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ENRICHING A PRESERVICE TEACHER'S CLASSROOM EXPERIENCES THROUGH CYCLES OF TEACHING AND REFLECTION

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ABSTRACT

This study adds momentum to the ongoing teacher education discussion by observing a preservice teacher's development and implementation of a lesson plan in a high school classroom. The consequences of his lack of teaching experience and incomplete content knowledge on his pedagogical content knowledge were observed during his planning and teaching of a lesson to a group of high school students. Although his experience in this study did not substantially alter his content and pedagogical content knowledge, he gained experience in preparing and teaching a lesson. The results indicate that preservice teachers benefit from multiple cycles of planning, implementing, and reflecting on their teaching, in stages of increasing awareness, under the supervision of their professors and experienced teachers.

Keywords: *Preservice teacher, reflection, content knowledge, pedagogical content knowledge.*

INTRODUCTION

The discussion regarding teachers' content knowledge and the roles of critical feedback and reflection are ongoing within mathematics communities (e.g., Ball 1990; Ball, Lubienski & Mewborn, 2001; Even, 1989; Sanchez & Llinares, 2003). Over the past decade, researchers have investigated preservice teachers' content knowledge and their views about teaching mathematics in microteaching situations based on the successful Japanese lesson study (e.g., Fernandez, 2005). In addition to examining a preservice teacher's content and pedagogical content knowledge of functions, this research extends these previous studies by observing a preservice secondary teacher's development and implementation of a lesson plan in an actual classroom. Because of this implementation of his lesson plan in a high school mathematics classroom, we were able to examine his limited perspective about teaching and learning.
According to Ball (1990), content knowledge of mathematics includes both knowledge *of* mathematics and knowledge *about* mathematics:

> Understanding of the nature of knowledge in the discipline: where it comes from, how it changes, and how truth is established; the relative centrality of different ideas as well as what it is conventional or socially agreed upon in mathematics versus what is necessary or logical. (p. 6)

Teachers' content knowledge influences their ways of teaching, and teachers with strong mathematical knowledge are more competent to help their students attain meaningful understanding of the subject matter (Even, 1990). Teachers ask questions, stimulate discussions, and suggest different points of views to students, and these activities and decisions

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require teachers to have adequate content knowledge, pedagogical content knowledge, and teaching experience (Even, 1989). When preservice teachers have misconceptions or limited content knowledge, they may pass on these misconceptions to their students or may fail to challenge them (Ball & McDiarmid, 1990). Their conceptions might limit their ability to present subject matter in appropriate ways, give helpful explanations, and conduct discussions (Even & Tirosh, 1995). Even (1993) found that many of the preservice secondary teachers had a limited understanding of functions influencing their pedagogical thinking. Researchers have shown that it is difficult to change preservice teachers' perspectives about teaching and learning. For example, Wilson (1994) examined a preservice teacher's understanding of the concept of function with extensive materials including functions, non-functions, and real life applications of functions in multiple representations: however, her perspectives of mathematics and mathematics teaching remained relatively narrow at the end of the study.

Teacher education programs have been a significant focus of research (Frykholm, 1998; Guyton and McIntyre, 1990; Artzt, 1999; Blanton et al., 2001). In particular, the supervision process of student teachers and interactions among the triad (i.e., student teacher, cooperating teacher, and university supervisor) has received considerable research attention. In examining the problems associated with developing mathematical knowledge for teaching, Ball, Lubienski, and Mewborn (2001) describe inadequate opportunities for teachers to develop the necessary content knowledge and the ability to use it in practice as a major source of problems in mathematics education. Research indicates that student teaching and supervision of student teachers, which are formative and significant components of preservice teacher preparation process, are mainly guided and influenced by cooperating teachers (e.g., Zahorik, 1988, Slick, 1997; Blanton, Berenson, & Norwood, 2001).

Despite the importance given university supervision in teacher preparation programs, results of the research on supervision of student teachers are questionable; that is, researchers (e.g., Bowman, 1979) suggests discontinuing supervision, whereas others (e.g., Blanton, Berenson, & Norwood, 2001; Borko & Mayfield, 1995; Frykholm, 1996) found the role of university supervisors quite effective and influential on student teaching. In an attempt to describe the roles of the supervisor and the cooperating teacher, researchers put forward models of student teacher supervision (e.g., Borko & Mayfield, 1995; Slick, 1997). For instance, Frykholm (1998) engaged in an important study in which preservice teachers were paired with doctoral student mentors for the student teaching experience. Having considered the role of university supervisors in the student teaching experience and preservice teachers' lack of experience with a reform-based philosophy and pedagogy as learner, Frykholm claimed that university supervisors too must be active learners in this process and participate in growth and active reflection.

