The goal of this presentation is to discuss using mixed methods to study preservice teachers’ (PST) geometry content knowledge. Effective geometry instruction practices in methods courses were investigated by qualitative methods to develop a protocol to enhance geometry learning of PST, then the effect of the protocol was studied by quantitative methods. The individual interviews (n=3), classroom observations and artifacts from the methods courses data yield to narrative analysis results and thematic analysis results. The following quasi-experimental (n=102) investigation to study intervention protocol which is developed from the qualitative investigation results, showed a significant change in treatment group participants’ geometry content knowledge and a significant main effect of knowledge but no significant interaction between geometry content knowledge and grouping.

INTRODUCTION

Teachers bear an important role in reform movements. “The desired learning environments can result only from knowledgeable teachers.” (Putnam, et al., 1990, p. 225). Teachers’ knowledge should be addressed in PST education and in professional development for in-service teachers. This study reports a two-phase research study which integrated qualitative and quantitative research methods to study elementary first PSTs’ geometry learning and then their geometry content knowledge. The first phase of the study was the qualitative investigation to understand elementary school PSTs’ geometry learning and the effective geometry learning experiences for PST. Integration of results from the study of the qualitative investigation and theoretical knowledge from the literature, the researcher developed a protocol for a mathematics methods course. The protocol used as the intervention for the quasi-experimental quantitative phase with purpose of improving the geometry content knowledge for teaching of PST.

REVIEW OF LITERATURE

The most commonly accepted definition of teacher knowledge was given by Shulman (1986, 1987), who developed a cognitive model of teacher knowledge, which consists three types of teacher knowledge; content knowledge (CK), pedagogical content knowledge (PCK) and curriculum knowledge. CK refers to knowledge base of the content one is teaching, such as mathematics. PCK “… goes beyond knowledge of subject matter per se to the dimensions of subject matter knowledge for teaching…” (p. 9). PCK is the type of knowledge that distinguishes the work of a teacher from the work of a scientist. The third knowledge, curriculum
knowledge addresses effective use of curriculum materials and being familiar with other subjects that students study.

Among these knowledge types, content knowledge stands out as a point of focus for teacher education. Brown and Borko (1992) asserted that PSTs’ limited mathematical content knowledge is an obstacle for their training on pedagogical knowledge. In the mathematics education field, mathematical knowledge for teaching (MKT) was developed as following the Shulman’s model for teacher knowledge (Ball et al., 2008). MKT model addresses how a teacher uses mathematics for teaching (Ball, 2000). According to MKT model, there are six domains of teacher’s content knowledge which can be categorized under Shulman’s different types of knowledge (Ball, Thames & Phelps, 2008). There are three domains under subject matter knowledge: common content knowledge (CCK, mathematics knowledge not unique to teaching), specialized content knowledge (SCK, mathematics knowledge unique to teaching), and horizon content knowledge (knowledge of mathematics throughout the curriculum). Also, there are three domains under pedagogical content knowledge: knowledge of content and students (KCS, interaction of knowledge of mathematics and students’ mathematical conceptions), knowledge of content and teaching (KCT, interaction of knowledge of mathematics and teaching methods), and knowledge of content and curriculum (interaction of knowledge of mathematics and mathematics curriculum).

Many leading mathematics education researchers, Ball (2000), Rowland, Huckstep and Thwaites (2005), Usiskin (2001) discussed role of addressing content preparation of teachers in the context of teaching. There are two practices stand out in the literature to address teachers’ knowledge which are using video discussion groups (Sherin & Han, 2004) and using students’ work to analyze (Kazemi & Franke, 2004). The synthesis of the literature on these two practices shows that the practice of video discussion groups allows for deeper discussion on PCK while absence of classroom environment in students’ work allows for deeper discussion on CK by teachers (Lampert & Ball, 1998; Sherin & Han, 2004). Using students’ work to analyze what students know and what they are learning to facilitate teacher learning results in teachers’ deeper subject matter knowledge (Kazemi & Franke, 2004). Therefore, using students work in a methods course could also improve PSTs’ mathematics knowledge for teaching especially when they have no classroom connection during the methods course.

