of number pattern lessons in schools and discussion of these observations in university component of School Practice II course.

Data sources are two pre-service teachers' lesson plans, micro-teaching lesson videos, interviews conducted after their teaching episodes, videos of pattern lessons taught by mentors in schools and videos of whole-class discussions during the university component of school practicum course.

Data was collected during ‘School Practicum II’ course. The instructor of this course is the second author of this paper. Instructor was tutoring eight pre-service teachers who taught number patterns to their peers as part of micro-teaching activities. After that pre-service teachers observed number pattern lessons during school placements for two weeks. Two pre-service teachers who were participated in this study observed different mentors (who will be called mentor A and mentor B). During the school placements, pre-service teachers observed mentors’ lessons using observation forms each of which focus on one component of PCK. During the university component, pre-service teachers watched the videos of mentors’ lessons on number patterns and made discussions considering the four components of PCK. Following this, they taught number pattern lessons as part of micro-teaching activities for the second time. Micro-teaching lessons and pre-service teachers’ discussions during the university component of school practicum course were recorded. In addition to that, semi-structured interviews were conducted during which pre-service teachers reflected on their teaching.

The data were analyzed to explore how participants plan for their lessons and how they teach number pattern lessons to their peers. This analysis was carried out before and after the school practicum course where they observed and discussed number pattern lessons in schools. Therefore, we aim to explore how school practicum course helped pre-service teachers to develop their PCK of number patterns.

3. Results

This section is organized in three sub-sections. In the first section, an analysis of mentors’ lessons on number patterns and discussion of these lessons in the university component of School Practicum course will be reported. In the second and third sections, PCK of two pre-service teachers, Ayla and Filiz, will be discussed in its four components.

3.1. Discussions on observations of mentors’ lessons

Participants of this study had observed two mentors in their school placements. Ayla observed mentor A and Filiz observed mentor B. Both mentors introduced the concept of number pattern in grade six. The aim of the analysis of mentors’ lessons is to evaluate mentors’ lessons in terms of PCK components: that is how they address student difficulties with patterns, what kinds of instructional strategies they used, how they assess student learning and how their curricular knowledge came into play during the lesson.

In terms of instructional strategies, mentor A’s lesson was student-centered and she helped students to construct concepts and relationship for themselves. Students discovered that there were more than one way to express a pattern and the need to find a rule for the pattern. Mentor A also used group work and evaluated the outcomes of the group work to help students to overcome their difficulties.

In terms of student difficulties, mentor A’s lesson offered opportunities to observe following difficulties:

- Focusing on the differences between consecutive elements and tending to find the next element from the previous one instead of the relationship between the term number and the corresponding term.
- Difficulties with finding the general term of the pattern algebraically.

As these difficulties occurred during the lesson, mentor A took these into account and developed approaches to address them. However, she did not use visual models in purposeful ways which could help in finding the rule of the pattern. For instance, she used a table of values instead of a visual model to find the general term of patterns.

In terms of assessment, mentor A used formative assessment in an effective way. She especially used questioning to monitor student learning. In terms of summative assessment, she assigned questions from the textbook.

Mentor B started his lesson with an activity in the textbook and asked his students to read the activity. He emphasized the relationship between the term number and the corresponding term. He used questioning technique extensively.

In mentor B’s lesson, it was observed that students had difficulties in three aspects: to make sense of n which represents the number of terms, to discover the relationship between the term number and the corresponding term (they focused on the increase in consecutive terms) and to construct the general term of the pattern.

Although his students expressed their difficulties in understanding the meaning of n , he did not address this difficulty in his lesson. In that sense, he can be considered less successful with addressing student difficulties which emerged during the lesson compared to mentor A. As similar to mentor A’s approach, he also did not use the visual

models to discover the relationship between the term number and the corresponding term. Instead, he preferred to focus on the table of values to construct the general term of the pattern.

In terms of formative assessment, mentor B used questioning during the lesson. However, he was not successful with monitoring his students' learning during questioning since his way of addressing students' difficulties was less effective. In terms of summative assessment, he assigned questions from the textbook.