A typical student teaching program, requiring university supervisors to visit a student teacher a few times in a semester, does not provide sufficient interactions between the university supervisors and the student teachers. During these visits, university supervisors observe student teaching and reflect on their teaching practices and lessons. As a result, preservice teachers rarely have the opportunity to receive continuing feedback from their university supervisors during their student teaching and generally work with their cooperating teachers. Moreover, the fact that many cooperating teachers utilize teaching strategies inconsistent with the NCTM standards (2000) amplifies the role of a university supervisor in improving the supervision process and enhancing preservice teachers' teaching, evaluation, and reflection.

This study proposes a model involving cycles of teaching and reflecting. With this model, I did not intend to claim that I am resolving the issues raised above; instead, I am describing a alternative model, which might be helpful in identifying weaknesses and strengths of preservice teachers' teaching and lesson plans and enriching preservice teachers' classroom experiences. Moreover, through analysis of his written work, interviews, and observations of his teaching, I also sought to understand the extent to which his perspectives about teaching and learning changed as he prepared and implemented a lesson plan on exponential functions and evaluated and reflected on his teaching.

Theoretical Framework

This study was framed by the research of Even's (1989) and Wilson, Shulman, and Richert (1987). Even identifies seven aspects of content knowledge for teaching functions. With Even's framework providing a general overview, I began the examination of the preservice teacher's content and pedagogical content knowledge of functions through the analysis of his responses to tasks presented in this study.

Shulman (1986) introduced the term, pedagogical content knowledge, which includes "how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (p. 8). According to Wilson, Shulman, and Richert (1987) "pedagogical content knowledge emerges and grows as teachers transform their content knowledge for the purposes of teaching" (p. 118). Wilson and his colleagues suggest a model that describes the process of pedagogical reasoning through six aspects of the teaching act: Comprehension, Transformation, Instruction, Evaluation, Reflection, and New Comprehension. Following their model, I organized the sequence of the tasks in my study to examine changes in Jack's perspectives about teaching and learning.

This model for pedagogical reasoning begins with *Comprehension*, which refers to teachers' critical understanding of a set of ideas or content. To examine Jack's understanding of functions, I administered a function questionnaire and an activity, which will be described in the next section. The second aspect, *Transformation* process, involves four sub-processes: *Critical Interpretation*, *Representation*, *Adaptation*, and *Tailoring*. *Critical Interpretation* for preparation involves reviewing instructional materials. A *Representational* repertoire consisting of metaphors, analogies, illustrations, activities, assignments, and examples helps teachers transform the content for instruction. *Adaptation* and *Tailoring* involve respectively fitting the material to the characteristics of students in general or to the needs of specific students. In order to help Jack through this transformation process, since he had limited teaching experience, I prepared and videotaped an experienced teacher teaching in an actual classroom two different lessons, one of which was teacher-centered and one of which was student-centered. I asked Jack to watch and analyze videotapes of these two lesson plans.

For the third aspect, *Instruction*, I asked Jack to prepare and teach a lesson on exponential functions in a high school classroom which I videotaped. He was asked to use this video as a tool for his *Evaluation* and *Reflection*, the fourth and fifth aspects of this model. When Jack evaluated and reflected on his teaching, this presumably would lead to the sixth aspect of this model, *New Comprehension*. Jack was able to benefit by the model from Wilson and his colleagues for experienced teachers despite his lack of teaching experience and I was able to determine the need of critically guided cycles of reflection because I asked him to prepare and implement a lesson in a high school classroom.

METHOD

A case study design was adopted to examine a preservice secondary mathematics teacher's content and pedagogical content knowledge as well as changes in his perspectives about teaching and learning as he participated in tasks, culminating, developing, and implementing a lesson in a high school classroom, during six–weeks of data collection. The data were collected through three stages and clinical interviews were conducted with Jack after each stage of the study: 1) a function questionnaire and a function sorting activity, designed to diagnose his content knowledge, 2) analyses of two video-taped mathematics lessons, and 3) preparing and implementing a lesson on exponential functions in a real classroom. The tasks and the preservice teacher's work can be found in Haciomeroglu's (2006) study.