Content knowledge of teachers is important for every subject including geometry. The limited number of research projects focused on knowledge of geometry for teaching concludes that beginning teachers are not equipped with necessary CK and PCK for geometry, and it is important to address this issue in teacher education (Jones, 2000; Swafford, Jones, & Thornton, 1997). In a study of middle and secondary school teachers’ geometry content knowledge, Fostering Geometric Thinking (FGT), content activities and analysis of student work were used with in-
service teachers (Driscol, Egan, Dimatteo & Nikula, 2009). FGT study showed significant difference between control group teachers who did not receive any professional development and treatment group teachers who received 20-week long intervention. The intervention was designed to provide geometry content experiences for teachers and analysis of student work from teachers own classroom in order to address geometry content knowledge in the context of teaching.

Therefore, this study strives to investigate the following research questions in elementary school mathematics methods course from the constructivist perspective to inform PSTs’ geometry preparation. The first two questions were investigated through qualitative methods in order to pursue deeper understanding of PSTs’ own perception on their geometry learning and effective practices to promote their learning.

1. What is elementary school preservice teachers’ understanding of geometry for elementary school?

2. What are the perceptions of elementary school preservice teachers on effective instructional strategies to promote their learning of geometry content knowledge in mathematics methods courses?

Integration of the results from the above research questions and literature on teachers’ mathematics and geometry preparation led the below research questions to be investigated by quantitative methods to study PSTs’ geometry content knowledge. For example the topic of geometry to focus, quadrilaterals were chosen according to the results from the qualitative investigation and suggestions from the literature.

3. Does use of geometry activities focused on quadrilaterals with analysis of student work influence elementary school preservice teachers’ geometry content knowledge for teaching as measured by CKM-T?

4. Is there a difference in geometry content knowledge for teaching as measured by CKM-T between preservice teachers who are in a traditional mathematics methods course and preservice teachers who are in experimental mathematics methods course?

**SETTINGS**

This study took place in elementary mathematics methods course in a large southeastern public university in the U.S. This course plays an important role in PSTs’ education because it is the only mathematics methods course for elementary school PSTs. Usually, there are three sections of the course for the spring semester whereas there are four sections for the fall semester. The qualitative investigation took place during the spring semester and the following quantitative investigation was conducted during the fall semester.
QUALITATIVE INVESTIGATION DATA SOURCE

The goal of the qualitative investigation was to understand PSTs’ geometry learning and effective instructional practices to promote their learning. The results of this study informed teacher education practice to develop geometry practices for methods course to be used in the second phase (quantitative investigation). One student from each of the three sections of the elementary mathematics methods, Christiana, Emma and Liz (pseudonyms) participated in this investigation. The data collection included observations of geometry instruction in each section, and the collection of materials for the geometry instructions. Field notes were taken during the observations. The primary data source was individual interviews. The interview protocol was designed for semi-structured and open-ended narrative interviews. The narrative interviews are tailored to intrigue story telling from participants through open-ended questions or probes (Reissman, 1993).

QUALITATIVE INVESTIGATION DATA ANALYSIS

Individuals may use narratives for meaning making or for sharing their experiences (Riessman, 1993). Furthermore, teachers may prefer to discuss their learning and their knowledge through stories (Cortazzi, 1993). According to Labov (1972) a narrative has a structure and a sequence. If a narrative is fully formed, it has six components; abstract, orientation, complicating action, resolution, evaluation, and coda. The structure of the narratives gives insights about how the participants perceive their experiences. In addition to structural analysis of narratives, thematic analysis (Coffey & Atkinson, 1996) was used and the whole interviews were coded. Literature supports using other analysis methods in addition to narrative analysis in order to deepen the analysis of the rich data similar to the data of this study (Lloyd, 2005; Reissman, 1993).

QUALITATIVE INVESTIGATION FINDINGS

There were two main kinds of stories with sub headings emerged from participants’ narratives: stories as a learner and stories as a beginning teacher. The thematic analysis yielded three themes from PSTs’ geometry learning: history of learning geometry, perceptions about geometry, and effective geometry instruction approaches.

