# Connecting Mathematics and Literature: An Analysis of Pre-service Elementary School Teachers' Changing Beliefs and Knowledge

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## Abstract

*The National Council of Teachers of Mathematics calls for students to see relationships and connections with mathematics (2000). This study examined the influences on eight preservice elementary school teachers' beliefs and knowledge of teaching mathematics through literature. The semester long project involved both the language arts and elementary mathematics methods courses, and involved the designing and implementation of mathematics lessons based around a young adult novel. Through qualitative analyses, the study reveals a significant shift in their beliefs, interest, and identification of benefits of teaching mathematics through literature and making connections across the curriculum. Teacher education programs can benefit from replications of this study.*

## Introduction

Studies supporting the integration of mathematics and literature indicate that there is a strong correlation between learning mathematics content by listening to and interacting with mathematical stories (Whitin & Wilde,1992,1995; Whitin & Whitin, 2004; Burns, 1992, 1995, Zambo, 2005). Yet there are very few studies regarding preservice teachers' attitudes and beliefs about using mathematics and literature with elementary students (Ward, 2005; Frykholm & Glasson, 2005). The present study explored preservice elementary teachers' beliefs and understandings of teaching mathematics through literature. We were concerned with what would happen if preservice elementary teachers, enrolled in the both the language arts and mathematics methods courses, were given responsibility for designing and implementing a mathematics-literature lesson. We were curious to learn about the preservice teachers' beliefs regarding the teaching of mathematics using literature. What if our preservice teachers implemented the project collaboratively with elementary students in a classroom setting? What would the elementary students and preservice teachers learn from the experience? How would the experience change their beliefs of the benefits of connecting mathematics with literature?

## Theoretical Background

With the current emphasis on mathematics and language arts serving as the primary subjects in many state testing programs as the measure for success and accountability, it becomes paramount for teacher educators to equip preservice teachers with information to integrate math content through the utilization of literature. The National Council of Teachers of Mathematics (NCTM) *Principles and Standards for School Mathematics* (NCTM, 2000) provides a detailed outline describing the role of written and oral communication in promoting mathematical understanding. More specifically, the Communication standard states, that whether it be through writing, reading, listening, or speaking, children learn about the world around them. The use of

children's literature in mathematics instruction fosters all forms of communication. The NCTM resource *Curriculum and Evaluation Standards for School Mathematics* (1989) supports the integration of children's literature into the K-8 classroom because, "Many children's books present interesting problems and illustrate how other children solve them. Through these books, students see mathematics in a different context while they use reading as a form of communication" (p. 28). Research has shown that the integration of mathematics and literature can deepen students' understanding of mathematical concepts (Whitin & Whitin, 2004; Burns, 1995). More and more educators are calling for increased integration of reading and content subjects (Vacca & Vacca, 2005; Tomlinson & Lynch-Brown, 2002; Tompkins, 2004). Literacy scholars advocate that reading is an interactive constructive process that allows students to interpret and comprehend content subjects such as mathematics while also promoting thinking skills.

Draper (2002) notes that "Literacy and literacy instruction are necessary parts of mathematics instruction" (p. 523). The National Council of Teachers of Mathematics along with the International Reading Association (IRA) and the National Council of Teachers of English (NCTE) call for the integration of subject areas through literacy. The integration of literature within content area instruction is not a new practice, but it has gained significant attention by national professional organizations and schools across the nation who have discovered the plethora of quality books that can be integrated throughout the curriculum (Tompkins, 2004; Vacca, 2000; Vacca & Vacca, 2005). Literature-based mathematics lessons parallel state and national standards for the teaching of mathematics and reading. Integrating literature within mathematics lessons not only develops literacy skills, but also promotes mathematical language and problem solving. Moreover, the visual representation in the literature books not only stimulates readers, but also provides informative story lines that foster children's curiosity. The power of children's literature and mathematics provide readers with opportunities to try different strategies and to scaffold previous experiences to broaden one's learning. Yet, there are very few studies about the facility of these programs and how teachers are using mathematics and literature within the context of their curriculum. Hence, as co-researchers of this study, our aim was to awaken preservice teachers' knowledge about the effectiveness of infusing literature to learn mathematics. According to various researchers, there are numerous benefits for integrating children's literature into mathematics instruction: provides a meaningful context for mathematics (Whitin & Wilde, 1992; Whitin & Whitin, 2004); allows students to see 'how math is applied in the real world" (Braddon, Hall, & Taylor, 1993); provides students with real-world applications and fosters, supports, and celebrates math as a language (Whitin & Wilde, 1992); "Allows [children ] to think, reason, solve problems, compare and contrast, critique, and communicate in both old and new ways" (Duocolon, 2000); and allows children to "gain experience with solving word problems in familiar stories" (Ward, 2005).