The function questionnaire was adapted from the studies of Even (1989) and Wilson (1992). The questionnaire includes fourteen items addressing different aspects of content knowledge, such as examples of functions and non-functions, different representations of functions and five items focusing on analyses of students' incorrect solutions. I used the function questionnaire to gather information about Jack's general knowledge of functions and possible approaches for teaching the topic.

The function sorting activity (Cooney, 1996) includes twenty-eight different examples of seven types of functions given in four different representations (i.e., tables, graphs, equations, and verbal descriptions): linear, quadratic, polynomial, exponential, logarithmic, trigonometric, and rational functions. The function sorting activity comprised twenty-eight different examples each of which was written on a separate index card. Jack was presented seven tasks in which he was given different arrangements of subsets of the entire set of twenty-eight examples of functions, and asked to sort them into piles using either different representations or different types of functions. I used this activity to examine how well Jack understood the relationships among different types of functions and how he utilized different representations to translate a function from one representation to another. Jack revealed his knowledge about four different representations of seven types of functions in this activity.

I administered the function questionnaire (Even, 1989; Wilson, 1992) and the function sorting activity (Cooney, 1996) to thirty-three preservice teachers enrolled in a secondary methods course during the study at a university in the southeastern United States. After the analyses of their written responses, Jack was selected for the study because I inferred that his understanding was more robust than the understanding presented by the other thirty-two preservice teachers. During this selection process, in an attempt to describe the nature of his understanding of functions using seven aspects of content knowledge for teaching functions posited by Even (1989), I also conducted two sixty-minute interviews in which Jack was asked to elaborate on his responses to the tasks on the questionnaire and the activity.

Since Jack was a preservice secondary teacher without teaching experience in an actual classroom, I asked him to analyze two videotaped mathematics lessons, one of which was student-centered and one of which was teacher-centered. By discussing these lessons, my goal was to encourage him to consider issues necessary for planning or teaching.

Mr. Middleton, a doctoral candidate in mathematics education at a university in the southeastern United States, agreed to participate in this study. He prepared and taught two lessons in a high school classroom, which were video–taped for Jack as an aid in his analyses of the two different lessons. His first lesson was teacher-centered; that is, throughout the lesson, Mr. Middleton told students what to do and what the results would be. His teaching in the second lesson was student-centered; that is, Mr. Middleton presented real-life applications of the concept and asked his students to work on the problems in cooperative groups. Throughout the teaching of this lesson, groups of students shared and discussed their findings with the whole class. Later, I conducted an interview with Mr. Middleton to discuss the lessons he had taught for the study and his reflections on the lessons.

After Jack watched and analyzed the videos of those lessons and Mr. Middleton's reflections, I conducted a sixty-minute interview with Jack to discuss what he thought about the lessons and Mr. Middleton's implementations of the lessons. I asked him to reflect on which lesson he thought better and why he thought it was better.

I provided a lesson plan guideline with objectives and asked Jack to prepare a 40-minute lesson plan on graphing exponential functions and identifying exponential data. After examining his lesson plan, I conducted another sixty-minute interview with Jack to discuss his preparation of the lesson plan and how he selected representations, examples, activities, questions, and explanations to implement his lesson plan. At this point, through examination of the written lesson plan that Jack had prepared, it appeared that he had selected an appropriate sequence of activities and examples. Thus, I continued the study by videotaping his class while he taught his lesson to a group of high school seniors. Having watched his teaching and analyzed the video, I conducted an additional sixty-minute interview with Jack and asked him evaluate and reflect on his teaching of the lesson.

At the time of the study, there were 23 high school students enrolled in mathematics course at a high school in the southeastern United States, and six students who volunteered were asked by the instructor to participate in the teaching experiment. The school is a laboratory school that provides research and development opportunities for educators and represents state's population demographics.

RESULTS

In the next section, under "Function Questionnaire and Function Sorting Activity," I will describe my inferences of his understanding of exponential and logarithmic functions based on his written work and responses. I then discuss Jack's reflections of Mr. Middleton's lessons, his descriptions of his lesson plan, his discussion and implementation of his lesson, and his reflection in this study.