Narrative Analysis Findings

(a) Stories as a learner. Even though all three participants took one of the required mathematics courses, only Liz had taken the content course before the methods course. All three participants told stories from the mathematics courses they took and they expressed that those courses were as a review of high school mathematics rather than rigorous study of mathematics topics for elementary school. The stories of Liz from the content course reflect her concerns of limited mathematics (especially in geometry) learning and the lack of the connection to her teaching career.
(b) *Stories as a beginning teacher.* The beginning teacher aspect, being able to relate college education into teaching, was briefly expressed in the narratives from mathematics courses. For example, even though Liz’s priority in that the content course was to learn mathematics as a student, she had thoughts about ways to transfer the presented knowledge into her teaching. Most of the stories of all three participants as a beginning teacher took place in methods course. Only one participant (Liz) was satisfied from her learning in the methods course. The other two participants expressed their frustration as the lack of the mathematical discussions and connection between content and the teaching methods (Emma) and the misguided flow of the course by moving to the more difficult topics before discussing easier topics (Christiana).

**Thematic Analysis Findings**

(a) *History of geometry learning.* Participants’ background in geometry played an important role in their learning in college courses especially the methods course. All of them stressed the emphasis on algebraic topics in K-12 education with limited opportunities to learn geometry. Furthermore, they all perceive geometry as being different than mathematics because they have the perception of mathematics as algebraic topics.

(b) *Perceptions about geometry.* All the participants recognized the importance of visualization in geometry. Participants think geometry as a study of shapes and measurement features related to the shapes (such as area). Other important topics of geometry such as transformation were not mentioned by any of the participant. Even for the two dimensional shapes they expressed their limited knowledge in quadrilaterals. They classified topics of three dimensional shapes as difficult. Their limited experiences with geometry resulted in distorted perception of geometry.

(c) *Effective instructional approaches.* The mostly emphasized instruction approach was addressing geometry topics for elementary school in addition to the studying pedagogical aspects of those topics. Even tough, participants perceived college mathematics courses as reviews before the methods course, because those reviews did not provide desired understanding of in-depth geometry for elementary school, they were expecting content preparation from methods course too. Some instructional practices were highlighted from the data. Those practices were considered while developing the protocol.

**QUALITATIVE INVESTIGATION DISCUSSION**

All three of the participants stressed the importance of providing discussion on content before pedagogy. The content as noted by participants is not college level geometry, but geometry that they would be teaching. Especially Emma emphasized content preparation because in spite of the effective pedagogical preparation she could not relate to the ideas. This emphasis on learning geometry for teaching is parallel with MKT model (Ball et al., 2008) in terms of knowing mathematics in the
context of teaching. The second aspect was to progress from easy to more difficult topics. Because of participants’ limited knowledge of geometry, they needed to study geometry from basic topics (e.g. 2-D shapes). Furthermore, they especially stressed that they could not learn classification of quadrilaterals in spite of studying that topic in college level courses.

DEVELOPMENT OF GEOMETRY PROTOCOL

The researcher developed a series of geometry activities to use in methods course for two weeks. The length of the protocol was limited because there were only two weeks for geometry topics. The topic of the activities was the classification of quadrilaterals as informed by the qualitative investigation. The first week of activities focused on content aspect of the topic whereas the second week focused on analyzing students’ work in order to address geometry topics in the context of teaching. There were three groups of activities: sorting shapes, attributes of shapes, and classification of polygons. In addition to individual characteristics of the activities, the combination of them provided coherence. Participants worked individually, in pairs and small groups. The participants experienced geometry topics with visual representations. Also, the activities progressed through van Hiele geometric thinking levels. Therefore, the activities reflected suggestions from both literature and qualitative results. Kazemi and Franke (2004) suggested that the student work to be used to improve teachers’ content knowledge should be challenging. In other words, the student work should show wrong student answers and misconceptions in order to intrigue teachers’ discussions on mathematics topics. With this purpose, the researcher collected student work from local elementary schools with mathematically struggling students. The participants were given a protocol to study student work. The protocol was developed by suggestions from several resources (E. Kazemi, personal communication, August 17, 2008; NCTM, 2006). First in pairs, the participants discussed what the student did, what the student knew (and misconceptions), what they would ask the student in order to learn more about the student’s knowledge of geometry. Then, in small groups (two pairs), participants discussed what they would do to teach these concepts to the student and how they would address the student misconceptions.

QUANTITATIVE INVESTIGATION DATA COLLECTION AND ANALYSIS

There were three instructors for four sections of the methods course for the fall semester. There were one hundred and seven students enrolled and 102 of them volunteered to participate in the study. All the participants were female. Two of the sections were assigned to be the treatment and other two to be the control groups.