Various research studies validate the breadth for integrating children's literature into mathematics (Burns, 1995; Draper, 2002; Siegel, Borasi, & Smith, 1989; Whitin & Whitin, 2004; Whitin & Wilde, 1992, 1995). Students at all levels intellectually benefit with an improved understanding of mathematics by listening to stories about mathematics. As preservice teachers learn the value of integrating literature and mathematics, they begin to experience reading in new ways. They come to understand that literature overlaps many areas of knowledge and that mathematics topics can stimulate the learning experiences for their students. The present study attempted to add to this body of knowledge by exploring preservice elementary teachers' changes in belief and knowledge of the benefits of teaching mathematics through literature.

## The Courses

Preservice teachers are often asked to reconsider their lived experiences, to step outside the parameters of the college classroom to visualize the responses of their own students. They must view themselves as social change agents as they grapple with their previous views of instruction, theory and reexamine dominant schools of thought (Zaragoza, 2002, Freire & Macedo, 1987). At (our university), preservice elementary teachers entering their junior year take an undergraduate course to explore the world of children's literature. The students read and evaluate available trade books and develop curricular connections. Preservice teachers also extend their knowledge of quality literature by participating in literature circles (Daniels, 2002; Campbell Hill, Schlick, & King, 1999) and reader response activities (Rosenblatt, 1985). Moreover, they build upon their knowledge of integrating curricular activities by developing a text set to plan an interdisciplinary unit.

During the following semester, the same cohort of preservice teachers enrolled in another series of methods courses including the Language Arts and elementary mathematics methods. The research project took place in these courses and required the preservice teachers to integrate and reflect (Dewey, 1938) on the content learned the prior semester in the children's literature course. Within the language arts course, there is a heavy focus on integrating language arts across the curriculum. Integrating language arts throughout the curriculum provides students with a meaningful learning context (Tompkins, 2004).

The preservice teachers complete the mathematics methods course during their junior year. Much of the course focuses on preparing preservice teachers to implement best practices in planning and teaching mathematics lessons (Pajares, 1992) as well as pedagogical content knowledge and curricular knowledge (Shulman, 1986). Throughout the course, preservice teachers explore case studies and discuss field experiences to address topics such as: effective pedagogical strategies, teaching via problem solving (NCTM, 2000), state and national standards, and lesson planning with mathematical connections.

## Methodology

Eight preservice elementary teachers voluntarily participated in the study during their last semester of their junior year. The cohort nature of the program enabled the eight students to take both the Language Arts course and Elementary Mathematics Methods course in the same semester. They completed the Children's Literature course in the previous semester and had twelve weeks in an urban field experience during the semester of the study. The professors for the Language Arts course and Elementary Mathematics Methods course collaboratively designed the study and served as co-researchers. Assignments and class schedules were coordinated to promote connections across the courses and avoid duplicated work.