Function Questionnaire

In this activity, I discussed 19 tasks such as examples of functions and non-functions, different representations of functions, and analyses of students' incorrect solutions. I will discuss his responses to the question about exponential functions and their inverses and present difficulties that he encountered for these functions. When I observed his experiences with students, several issues emerged and will be discussed below. The question in Figure 1 was presented to Jack. Jack struggled with the concept of inverse function and assumed that logarithmic function and root function were equivalent and inverses of $f(x)=10^x$.

A student said that there are 2 different inverse functions for the function $f(x)=10^x$.
One is the root function and the other is the log function.
Is the student right? Explain.

Figure 1. The function question

In his response to this question, he wrote the following statement indicating that root and logarithmic functions were equivalent expressions:

> The student is correct in that there exist two different methods of defining the inverse. However, because of the definition of inverses (and in this case the ability to show the equality of the two inverse equations), the two equations must be equivalent. Thus, for all purposes, these two equations are both the same function.

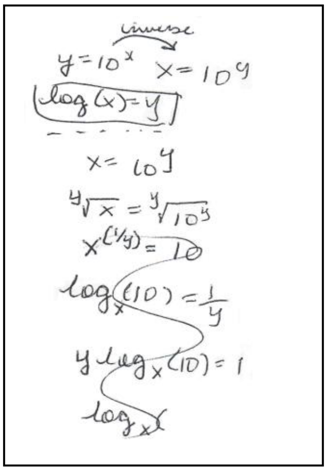

Figure 2. Jack's solution for the function question

In his solution in Figure 2, after interchanging the variables in the equation, $y=10^x$, and taking the logarithm of both sides to determine the inverse function, Jack, without considering the graph or the domain of the root function, tried to find equivalent inverse function by interchanging the variables in the equation, $y=10^x$, and taking the *y*th root of both sides. However, he could not reduce the expression, $x^{(1/y)}=10$ to the form of $\log x = y$ in Figure 2. In frustration, he drew a line through his work as seen in Figure 2. To explore his thinking further I discussed his solutions to the question in my follow up interview:

> I was able to find one inverse, and the other one, I think I messed up somewhere and I wasn't able to find the second one. In order for that equation to have two inverses, those two inverses have to equal each other. This is the two ways of representing the same data or the relationship between the two sets of data that are representing two different equations.

From his responses, I inferred that Jack still thought that an exponential function had two equivalent inverses; that is, taking the logarithm or the yth root of both sides of $y=10^x$ would produce equivalent equations, which were the inverse of the exponential function $f(x) = 10^x$. His responses to this task revealed his incomplete understanding of exponential, root, and logarithmic functions.

Function Sorting Activity

In the card sorting activity, on which the functions were written on index cards, Jack was able to sort functions according to four different representations. He was able to recognize functions presented as equations or graphs; however, he had difficulty translating functions given in tables or verbal representations. At this point, I concluded that his understanding of the relationship between logarithmic and exponential functions was incomplete. For instance, I observed that Jack was able to recognize exponential and logarithmic functions given as an equation or a graph, but he had difficulty determining exponential and logarithmic functions given in tables and relied on a point-wise approach; that is, he plotted to points to determine the functions given in tables.

Jack's Analyses of Mr. Middleton's Lessons and Reflections

In this section, I discuss Jack's analyses of Mr. Middleton's videotaped lessons and his reflections. In the interview with Jack, he was asked to compare and explain which of the two lessons he thought was better. Jack noticed that the teacher provided definitions and formulas in the first lesson without allowing the students to explore the concept. In describing his thinking, Jack said:

> In the first one, it was kind of general by the book definition represented to the class and then work's done. I did not like giving the definitions. He [the teacher] did go into asking them kind of what they thought probability was. He did try to get to students develop a definition for themselves…Just giving; it isn't necessarily the most advantageous method for teaching that certain lesson.

Jack said that the second lesson was better because the lesson was discovery-based: the students investigated the concept through the real life problems in groups and were involved in solving problems. He noticed that the students were asked to discuss their findings in small cooperative groups and then share with their classmates. Consider the following excerpt from the interview:

> I definitely like the second one better in the way that material was presented. It wasn't just stating definitions. I believe it was more kind of discovery type learning. I think that's probably not nearly as time efficient as giving them information and having them work with the information, but I think there are a lot more advantages for the students' understanding.