All the instructors were teaching geometry for two weeks during the last third of the semester. The intervention took 90 minutes (half of one class meeting) of each geometry week. The remaining half of the time of class meetings were used to discuss other geometry topics.
The instrument to measure PSTs’ geometry content knowledge, Content Knowledge for Teaching Mathematics Measures (CKT-M Measures)\textsuperscript{1} was developed as a continuum of research on mathematics knowledge for teaching (MKT) which provides the theoretical framework for this study. The instrument aims to measure elementary school PSTs’ mathematics knowledge in the context of teaching. For this current study, only the geometry section of the instrument was used. Two parallel forms of the geometry section of the test were administered as pre and post test.

Participants completed the CKT-M Measures geometry test one week before their geometry instruction. For the next two weeks they received the geometry instruction and the following week they completed the post-test. Both pre and post tests were administered at the beginning of the class. In order to address the last two research questions, geometry knowledge growth of treatment group and detection of any difference of knowledge growth between treatment and control groups, two different analysis methods, repeated measures ANOVA and mixed ANOVA, were used, respectively.

**QUANTITATIVE INVESTIGATION RESULTS**

In order to study the first research question, geometry knowledge growth of treatment group, repeated measures ANOVA was used. Results showed a significant change in participants’ geometry content knowledge, $F(1, 49) = 16.08$, $p<.001$, $R^2 = .25$, $\eta^2 = .25$. This indicates a statistically significant positive change in treatment group participants’ geometry content knowledge. A mixed ANOVA method of analysis was conducted to study whether there was a difference of knowledge growth between treatment and control groups. Results indicated a significant main effect of time $F(1, 91) = 28.38$, $p<.001$ but there was no significant interaction between time and grouping (treatment/control), $F(1, 91) = .21$, $p=.646$. The results showed that geometry knowledge of participants was increased significantly, however the grouping did not have any effect on participants’ knowledge growth. It can be concluded that even though treatment group participants’ geometry content knowledge growth was significant, the difference between treatment group and control group participants’ growth in geometry content knowledge was not significant.

**QUANTITATIVE INVESTIGATION DISCUSSION**

The analysis of growth in treatment group can be interpreted as that use of the protocol developed from the previous studies resulted in significant increase in PSTs’ geometry content knowledge. However, the control group results showed increase in PSTs who received regular instruction too. Even though treatment group participants’ increase was more than the increase of control group participants, the difference was not statistically significant. However, it should be noted that the regular instruction for the control group also addressed the geometry topics from the perspective of learning mathematics in the context of teaching. During the geometry
instruction of the control group, the researcher observed the control group instruction. For further research, the control group instruction designed not to address geometry in the context of teaching may provide further information on affect of using the protocol with PSTs. Furthermore, using student work with PSTs to promote their content knowledge might not be as effective as using them with in-service teachers (e.g. Driscoll et al., 2009). In the case of in-service teachers, participants first experience teaching the materials and then analyze student work. On the other hand, in the case of PSTs, participants only experience the materials without teaching them. Therefore, this study might start the discussions on the role of actual teaching of the materials before analyzing student work.

CONCLUSIONS

Therefore, this study provides further understanding on teacher’ geometry content knowledge. It informs mathematics teacher education in three important points. For the qualitative investigation, PSTs reported that they have limited geometry knowledge as previous research studies have showed (Jones, 2000; Swafford et al., 1997). Since PSTs perception of geometry for elementary school is limited to the 2-D shapes, it may be suggested to conduct further studies on geometry content knowledge of PSTs for other geometry topics too. Lastly, use of student work in PST education may not lead to similar results as using with in-service teachers.

Endnote 1: Copyright © 2006 The Regents of the University of Michigan. For information, questions, or permission requests please contact Merrie Blunk, Learning Mathematics for Teaching, 734-615-7632. Not for reproduction or use without written consent of LMT. Measures development supported by NSF grants REC-9979873, REC- 0207649, EHR-0233456 & EHR 0335411, and by a subcontract to CPRE on Department of Education (DOE), Office of Educational Research and Improvement (OERI) award #R308A960003.

REFERENCES


