Co-teaching math content and math pedagogy for elementary pre-service teachers: A pilot study

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Abstract

With a national need to improve Science, Technology, Engineering and Mathematics Education (STEM), elementary pre-service teachers must be provided with ample opportunities to increase their own knowledge and confidence in STEM disciplines. This article describes a Math Block experience developed for a special population of non-traditional students in an Early Childhood Unified program. The block blended a math content course with a math methods course and was co-taught by a mathematician and teacher educator.

Background

With major efforts to reform K-12 mathematics education, the traditional approach for preparing elementary teachers is not adequate (CBMS, 2001). Among specific content recommendations from the Conference Board of the Mathematical Sciences are implications for redesigning the way mathematics classes are taught. Because of the importance of both pedagogical knowledge and content knowledge, teacher preparation programs are seeking ways to improve traditional models that typically have arts/ science faculty teach content and education faculty conduct the different subject matter methods courses. Implications from past research also indicate that opportunities in teacher education preparation must include instruction that deepens mathematical knowledge, perhaps through the integration of math methods courses with conceptually based content courses (Schram, et. al, 1988).

Although many critics claim that teachers' ineffectiveness in classrooms is directly associated to a lack of content knowledge, educators contend that all teachers model pedagogy, whether purposeful or not (Warren, 1998). Studies exist to refute the charge that teachers only need to have subject matter knowledge to teach well, yet often this evidence continues to be ignored (Berliner, 2000). There is supporting evidence that confirms an interconnection between content and pedagogy (Lampert & Ball, 1998). As teacher education programs work to strengthen the preparation of teachers, the balance of content and pedagogy remains a concern. Acquiring this balance, however, may be an extremely difficult task for institutions of higher education because of the complexities involved and it also has the potential to place more tension between education faculty and arts/ science faculty.

An integral goal of teacher education programs should stress not only the content they will be required to teach, but also how the content is learned and can be taught. Cohen (1998) argues that this form of instruction enables preservice teachers to learn "two faces of the same body of knowledge" (p. 169). In an intensive, national study,

research on learning concluded that teachers must obtain an understanding of effective instructional practices for each subject that they teach, while also demonstrating an understanding of children's cognitive development, individual learning needs, and the role of cultural beliefs on the learning process (Carter, 2002). Perhaps the most substantial contributions to developing a theoretical framework related to pedagogical content knowledge for mathematics, were studies by Ball (1990) and Ma (1999) where particular mathematics topics were situated in teaching and used as survey items with preservice and practicing teachers. These studies revealed that the knowledge of a particular concept held for oneself was not reflective of the knowledge needed for teaching mathematics. These studies also suggested that students' learning is dependent on more than one factor: the teachers' content knowledge and the interaction between this form of knowledge and the students' thinking about the mathematical content (Ball, et. al, 2002). Furthermore, they implied that methods courses should focus on developing pedagogical content knowledge. The definition of Shulman's (1986) pedagogical content knowledge known as "the content knowledge needed for teaching" provides an additional argument for redesigning the elementary mathematical preparation in teacher education programs. With an overlap of content, pedagogy, and teacher education's goal of developing preservice teachers who are reflective practitioners, is the implication of bridging the three separate entities into one coherent plan.

Prospective elementary teachers need opportunities to develop deep understandings of the mathematics they will be accountable for in schools including mathematical topics related to the content strands of Number and Operations, Algebra, Data Analysis and Probability, Geometry, and Measurement (CBMS, 2001; NCTM, 2000). Typically, most of this mathematics is addressed in mathematical content courses offered for elementary preservice teachers at universities across the country while the overlying goal of a math methods course is to develop understanding for how children learn various mathematical concepts and skills and learn how to teach particular mathematical ideas to children – also referred to as pedagogy. It is critical that elementary preservice teachers have a deep understanding of the connections between math content and math methods in the elementary classroom.

The best undergraduate elementary education preparation is a product of a partnership between mathematics and pedagogy, linked to meaningful field experiences (Ball, 2000; Ball and Bass 2003; American Council on Education, 1999), which demand truly interdisciplinary work. Theoretically, interdisciplinary work can bring insights from different perspectives, thus maximizing preservice teachers' professional competencies through integrative learning experiences (Mansilla, Miller, & Gardner, 2000). The CBMS specifically recommends mathematicians and mathematics educators collaborate for preservice teacher mathematics education (CBMS 2001). Integrated learning experiences also were found to be valuable in mathematics education; however, limited studies currently exist to document attempts to integrate math content, pedagogy, and field experiences.

