THE NATURE OF PRESERVICE TEACHERS’ PEDAGOGICAL CONTENT KNOWLEDGE

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The focus of this paper is to present some of the findings emerged from a study investigating the development of preservice mathematics teachers’ pedagogical content knowledge (PCK) in a methods course and its associated field experience. Six preservice teachers participated in the study and the data were collected in the forms of observations, interviews and written documents. The analysis of data revealed that preservice teachers’ knowledge of subject matter was influential on the development of their PCK.

Keywords: pedagogical content knowledge, preservice, mathematics, secondary

INTRODUCTION

The major goal of teaching is to enhance students’ understanding and learning. Teachers need to be equipped with various knowledge and skills to establish and maintain effective teaching environments that enable them to achieve that goal. Shulman (1986) used the term pedagogical content knowledge (PCK) to name a special knowledge base that involves interweaving such various knowledge and skills. He defined PCK as “the ways of representing and formulating the subject that make it comprehensible to others” (p. 9). He stated that PCK includes teachers’ knowledge about specific topics that might be easy or difficult for students and possible conceptions or misconceptions that student might have related to the topic.

Many scholars accept PCK as a distinct knowledge domain for teachers but there is no single definition of PCK due to ambiguity of what constitutes PCK (e.g., Hill, Ball, & Schilling,
2008). Because PCK is perceived as knowledge of how to teach a particular subject matter (An, Kulm, & Wu, 2004), viewing PCK as the integration of content and pedagogy would not address all requirements needed for effective teaching. Teachers not only need to possess knowledge of subject matter and pedagogy but also they need to know about students, curriculum, educational goals, and instructional materials to promote students’ understanding as well as to achieve learning goals identified in the curriculum. Therefore, some scholars (e.g., An, Kulm, & Wu, 2004; Marks, 1990) accept knowledge of subject matter, knowledge of pedagogy, knowledge of students, and knowledge of curriculum are the components of PCK. Teachers need to know characteristics and needs of a particular group of students, and their conceptions and misconceptions about a particular topic that will be taught. They also need to know the arrangement of the topics covered in a particular grade level and how to use curriculum materials to achieve the learning goals identified in the written curriculum. Therefore, not only knowledge of subject matter and knowledge of pedagogy but also knowledge of students and knowledge of curriculum are essential components of PCK (Park & Oliver, 2008).

Pedagogical content knowledge is assumed to be developed as teachers gain more experience in teaching because it is directly related to act of teaching (Borko & Putnam, 1996). However, studies of preservice mathematics teachers’ knowledge and skills related to teaching have revealed that methods courses and field experiences are likely to contribute to the development of PCK to some extent (e.g., Tirosh, 2000; van Driel, de Jong, & Verloop, 2002). Although there is no widely accepted standardized instrument specifically developed to measure teachers’ PCK or the development of their PCK, researchers could learn about the nature of teachers’ PCK by using different methods such as classroom observations, structured interviews, questionnaires, and journals (e.g., An, Kulm, & Wu, 2004). In
other cases, workshops for inservice teachers could be designed with an intention of raising their awareness about the level of their PCK and improving their PCK through various practice (e.g., Barnett, 1991) or a methods course for mathematics teachers could be designed in a way that preservice teachers would have various opportunities such as analyzing students’ error, developing a task, and microteaching to improve their PCK (e.g., Ball, 1988). Therefore, I aimed to investigate what components of preservice secondary mathematics teachers’ PCK developed in a methods course and its associated field experiences.

THEORETICAL FRAMEWORK

Based on my review of the literature, that I could only discuss very limited part of it above, I accepted that PCK involved four components; knowledge of subject matter, knowledge of pedagogy, knowledge of students, and knowledge of curriculum, and there exists reciprocal relationship between them. In my definition of PCK, knowledge of subject matter refers to both teachers’ procedural knowledge and conceptual understanding of mathematics. Teachers should not only know mathematical rules or procedures but also justify why they work. They also need to know how mathematical concepts are related. Knowledge of pedagogy refers to teachers’ ability to choose appropriate tasks, examples and representations for a particular group of students and their repertoire of teaching strategies. Knowledge of students involves teachers’ knowledge of students’ conceptions, misconceptions, and possible difficulties about a particular topic and their ability to diagnose and eliminate such misconceptions and difficulties effectively. Finally, knowledge of curriculum includes knowledge of learning goals for different grade levels and knowledge of instructional materials.