Jack's Lesson Plan

Jack was given a lesson plan guideline with lesson objectives and asked to prepare a lesson that he would later teach to a small group of senior high school students. By the end of a forty-minute lesson, Jack wrote that he expected students to graph exponential functions and to identify data that display exponential behavior. To introduce the idea of exponential growth to the students, he wanted to begin with an activity that he had found online, Light in the Ocean (NCTM, 2007). In this lesson, he planned to ask the students to make a conjecture about how the intensity of light changes as a function of the depth of the ocean. Jack thought this activity, in which light dims as one goes deeper in the ocean, helped them understand functions. Jack explained why he chose this activity:

> They have to understand it [exponential functions] in a real world application. So, my first instinct was in order to motivate the students to get them into the lesson was to

> have an opening sort of problem where in groups they will be able to discuss it, maybe come to some sort of consensus and then kind of start the lesson there. So, I was looking for possible problems and then I found the one about the light versus the water depth. I thought that would be a good starting point.

Jack stated that he planned to have the students draw possible graphs depicting how the light intensity decreases as the water depth in the ocean increases. After discussing the activity and possible graphs that represent light intensity versus depth of the water, Jack planned to revisit their thoughts and graphs later in the lesson.

> I wanted them to reassess their ideas about the light versus water depth and see if information [generated during class discussion] affected their ideas about the situation given.

After the class discussion of the opening activity, Jack planned to draw and compare different exponential functions: $y=3^x$, $y=3^{x+2}$, $y=3^{x-2}$, $y=2^x$, $y=2^x+2$, and $y=2^x-2$; that is, he planned to illustrate the graphical effects of changing the exponents or bases by having the students make a table and draw exponential graphs. When I asked Jack to explain his goals for presenting and discussing these functions, changing the parameters such as the bases and the exponents, he said he wanted the students to make generalizations about the graphs.

> I want them to have a table, have them plug in values, and then graph the values. Take those points and put into a coordinate system. I was hoping with each of these different sections they will be able to make a generalization that if you change one parameter, then this is what happens graphically to a function. I hope from the generalizations by just looking at the equation, they know how it would affect the data graphically.

Jack's Implementation of the Lesson Plan

I observed Jack's implementation of his lesson in a high school classroom. He began his lesson by writing a question on the board: "Have you ever noticed how the amount of light decreases the further you are under water? Consider how the light intensity changes from the surface of the water to the bottom of the ocean." Then, Jack asked the students to work in groups and draw possible graphs representing the relationship between decreasing light intensity and increasing water depth. Jack walked among the students working groups and made comments about the graphs they were creating. After he let the students work on the activity for a few minutes in their groups, in the absence of any meaningful dialogue about possible graphs modeling this phenomenon among his students, he resorted to posing functions out of context about a square function, $y=x^2$, and an exponential function, $y=2^x$.

Jack asked them how they would graph the equations $y=x^2$ and $y=2^x$ on the interval [*– 4*, *4*]. Jack noticed that the students had difficulty calculating the value of negative exponents and explained how to calculate these values with an example. Jack substituted values for *x* to make tables and draw the graphs so that the students could see the values of these functions and determine which function would rise faster. Then, he asked students to make a table and draw the graph of $y=4^x$. While students were working on this task, he determined the graph of the function $y=4^x$ with a graphing calculator and drew this graph on the same coordinate plane on the board. He asked students to compare the graphs of $y=2^x$ and $y=4^x$. Without discussing these exponential functions with different bases, Jack used the exponential functions, $y = 4^x + 2$ and $y = 4^x - 2$, to discuss the concept of horizontal asymptotes. Without making any connections between these exponential functions and his beginning activity, Jack returned to the light-versus-water-depth activity and asked them if anyone wanted to alter their graphs. There was no response from the students. Moreover, he was unable to connect these examples of functions to the activity with which he started the lesson. The class discussion was not fruitful, and Jack ended the lesson.

Jack's Reflection on his Teaching

When I asked him to evaluate and reflect on his experience in the classroom while watching the video of his teaching, Jack said that the lesson did not go as well as he had expected. He indicated that it was difficult for him to motivate them with the material and emphasized the importance of engaging students in tasks. He made the following comments.

> I think it was a moderate success in some ways. I felt like it was hard to connect to the students and motivate them with the material because I didn't know their names. I know I wasn't able to go over everything that I planned to go over. I've ended up not necessarily working out everything.