In one of the earliest integrated designs, Feiman-Nemser (1990) described how two professors worked together to team-teach a mathematics content course and a methods course, focusing on building a conceptual understanding of mathematics.

The field component entailed pairing each preservice teacher with a mentor classroom teacher. Assignments, which developed as part of the mathematics content/methods block, were carried out in the classroom setting. Although findings from the study indicate improvement in preservice teachers' ability to understand relationships between procedures and rules, skepticism about instructional practices remained the same.

Lloyd and Frykholm (2000) designed a geometry course for elementary school teachers through the use of middle school curriculum and purposeful activities to explore the teaching of such concepts. Their study implies that integrating mathematical content with pedagogy and the use of actual school math curricula encourages preservice teachers to understand connections between mathematics teaching and learning. In a review of high quality research for the US Department of Education, three studies documenting the interaction between content and pedagogy were found (Wilson et. al, 2002). These studies implied that preservice teachers' consideration of content knowledge in subject specific methods courses allows for reorganization of knowledge by classifying how the content should be taught. Most models of integration include purposeful course development that emphasizes the blending of content with pedagogy within a methods course designed for preservice teachers. Interpretive studies of math methods courses show many similar features with the math content courses for elementary school teachers (Hiebert & Carpenter, 1992). For example, both courses emphasize the preservice teacher as a learner with the goal of developing mathematical habits of mind. Engaging preservice teachers in meaningful explorations involves carefully selected content that connects to school mathematics. Through the learning process and rich discourse, preservice teachers come to understand how children learn while given opportunities to think about the applications in an actual classroom.

Although no collaboration existed among the content and methods instructors, Strawhecker (2004) reported that elementary preservice teachers' concurrent enrollment in a mathematics methods course, a mathematics content course, and a field experience resulted in significant gains in pedagogical content knowledge, as well as positive changes in beliefs about teaching elementary mathematics. When preservice teachers take content and mathematics methods courses concurrently, the connections between mathematical topics have potential to become clearer. Additionally, when preservice teachers engage in a field experience, they gain appreciation for the difficulty of teaching "basic" mathematics to students, and are thus more receptive to learning the mathematics content and methods on campus (Heaton & Lewis, 2001).

Although many acknowledge the value of interdisciplinary work, robust instructional partnerships between mathematicians and mathematics educators are very difficult to develop (Latterell, 2005). A commonly cited barrier to enacting close partnerships is finding time to plan and conduct integrated lessons (Mervis, 2006). Other barriers include lack of mutual respect between some mathematics and teaching departments and also a lack of knowledge of how to plan and conduct integrated lessons. The successful implementation of co-teaching involves careful planning, willing instructors for co-teaching, students that are encouraged to think for themselves, and administrative support (Shafer, 2000).

Students at all levels, though less so at the college level, are taught and participate in collaborative activities though they are not experiencing collaboration among their instructors (Pace & Austin, 2003). It is important for all students, especially preservice teachers, to see successful implementation of co-teaching.

Context

At the Midwest institution where this pilot was conducted, elementary preservice teachers are encouraged to co-enroll in the mathematics content course, methods course, and field experience. But the current system has flaws, which allow for frequent deviation to the sequence. For example, a preservice teacher may take a mathematics content course during his freshman year and wait until his junior year to co-enroll in the methods course/field experience leaving a 2-year gap between the "linked" content and methods. Furthermore, the university is currently transitioning its more traditional student teaching experience to that of a co-teaching model.

The pilot study was initially developed to accommodate a small group of twelve preservice teachers who were in the process of obtaining a degree in Early Childhood Unified. This particular cohort was comprised of Head Start staff working to comply with the Teacher Qualification Mandate:

> By September 30, 2013 at least 50% of Head Start teachers nation-wide must have a baccalaureate or advanced degree in Early Childhood Education or a baccalaureate or advanced degree in any subject, and coursework equivalent to a major relating to early childhood education with experience teaching

Several of the preservice teachers in the cohort were spread across the state, had no previous college experience, and all began their coursework on the community college level prior to enrollment at this four-year institution. At this point in their program, all cohort members had formally applied and been admitted into the university's teacher education program. Moreover, each had previously completed the prerequisite courses to enroll in this block, which included: Math for Elementary Teachers I, Math Methods I, and Management and Assessment for Elementary/Preschool Classrooms.