METHODOLOGY
I conducted a qualitative study to investigate what components of secondary mathematics preservice teachers’ PCK developed in a methods course and its associated field experience in fall 2008 at a large public university in the southeastern U.S. I wanted to understand the variety and the extent of the issues discussed in these courses and how preservice teachers could benefit from those discussions and field experiences. There were 29 preservice teachers taking both courses. I administered a questionnaire at the beginning of the semester to learn how they perceived their level of PCK. The questionnaire consisted of 13 items; 8 of them were multiple-choice, 1 was Likert-type and 4 were short-answer question. Based on their overall scores, I formed a representative group consisting of 6 preservice teachers varying degree of perceived level of PCK (low, medium, high).

I was a participant-observer in all class sessions in both classes and I took some notes and collected any written documents given in the courses. I also conducted three interviews with each participant during the semester. At the beginning of the interviews, I asked them to reflect on the issues discussed in the methods and the field experience courses and how they contributed to each aspect of their PCK. Then I gave them some content-specific questions to understand the nature of their PCK. Although the methods course and its associated field experiences were not designed with an intention of developing preservice teachers’ PCK, in each session, the preservice teachers were discussing how to teach a particular mathematical concept that was determined by the instructor. Therefore, I used my field notes to prepare content-specific tasks that I asked during the interviews. I also wanted the preservice teachers to reflect on their field experiences. I looked at the students’ assignments to gain a better understanding of the course topics and students’ thoughts and reflections about those topics. During the last interview, I gave them a shortened version of questionnaire to see how they perceived their knowledge levels at the end of the
semester. Furthermore, I asked them to make an overall evaluation of the methods and field experience course in terms of their gains from these courses. Then, I transcribed all interviews and coded them according to PCK framework developed for this study. I compared the answers to similar types of questions to determine the similarities and differences between the explanations and also to detect any change, if there was, in their knowledge level of that particular knowledge domain. I discussed my decisions about each participant’s responses to the interview questions with a faculty from the mathematics education department and we agreed on almost all of them.

RESULTS

I identified 4 salient features of the nature and the development of preservice teachers’ PCK: 1) knowledge of subject matter is a crucial component of PCK and influences the quality of the other aspects of PCK, 2) the course practices and field experiences raised preservice teachers’ awareness of some issues of teaching and learning mathematics; however, they were not able to apply this knowledge, 3) the preservice teachers benefited from the course practices and field experiences to varying degrees, and 4) the preservice teachers generally overestimated the level of their knowledge of each aspect of PCK. Because of space limitation, I will not discuss the findings in detail, but give examples from interview data to support only the first bullet.

Choice of Teaching Activities, Tasks, and Examples

The preservice teachers’ knowledge of pedagogy was investigated in terms of their choices of tasks, examples, and teaching activities and their repertoire of teaching strategies. The findings revealed that the preservice teachers’ choices of teaching activities, tasks, and examples depended on their views of teaching and learning mathematics. Collectively, the preservice teachers viewed mathematics as the set of rules, procedures, and
facts. When asked to teach a particular topic, they mostly stated mathematical facts and described how to carry out the procedures or apply a rule. Given a set of examples and asked to place them in the order in which they would solve, some of the preservice teachers looked at their surface features such as the number of terms involved in a given equation or number of steps to solve that equation rather than paying attention to how the examples would facilitate students’ understanding. For instance, given the task shown in Figure 1, four of the preservice teachers preferred to begin with the fourth example because it seems easier. One of them told that she would begin with the second one because she would get a linear equation when cross multiply the terms and it is easier to solve a linear equation. The other one would begin with the third example because students are familiar to adding fractions with unlike denominators so they would solve it easily.

Similarly, during the second interview I asked them put given linear equations in an order to teach how to graph linear equations. Two of the preservice teachers preferred to begin with line \( y = 5 \) because it is horizontal line and there is nothing to think about. Although drawing horizontal line is easier than drawing the graph of \( y = x + 5 \), students usually fail to recognize that \( y = 5 \) is a line not a point. Therefore, teachers should make sure that students know the difference between a line and a point.

<table>
<thead>
<tr>
<th>In which order would you like to use the equations to introduce rational equations?</th>
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<tr>
<td>( \frac{2}{x(x-2)} = \frac{1}{x-2} )</td>
</tr>
<tr>
<td>( \frac{1}{x-4} = \frac{2}{3x+1} )</td>
</tr>
<tr>
<td>( \frac{5}{x} + \frac{x}{x-1} = 1 )</td>
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<tr>
<td>( \frac{3}{x+1} = \frac{x}{2} )</td>
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*Figure 1. The solving rational equations task.*

**Identification of Source of Students’ Difficulties and Errors**

The nature of preservice teachers’ mathematical knowledge and their views about mathematics reflected on how they would help students when the students had misconceptions
about or difficulties in understanding of a particular topic. The preservice teachers thought that the students fail in mathematics because they do not know the mathematical rules or procedures or they apply them wrongly. They did not state how flaws in students’ conceptual understanding would likely lead to failure in generating a correct solution. Therefore, when they were asked to address students’ errors they inclined to tell how to apply the rules or carry out the algorithms correctly. They did not attempt to justify the reasoning underlying those rules or algorithms.