When I asked why he wanted to introduce the light-versus-water-depth activity at the beginning of the lesson, Jack responded as follows:

> Throughout the lesson, they possibly come to reassess their initial thoughts by the end of the lesson, maybe change the original conclusions. I thought it would be more interesting for the students. Because it's not only just kind of either expect them to know what is coming in a lesson or expect them to regurgitate what's going on in the lesson. I think it's more engaging for the students that way.

Jack had a good idea to introduce exponential functions with what he thought was a real life activity. However, this was not a context familiar to the students, and he brought in no data or other supporting material. Jack attributed lack of success of the activity to the fact that he experienced difficulties calling on the students as the following excerpt indicates:

> I saw him [a student] draw a straight line at the beginning of the class. I knew he had a different answer. By the end of the class, I was asking them if they had any graph that didn't look like this [graph]. I didn't specifically know his name and I felt like it would be out of place to ask him to show it [his answer] at the board. Especially when would be in front of the kids who had the same thing at certain time. I thought it could have opened up for a nice discussion. At that particular time point, I just had a problem with calling on him.

When I asked Jack what he would change in his lesson if he were asked to teach it again, he said that he would use technology to draw and compare the graphs of exponential functions more efficiently. However, he did not indicate how this would enrich his light-versus-water-depth activity.

> It would possibly include some sort of technology. Have them use their own graphing calculators, get them into groups and give them a list of equations, ask them how they would change. This would be after they work a couple of problems by themselves, by hand.

CONCLUSION

In this study, I observed the consequences of Jack's lack of teaching experience and incomplete content knowledge of mathematical functions on his pedagogical content knowledge during his planning and teaching of the lesson. This lack of experience and his incomplete content knowledge prevented him from choosing and presenting an appropriate context for exponential functions, and he was unable to recognize the source of the students' difficulties.

As a result of his participation in the extensive activities of this study, Jack gained experience in preparing and teaching a lesson; however, since I completed only one cycle of teaching and reflection with Jack, his experience in this study did not substantially enrich his content and pedagogical content knowledge of functions. His views about teaching and learning of functions changed insignificantly due to his incomplete content knowledge and lack of experience in mathematics classrooms. By analyzing, evaluating, and reflecting on his teaching, he began a process of identifying weaknesses and strengths of his teaching and lesson plan. During the first cycle of his reflection, Jack was not able to see why his lesson was not successful. In addition his first round of reflection indicated that simply asking students to explore and compare more functions with technology or a graphing calculator was what he needed to improve his lesson. However, he did not indicate how he would use technology to implement the activity successfully.

I believe that preservice teachers benefit from multiple cycles of planning, implementing, and reflecting on their teaching. I was able to observe his difficulties only after observing him attempting to implement a lesson in an actual classroom. These difficulties likely would not have been diagnosed in microteaching (Fernandez, 2005) conditions in which preservice teachers, playing the role of students, do not provide the quality of feedback I found in actual classrooms. I conclude that this is a result of two factors: 1) classmates in these microteaching situations focused on the strength of the lessons due to their lack of willingness to criticize their classmates playing the role of teacher, and 2) preservice teachers, playing of the role of students in a microteaching conditions, do not experience the same difficulties that can be diagnosed in mathematics classrooms comprising of high school students.

I agree with Ball (1990) that content knowledge should be a central focus of teacher education in order to teach mathematics effectively. I suggest preservice teachers prepare lesson plans, videotape their lessons, and evaluate and reflect on their teaching in high school mathematics classrooms, in stages of increasing awareness, under the supervision of their professors and experienced teachers, because "knowledge is developed through cycles of planning, implementing, and reflecting on lessons (Fernandez, 2005, p. 38)." Building on the model of Wilson, Shulman and Richert (1987), experience of the preparation and analyses of lesson plans and teaching episodes in high school mathematics classrooms holds potential in teacher education courses. The model of this study may be followed in methods courses for preservice teachers. I believe that only by teaching in an actual classroom under the supervision of experienced professionals who lead them in structured reflections and evaluations of their teaching episodes, it is possible for preservice teachers to enhance their teaching of mathematics and their own professional growth. I believe this study will help mathematics educators better understand ways of incorporating these experiences in the professional development of teachers.

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