Instruction for the block began with a one-week online module; hence, 20% of the pilot "block" course was taught in an online format. The cohort met with both instructors in a centralized location off-campus on eight occasions over a four-week period during the summer session. They were co-enrolled in a 3-credit content course, Math for Elementary Teachers II, and a 2-credit methods course, Math Methods II. The face-to-face sessions met for seven hours. The topics covered in the block included whole number algorithms, fractions, percents, proportion, and geometry.

The instructors' model for co-teaching was built from a foundation where both instructors were jointly responsible for course content, presentations, and grading. For the pilot experience, the class sessions were carefully planned to ensure that both instructors would be teaching the related topics on the same day but through the different lenses of math content and math methods. Consistent with a co-teaching model, one instructor often led the class while the second instructor assisted, often working to help make more explicit connections between content and methods. Some

topics, such as geometric solids, were taught jointly. Though pedagogy and content were blended in multiple ways, the instructors desired to make it clear to the preservice teachers how the math in the content course, combined with the math methods strategies aided them in learning the content and recognizing their own struggles. With the math content taught at a deeper level than what they would teach in their own classrooms, the preservice teachers reflected on how, as teachers in their own classrooms, they would be able to help their students learn the "basic" elementary mathematics with understanding.

Methods

We were interested in understanding how the pilot study participants perceived the co-teaching model they had experienced for math. The preservice teachers included in this study were purposefully selected from the pilot study cohort of only twelve preservice teachers. A small sample size of three cohort members was chosen to allow for an in depth analysis of students' perceptions of learning in the co-teaching environment.

The preservice teachers' online journal reflections, written assignments, and a culminating survey at the conclusion of the block were analyzed (see Appendix). The survey was administered after the 25 clock-hour field experience, which was a requirement for the participants during the fall semester. We used a Constant Comparative Analysis to code the data independently. According to Glaser & Strauss (1967), the Constant Comparative Method of Qualitative Analysis is a simultaneous coding and analysis of data to "locate and build a theory" which is typically carried out in four steps:

1. Compare incidents applicable to each category.
2. Integrate categories and their properties.
3. Delimit the theory (we refer to these as our common themes).
4. Write the theory.

Following our individual analysis, we met to discuss common themes among the data. Three key themes emerged and are discussed in the sections below. Pseudonyms have been used to replace the actual names of the three preservice teachers, all of whom are non-traditional students due to the nature of this particular program.

Lisa completed three years of high school mathematics with a B average, but has experienced more challenges with the college-level mathematics courses, averaging a D+/C-. When asked to reflect on the experiences that have shaped her mathematical disposition prior to this pilot block course, she wrote:

> I really believe that some people are just naturals with understanding math, and some people have a more difficult time with it. This could truly just be because of people's experience with how they were taught math. I believe in more of a hands on approach to understanding mathematics. I think it's good to use visuals or things that children can manipulate because they understand better than just sitting in a desk watching the teacher write on the chalkboard or read it aloud. I personally really enjoy math but sometimes it's hard for me especially when it comes to geometry.

> I never really understood it and there's no way I could explain it to someone. I also think it's good for the children to be able to explain back to you why they came up with the solution or answer that they did. It not only helps them articulate how they solved a problem but it's good literacy skills and social skills as well. Working in small groups can be very important because it teaches children social skills and also helps them problem solve together.

The second subject, Betsy, completed four years of high school mathematics with a B average. In self-reporting her college mathematical aptitude, she reported having a B average in college math classes. At the beginning of the experience, Betsy wrote:

> Mathematics has never been my strong suit. Language Arts is my area of expertise. I suppose that the main reason for this is the right brain-left brain issue. I don't remember if Mathematics was ever easy for me. I doubt it. I do know that several experiences when I was younger shaped my fear and dislike of mathematics. I am much older now and have returned to higher education in the hopes of attaining my Early Childhood Unified field endorsement. I took Math Methods I last summer with much trepidation. This was due to the 20+ year gap in my collegiate learning and the fact that it was a MATH class. However, I enjoyed the class and did well. That class helped me start to overcome my fear of mathematics. Even with this small start, I am still almost terrified to take this class. This terror will fade soon, I am sure, because my fellow classmates are in similar straits; thus, they are a great support team for me. The fear of the unknown, matched with the terrifying math monster, has most likely created a terror in me that is totally unfounded.