During the third interview, I asked the preservice teachers how they could help a student who made a mistake when solving inequalities such that the student did not change the direction of the inequality after dividing the coefficient of the x term by a negative number. All participants stated that they would tell the student that when dividing by a negative number you need to flip the inequality sign. To convince the student that the answer was incorrect they would ask her to check the reasonableness of the result by assigning a value from the solution set to x. Furthermore, all of them were aware of that there was a mathematical explanation for why they need to change the inequality sign; however except one preservice teacher they failed to state it clearly.

**Conceptual Understanding of Mathematics**

The preservice teachers’ answers to the content-specific questions revealed that their knowledge of subject matter is mostly procedural and they did not know the conceptual foundations of some topics such as ellipses, polynomial equations, permutation and combination. Furthermore, they sometimes failed to justify their reasoning about how two topics are related to each other. For instance, none of the preservice teachers were able to define what ellipse is. They knew what it looks like but they had no idea what is used for in mathematics. Two of them told that you could form an ellipse by combining
two parabolas. Although an ellipse could be visualized as a combination of two parabolas, it is a mathematically invalid argument. They also failed to remember the expressions for $P(n, r)$ or $C(n, r)$ even though they knew that permutation refers to ordering objects while combination is finding different combinations of given objects.

The weakness of preservice teachers’ conceptual knowledge of mathematics was evident when answering other type of content-specific tasks such as identification of the source of students’ errors. Because they did not know the reasoning for flipping the inequality sign when dividing or multiplying inequality with a negative number, they would tell their students that it is a rule. Furthermore, some of them said that they neither had been taught some of the concepts such as ellipses in depth in high school nor studied on them in the college. Therefore, they did not have any idea about them.

DISCUSSION

The findings of this study supported the fact that PCK involves various knowledge and skills which are highly interrelated to each other (e.g., Even & Tirosh, 1995; Mishra & Koehler, 2006). A teacher should possess in-depth knowledge of subject matter, have a rich repertoire of teaching strategies, and be able to critically select tasks, examples, representations, and instructional materials to promote students’ understanding of a particular topic, and to diagnose and eliminate students’ errors and misconceptions effectively. Moreover, among the other components of PCK, knowledge of subject matter needs a specific attention because a teacher should have strong knowledge of the subject matter s/he would teach in order to be able to develop effective teaching strategies that are appropriate for a particular group of students, to choose appropriate tasks for them, and to identify the reasons underlying their errors and address them effectively.
The findings of this study supported the fact that preservice teachers lack knowledge of pedagogy (e.g., Ball, 1990) and knowledge of students (e.g., Morris, Hiebert, & Spitzer, 2009). For instance, when the preservice teachers were asked to order given examples of linear equations, some of them preferred to start with “y=5” because they thought that it was the simplest one. They disregarded the fact that some students might fail to distinguish between a line and a point, therefore “y=5” might not be easily understood by students as they assumed to be so. As indicated in the solving inequality task, the preservice teachers perceive teaching as telling the rules, showing students how to use them, and then having students practice them (e.g., Kinach, 2002). Furthermore, preservice teachers’ pedagogical decisions are influenced by their knowledge of subject matter (e.g., Borko & Putnam, 1996). When they were not sure about the reasoning underlying the algorithms as in the case of solving inequalities, they just preferred telling rules.

Although the purpose of this study was to investigate the development of preservice teachers’ PCK in a methods course and its associated field experience, I was not able to detect improvement in their PCK, because their knowledge of subject matter was the overriding determinant of their success in answering the questions. I used various tasks involved secondary school mathematics content for the questionnaire and interviews, and I used different items in each interview. This was problematic because if the preservice teachers did not have a strong conceptual understanding of the subject matter involved in an item, the item revealed their knowledge of subject matter rather than another aspect of their PCK. For instance, at the beginning of the semester some of the preservice teachers were able to provide conceptual foundations underlying mathematical facts because they knew the subject matter involved, but at the end of the semester they performed poorly on a similar item.
involving different subject matter because they did not know much about it.

REFERENCES