Since literature is a vehicle to integrate reading, writing, speaking, viewing, listening, and visually representing (Tompkins, 2004), the preservice elementary teachers were required to read the novel entitled *Chasing Vermeer* (Balliett, 2004). *Chasing Vermeer* is a fast-paced and imaginative work about the disappearance of one of the artist Vermeer's most famous paintings. The main characters of the book, Petra and Calder are at the center of an international art scandal. Using their intuition, problem-solving skills, knowledge about art, pentominoes, and communication skills, they try to solve the mystery. The book has received many positive reviews and Scholastic, Inc. recently announced that the book will be converted to media form. There is an entire interactive web site available at www.scholastic.com where readers can

download sample pentomino pages and learn more about Vermeer and his work. The popularity of the novel coupled with its potential for curricular connections made this an excellent choice for our project.

Throughout the semester, the preservice elementary teachers maintained a reader response notebook which was collected at three different points throughout the study. Reader response notebooks afford readers with ongoing opportunities to respond to the story by expressing personal thoughts, feelings, and images. Transactional theory posits that a reader carries on a "dynamic, personal, and unique activity" as he or she interacts with a text (Rosenblatt, 1985). In addition to encouraging preservice teachers to build upon prior knowledge and to share their personal responses to *Chasing Vermeer*, they were also required to record the interdisciplinary connections to language arts including possible mini-lessons for grammar, vocabulary, discussion prompts, writing, art, etc. Moreover, students discussed the novel within literature circle groups and collaboratively shared their connections making sense of theory to practice. At the end of the semester, the elementary preservice teachers worked within small groups to create a written dramatization of a scene from the novel. The dramatization was later presented to a group of elementary students in an urban school district. Dramatization creates motivation for students to participate and facilitates students' responses during instruction (McMaster, 1998). Using dramatic activities as a tool during a mathematics-literature lesson was based on the principle that drama would involve the audience to be more interested in learning (Fleming, Merrell, & Tymms, 2004).

As part of the mathematics methods course, students wrote a mathematical autobiography addressing favorite mathematical topics, fears of mathematics, favorite mathematics courses, etc. They were also asked to describe any literature experiences they had in any of their mathematics classes, what novels they read that connected to mathematics, and any dramatizations they may have experienced in a mathematics class. Near the end of the course, the preservice teachers collaboratively planned some upper elementary/middle school mathematics lessons based on the use of pentominoes. Since the characters in the novel used pentominoes throughout the story, the lessons focused on mathematical concepts related to pentominoes such as: transformations, lines of symmetry, and area and perimeter. The preservice teachers were given a short lesson on pentominoes during the course, but were required to research the topic and design and implement engaging and inquiry-based lessons. The lessons would be shared with the elementary/middle school students following the dramatization of the novel.

## Data Collection

A combination of methods including interviews, written responses to focused group questions pre and post study, reader response journals recorded by the preservice teachers as they read the novel, mathematical autobiographies of the preservice teachers, field notes of the dramatization and mathematics lesson by the researchers, and the mathematics lesson plans were used to triangulate (Wolcott, 1994) data for analysis of preservice elementary teachers' knowledge and beliefs regarding the use of literature in teaching mathematics.

At the beginning and end of the semester, the preservice elementary teachers were asked to respond to several focus group questions (See Appendix A) to determine if there were any changes in their beliefs or knowledge about using literature to teach mathematics (Morgan, 1998) as a result of the study.

Four elementary classroom teachers from different schools in the local school district volunteered to have the preservice teachers perform the dramatization and teach the mathematics

lessons for their students. The preservice teachers were divided into two groups of four and each group was assigned to two different classrooms. The dramatizations were conducted on the same days for each group. The researchers observed all the dramatizations and recorded field notes (Gay, Mills, & Airasian, 2006) during the mathematics lessons in the urban classrooms.