Heidi, the final subject in the study, also completed four years of high school math. Moreover, she has maintained an A average throughout her mathematical coursework in both high school and college. At the beginning of the semester, she wrote:

> My experience from school is remembering how I was taught math. We were taught one way to do problems so I didn't experience problem solving on my own. In grade school and junior high, my experiences were not good. I remember being drilled for memorization, and that is just not my thing! I “got by” in math until I was a senior in high school and I took an applied math course just for the heck of it. In that class I learned that I could actually enjoy math. I excelled in it because my teacher used real life problems that made sense to me. I remember just thinking "FINALLY! It makes sense!"

Findings

The analysis of written reflections from the three preservice teachers clustered around three key themes: connections between content and methods; empathy for those learning new material; and developing confidence in learning content beyond

their desired teaching level.

Connections between content and methods. Throughout the summer session and again in reflecting upon the block experience, each of the three preservice teachers discussed the blend of content and methods and its impact on both their learning and teaching philosophy. Lisa wrote in her online journal:

> During this class I thought there was a good balance between learning mathematical information and being able to use manipulatives so we understood math better.

During the middle part of the class, Heidi was struggling with some of the content in geometry and discovered that strategies in the methods course helped her learn the material.

> The main thing for me that is going around in my head is the overall confusion for me as a student in geometry. I read terms in one geometry section (of the content course textbook) and think I may understand a couple. Then I go on to another section and find myself needing to go back to the previous chapter. For some reason geometry terms are not sticking in my head. For me trying to figure out geometry is tough, so the thought of teaching it to children is very scary. I feel like I need my own vocabulary booklet, similar to the one that was shown to us during Methods. Then I also learned about polyhedrons from both classes, which reminds me of the importance of repetition. When I saw it in the content course textbook after our discussion in class Tuesday I felt like the concept was solidified.

In the methods class, the preservice teachers are exposed to various tools, materials, and resources for teaching. Near the end of the session, Betsy's and Lisa's reflections related their content experience to their future roles as a teacher and making decisions in material selection.

> I am thoroughly confused reading the content textbook and appreciate the personal instruction. How can any teachers continue to simply teach "out of the textbook"? (Lisa's weekly reflection)

> The only struggle that I am still having in this class is the content textbook. I feel like I am reading a foreign language. This also reinforces the importance of the teacher to clarify his/her own instruction. I would be failing these classes without the personal instruction of our professors. (Betsy's weekly reflection)

When asked to reflect on the block course design that included two instructors for the two math classes and one location for learning, the participants wrote:

> I struggled with the math content course, but it had been a long time since I had math classes. However, the co-teaching format assisted me with

> understanding better, as the teachers could assist each other in explanations (Betsy's survey).
>
> I liked the co-teaching. I feel it's beneficial when like information is shared how it can either build on from each other or know it was hit hard by one teacher so needed less (focus) from the other teacher. I also think if doing longer sessions as we did, it's nice to have a change of pace with different instructors (Heidi's survey).

Empathy for those learning new material. During the course, Lisa reflected on the challenge of traditional assessment of student learning.

> I am truly struggling with the math content course tremendously and I honestly do like mathematics; when I understand how to figure out a problem. The things I'm struggling with are; I don't feel like we get enough time with you throughout the day to go over questions or problems we are having. Everyone is at different levels and honestly sometimes I just get so frustrated that I don't know what else to do, so I give up. I also have big issues with timed tests, honestly that was half my problem last Friday. It does take me a while to process things but when I have to get it done in a certain amount of time it just makes me panic even more. We talk over and over about kids taking timed tests and how it's not best practice and obviously it's something that's still hard for me but that's just something I'm going to have to deal with on my own.

Heidi came to the conclusion that students learn mathematics better when they can take ownership of the process and develop their own connections and conclusions.

> Even though I train and supervise home visitors who work with infants and toddlers, and most of this is beyond that age group I can still relate that even infants and toddlers in their learning need to explore ideas on their own and be given time to problem solve. Since I don't plan on teaching after I get my degree and truly love the program I work for (as that is the reason I'm getting my unified degree in order to keep my job) I find these classes will help me as a parent. I can try to use this knowledge to help make math fun for my own children, and also help them find ways to discover their own meanings for math.