During the discussions of mentors' lessons, various issues concerning PCK have been raised by eight pre-service teachers. Among those, students' difficulties with patterns came into prominence. Difficulties identified by pre-service teachers are summarized as follows:

- Difficulties with variable n
- Difficulties with finding the algebraic rule of a pattern
- Believing that every pattern can only be expressed with a unique algebraic rule.
- Focusing on the differences between consecutive elements instead of the relationship between n and the corresponding term e.g. $2n+1$.
- Difficulties with finding the quotient of n in the algebraic expression.

Pre-service teachers not only discussed the difficulties considering their observations of students in the classroom but also evaluated how mentors addressed or could not address these difficulties. They criticized mentor B's lesson since he was dependent on the textbook. Concerning the difficulties with finding the algebraic rule of the pattern, pre-service teachers mentioned that mentor A gave students opportunities to find different algebraic rules of a pattern and emphasized that patterns could be expressed with more than one algebraic rule. On the other hand, they criticized mentor B's lesson since he did not find alternative rules of a pattern. Similarly, they criticized mentor B's lesson since he did not explain how the quotient of n was found (The difference between consecutive terms gives the quotient of n for a linear pattern). Finally, they criticized both mentors since they did not use visual models to find the algebraic rule of a pattern.

3.2. *PCK development of Ayla*

In terms of instructional strategies, Ayla planned lecturing and questioning for her first micro-teaching practice. On the other hand, she planned an activity-based lesson for her second micro-teaching lesson. During the interview, she stated the following:

As I observed mentor's lesson, I realized how instructional strategies could be effective for learning. Lecturing leaves big questions in students' minds. Pattern is a subject where concrete materials could be used. That's how I tried to teach...being honest, there were a lot of questions in my mind regarding how we should teach to meet the new curriculum's standards. Because, in the new approach, there are no definitions or exercises to begin with. There is the activity. The question is: Can students understand? How would they react to the activities? But now, I believe that I can teach this new way. These observations were very useful for me in that sense.

As can be seen from the excerpt above, Ayla especially reflected on her development with regard to activity-based teaching which was suggested by the newly announced curriculum.

With regard to student difficulties, Ayla considered generalizing to n as the main difficulty with patterns. However, the analysis of her first micro-teaching indicated that Ayla's subject knowledge was inadequate and she herself had great difficulties with finding the rule of a pattern.

Observations of number pattern lessons also contributed to Ayla's knowledge of student difficulties with finding the algebraic rule. During the class discussions in the university component of school practicum course, Ayla mentioned that students had difficulties to explore how many steps were needed to be convinced of the rule. With regard to that, she found teacher's (mentor A's) approach helpful.

During the interview which was conducted after the micro-teaching sessions, she reflected on her teaching and compared her two lessons. In her reflections, she mentioned that observation of pattern lessons in school practicum helped her to improve her teaching:

Researcher: Did you consider student difficulties with patterns in your first micro-teaching lesson that much?

Ayla: No. Because I could not guess what kinds of difficulties students have. In the curriculum, there is the notion of algebraic expressions before patterns...However, now I realized that students could move to algebraic expressions after they learn patterns. Now I understand why students find it very difficult to understand the variable n . I examined the new curriculum's approach in dept for my preparations for the second micro-teaching lesson. I observed students' reactions in the classroom. I also examined student exam papers. Therefore, my observation in the classroom was very useful for me to shape my teaching approach in my second lesson.

As can be inferred from above, observations of number pattern lessons contributed to Ayla's knowledge of student difficulties with finding the algebraic rule of patterns. She made insightful observations of students' difficulties and improved her teaching during her second micro-teaching lesson.

In terms of curricular knowledge, observations helped Ayla to comprehend the new teaching approach of the curriculum. She mentioned that she had a chance to observe an activity-based lesson in action. Through the school practicum course, Ayla also improved her knowledge of assessment. During her first micro-teaching lesson, she did not plan for formative assessment. She used questioning during the lesson. However, as she mentioned during the interview, she did not make use of student answers to monitor student learning. In terms of summative assessment, she assigned questions from the textbook. On the other hand, for her second micro-teaching lesson, she prepared a worksheet which requires students to find rules of patterns given with models.