Finally, the reader response journals and written responses to the focused questions were collected, and the preservice teachers were informally interviewed to determine the impact of using literature to teach mathematics. The interviews were unstructured to find out where the preservice teachers are coming from and what they have experienced (Agar, 1980). The participants' mathematical autobiographies were also analyzed for data and used to frame some of the questions for the interviews. The two researchers independently analyzed the data and compared results. They each coded the preservice teachers' responses to the focused questions, interviews, and their reader response journals, and then compared their codes to identify both similarities and differences (Vaughn, Schumm, Klingner, & Samuell, 1995). A total of 88 text segments were coded, placed on individual index cards, and sorted into common categories. The researchers then decided that a theme occurred when a category had a minimum of 10 cards. The cut point of 10 was selected because it represented a large effect size (Cohen, 1988). Results of the coding indicated three main themes: (a) the use of literature helps motivate students to want to learn mathematics (b) designing mathematics lessons around literature helps make the mathematics more meaningful (c) teachers need to make mathematical connections with literature.

## Findings

Through the focused questions and mathematical autobiographies, the preservice teachers revealed they rarely had any experience as learners with literature and mathematics connections. While most of them enjoyed language arts, they did not share similar feelings about mathematics. Their mathematical experiences were primarily routine practice with problems copied from the board or on worksheets. The thought of reading part of a novel or performing a dramatization based on a book to introduce a mathematics lesson never occurred to them as an instructional approach. The theme of having teachers make mathematical connections with literature emerged from comments in the interviews. As Erica noted, "From what I can remember, my mathematics courses were dominated by worksheets and bookwork. Rarely were we placed into groups to work collaboratively. My classes were all boring." Matt quoted, "I learned math by memorizing facts, doing worksheets, and through direct instruction by the teachers. I never saw any need or understood why I did what I did." Allie added "My experiences learning math content were never positive ones. I remember drills and tons of worksheets. If I had learned with a story as the context, it would have been much better." The written focused group questions included comments such as: math does not need to be dry, teachers need to integrate, connect mathematics, work with language arts teacher, and finding good books with math.

As the preservice teachers worked together on the development of the dramatization and the mathematics lessons, they discussed major themes and clues in the novel to help the reader solve the mystery. Their knowledge about language arts and mathematical concepts were enhanced as they explored various ways to connect the novel to the mathematics lesson. For example, at the beginning of the mathematics course, preservice teachers knew little about transformations. After the study, they were able to define and demonstrate reflections and rotations. Through their journals, they also gained confidence in their knowledge of these subjects related to the novel and to the mathematics embedded within the novel. Several statements included: "I was amazed

at how much math I learned as a result of the book" (Cara) and "I learned a lot about math that I didn't understand before. For students, like me, who are not good in math or who don't like math, incorporating good children's literature give students a chance to learn math in a way that is more enjoyable to them" (Erica). The theme of making mathematics more meaningful was used to describe students comments such as: active learning, making sense, see how it can be used, why we need to learn about pentominoes, how to help students see why they should learn the math.

The preservice teachers realized teaching inquiry-based and engaging lessons work best. They noted the need to motivate students to want to learn is so important, especially in middle schools. During our focus group discussion, Cara, Erica, and Allie indicated the following: "The use of a dramatization to connect the literature and mathematics really captured the students' interest." "They (the middle school students) really were into the story and the lesson." "I can see now the importance of using literature to excite students into a math lesson." Reflective journals included student comments such as: "I can see where literature can motivate a student to want to explore the mathematics," "the story really made me want to learn the math that I didn't know before," and "I saw how the book really made you want to do the math."

Teacher educators need to provide opportunities for preservice teachers to explicate their beliefs with experiential learning outcomes (Borko & Putnam, 1996; Calderhead, 1996; Freeman, 1991). The comparison of pre- and post focused questions and the reflective journals revealed the preservice teachers' beliefs regarding incorporating literature and mathematics changed. The *Chasing Vermeer* project influenced how they now think about integrating literature and mathematics and the importance of connecting the two disciplines. For example, prior to the study, the preservice teachers' responses to a focused question regarding how they would use literature in a mathematics class included: "I am not sure how to use children' literature to teach math," "Until now, I have never had a math class that used literature other than the math book itself. So I really have never considered integrating the two subjects," "The only books I can see using in a math class are counting books. I really can't see how literature can help with math".