As Betsy struggled to learn the material, she made a connection to teaching style and a supportive classroom environment.

> I have to concentrate so hard on understanding the material that I am exhausted by evening. But, I am also learning a great deal and having plenty of "aha" moments. It just seems to take me longer to "catch on" than my classmates. However, I do appreciate my classmates and my instructors for not judging my ineptness in mathematics.

Developing confidence in learning content beyond their desired teaching level. Several reflective statements reveal all three participants' skepticism as well as "developing" confidence for topics that are viewed by them as beyond their desired teaching level. Lisa, the participant with the lowest of the three self-reported math aptitudes, commented:

> I think that many elementary teachers do not like math or have little understanding of all the algorithms, so it is harder for them to teach the subject and harder for some students to comprehend. So I know I will have to study the lessons very carefully for the grade that I teach so that I will be able to bring that math confidence that you have to the classroom.

Similarly, Heidi felt uneasy about teaching whole number algorithms at the beginning of the summer session; however, after her field experience, her comments reflect a gain in confidence.

> It made me realize that I know the standard algorithms, but I definitely don't always understand why they work (Week 1 entry).

> I utilized some math content knowledge when doing my field experience with students at the grade school. I was pretty rusty on math concepts so it gave me a little more confidence that I actually understood what I was teaching (Culminating survey).

Perhaps more telling, was Betsy's journal entry made in the middle of the summer session:

> I couldn't fathom why an Early Childhood endorsement required Math for Elementary Teachers II. I realized that I have had "tunnel vision" up to this point. While our cohort is focusing on preschool, the Early Childhood endorsement covers up to 3rd grade. I plan to stay with my current job and therefore, will be working predominantly with children ages 0-5. But, I am old enough to know that our life "plan" doesn't always work out the way we want it to! It dawned on me that someday, I could be teaching 3rd graders! And, if I had a 3rd grade classroom, or any grade level actually, I would need to know their conceptual knowledge and how to build on it or even have to start at the basic level. But, I would also need to know what concepts to build on myself for their future mathematical learning. This was a huge realization for me.

After working in the field setting and completing the survey for this block, the confidence issue - particularly with the preservice teachers' content knowledge- was mentioned.

> In working with children, I realized that I struggled to explain certain mathematical concepts because I didn't understand them myself. (Betsy)

Discussion

The feedback from this pilot experience of a blended course of math content and math methods co-taught by a mathematician and a math educator indicates a general support for this style of class from this set of subjects. The three main themes in the preservice teachers' journal reflections and culminating survey are as follows; connections between content and methods; empathy for others learning new material; and developing confidence in learning content beyond their desired teaching level.

In sorting comments by mathematical aptitude, we found that there was little difference in the preservice teachers' confidence level, though the student with the highest mathematical aptitude discussed more connections between the math content and math methods. Teachers with depth of content knowledge are better prepared to represent a concept in multiple ways and think about things in a manner other than their own (Ball, 2000). Furthermore, we were able to conclude that the low math aptitude student made the highest number of negative comments toward math content in comparison to the other two preservice teachers.

The survey that was conducted at the conclusion of the preservice teachers' mathematical field experience also revealed information that was useful to us as course instructors. We noted that each of the three participants could reflect on specific applications of math content and methods and they wrote more about the strategies from the methods. If authentic methods were put into practice, perhaps these experiences were more novel and memorable than preservice teachers' use of math content; hence, they were able to elaborate on these experiences. Another hypothesis is that the participants still lack the depth of content knowledge for mathematics teaching.

There is limited research on the effectiveness of co-teaching at the post-secondary level, including the perception of students (Pace & Austin, 2003). Developing an effective co-teaching model for elementary mathematics preparation in math content and math methods is a major task and time commitment for all involved parties. Much work remains. Continued research to determine more specifically what preservice teachers learn, the connections within their mathematical knowledge for teaching, and how co-teachers prepare is recommended.

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Appendix

Reflect on your TE 313 math field experience last fall.

- *How did you apply your knowledge of math content (Math 330)?*

- *How did you apply your knowledge of math methods (TE 312)?*