3.3. PCK development of Filiz

In terms of instructional strategies, Filiz used lecturing and questioning during her first micro-teaching lesson. She presented number patterns on the board and focused on the increase in consecutive terms. She found it difficult to discover the algebraic rule of the pattern '0, 2, 4, 6, 8...' which was originally '2, 4, 6, 8...' in her lesson plan. During the interview, she mentioned that she did not use questioning in an effective way:

I used questioning but I could not give feedback considering students' responses. Because they are not real students. Therefore I did not do anything to overcome students' misconceptions.

As can be concluded from her excerpts, she is aware of the importance of questioning and interaction between the teacher and students. However, because of the artificial nature of micro-teaching lesson, she could not find opportunities to practice it.

In her second micro-teaching lesson, she did not depend on heavy-lecturing. Her lesson was more student-centered. She also improved her teaching in terms of strategies she used to find the rules of the patterns. In her second lesson, she focused on the relationship between n and the corresponding term instead of consecutive elements.

In terms of student difficulties, Filiz mentioned difficulties concerning finding the algebraic rule of the pattern during the interview which was conducted after her first micro-teaching lesson. The analysis of her first lesson indicated that she herself had such difficulties during her teaching. Before her second micro-teaching lesson, Filiz evaluated her first lesson and mentioned that she did not address students' difficulties and her subject knowledge was inadequate. The analysis of her second lesson also indicated that Filiz improved her teaching in terms of addressing student difficulties with finding the algebraic rule of the pattern. For instance, she constructed the algebraic rules of patterns focusing on the relationship between n and the corresponding term instead of constructing the elements from the previous ones.

Filiz's PCK also improved in assessment component. For her first micro-teaching lesson, she did not use assessment efficiently. On the other hand, she was more aware of the need for assessment for her second micro-teaching lesson. She said she started the lesson with a question and asked the same question again at the end of the lesson. The question was related to figure patterns, which was asked to her by her neighbor's daughter: "There are circular figures in rows on a cartoon. How many figures will there be for the next rows?". She mentioned that they will be able to answer this question at the end of the lesson. As she mentioned in the interview, her aim was to monitor how her peers improved during the lesson. For the purpose of summative assessment, she wrote two number patterns on the board and asked her peers to find their rules. She said that the aim of these questions was to reinforce student learning.

Her PCK was also enriched in terms of curricular knowledge. During the discussions of mentors' lessons and interview, she mentioned that she became aware of how patterns and exponential numbers were sequenced in the curriculum. In the curriculum pattern precedes exponential numbers and Filiz realized that introducing patterns provides a background for students to learn exponential numbers since there is also a pattern in exponential numbers.

4. Discussion and Conclusion

The analysis of data indicated that the observations and discussions of number pattern lessons as part of the school practicum course resulted in considerable change in pre-service teachers' PCK especially in terms knowledge of students' understanding of and difficulties with number patterns. Both pre-service teachers mentioned in the interview that they did not consider student difficulties in their first micro-teaching lessons. Before their school placements, when they were asked to describe what kinds of difficulties students might encounter, they described difficulties in a general sense such as difficulties with generalizing to n . On the other hand, after the school practicum course they were more successful not only with articulating student difficulties but also in addressing these difficulties during their lessons. The analysis of discussions during the university component of school practicum course indicated that pre-service teachers identified various student difficulties by observing students in actual classrooms.

It was also found that the development of pre-service teachers' knowledge of student difficulties affected their strategies for teaching number patterns. For example, they focused on the relationship between n and the corresponding term instead of the differences between consecutive elements as suggested by research findings (Orton & Orton, 1999).

With regard to the effectiveness of the activities in the school practicum course, it can be concluded that observations in real classroom settings and discussions of these observations in the university component of the course resulted in considerable improvement in two pre-service teachers' pedagogical content knowledge. PCK framework which was used to structure the observations made in schools has been a useful framework and helped pre-service teachers improve their teaching practice.

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