Post focused question responses provide evidence of changes in the preservice teachers' perspectives and beliefs. During our follow up discussion, preservice teachers shared the following sentiments: "Reading related books to complement content will help the students' comprehend the material and will motivate them" (Allie). "Using literature helps to make interdisciplinary connections that are so important for students" (Cara). "Teaching mathematics based on a novel helps to motivate the students to want to read the book and to do the mathematics" (Mark). The preservice teachers also noted the importance of selecting content rich texts, creative novels and nonfiction literature. As Cara stated, "I will look for books that are written by a credible author, have rich language, accurate information, and books that my students will find interesting." Moreover, Allie added "Using children's literature will help my students have a better understanding of mathematics. I believe that connecting a mathematics lesson to a book geared towards girls and minorities might especially be appealing to the students," Mark concurred with this notion and shared that "Literature can be used in every subject, it's just a matter of finding books that compliment a lesson." Through their reflective journals they also recognized the need to seek novels that include various aspects of mathematics or other subjects. "The literature needs to evoke substance for content learning." The reflective journals also indicated that the preservice teachers recognized the need to seek novels that include various aspects of mathematics or other subjects. "Just reading literature and following it

with a mathematics lesson would not be as effective as acting out a dramatization." The nature of the book you use is critical."

## Conclusion

The study generated positive results and beliefs on connecting literature and mathematics instruction among the preservice elementary teachers. The use of the novel helped the preservice teachers realize first hand the extent of mathematical learning that can occur through literature. They found literature served as a great motivator to engage students in mathematics and help inspire a sense of motivation to learn mathematics. The preservice teachers noted the use of literature provided them with opportunities to make the mathematics more meaningful and relevant to other disciplines. They were able to emphasize mathematical connections to help students see various applications of the concepts. The authentic experiences with literature and mathematics helped them see the extent to which using literature can support and enhance students' mathematical learning. As Hoewisch (2000) noted, "The value of children's literature to children's literacy development cannot be contested. Preservice teachers cannot be expected to know how to use children's literature as a purposeful and meaningful educational tool unless we teach them well." Therefore, this project provided them with the opportunities, tools and content knowledge to explore the interconnectedness of literature and mathematics.

In addition, the preservice teachers learned the importance of collaborating to plan and design effective classroom lessons. Their reflections noted their hopes to work with colleagues to co-design lessons in their future teaching positions. Preservice elementary teachers need to experience using children's literature as a basis for an instructional lesson if they are expected to teach as such. Where possible, teacher education programs should include interdisciplinary assignments in teaching preservice teachers' content and pedagogical knowledge. Cross connecting disciplines helps preservice teachers enhance their content knowledge and instructional practices. They must have opportunities to experience and practice what they have learned to embed the learning. The results of the study suggest teacher education programs need to find ways to provide literature-based mathematics experiences to help preservice teachers challenge their perspectives and beliefs about ways to effectively teach mathematics. The findings support recommendations by Minor et al. (2002) to allow teacher education faculty and preservice teachers the opportunities to design experiences (e.g., lessons, readings, practica, case studies) that help candidates develop conceptual models of effective teaching that will guide their decision making once they assume responsibilities as practitioners.

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Appendix A

## FOCUS GROUP QUESTIONS

1. To what extent can literature be used to teach content subjects? Please explain your response.

2. Describe your experiences learning mathematics content throughout elementary, middle, high school, and college

3. In your opinion, how will the utilization of children's literature improve students" understanding of mathematical content knowledge?

4. Explain how you foresee using children's literature to teach mathematics.

5. To what extent do you feel the use of children's literature will affect students' understanding of mathematics?

6. List the criteria that you would use to select mathematics trade books.

7. List any mathematics related children's literature books that you have read.

8. Be as explicit as possible and include the types of mathematical experiences with or without literature that you had in elementary school, middle school, high school or college.