12-2010

# The Impact of Content Courses on Pre-service Elementary Teachers' Mathematical Content Knowledge

Michael Matthews
*University of Nebraska at Omaha*, michaelmatthews@unomaha.edu

Janice Rech
*University of Nebraska at Omaha*, jrech@unomaha.edu

Neal Grandgenett
*University of Nebraska at Omaha*, ngrandgenett@unomaha.edu

# The Impact of Content Courses on Pre-service Elementary Teachers' Mathematical Content Knowledge

Michael Matthews
University of Neberaska-Omaha
Department of Mathematics
DSC 203
Omaha, Nebraska 68182
michaelmatthews@unomaha.edu

Janice Rech
University of Neberaska-Omaha
Department of Mathematics
DSC 203
Omaha, Nebraska 68182
jrech@unomaha.edu

Neal Grandgenett
University of Neberaska-Omaha
Department of Mathematics
DSC 203
Omaha, Nebraska 68182
ngrandgenett@unomaha.edu

## Abstract

*In response to research documenting the mathematical deficiencies of pre-service elementary teachers, many teacher preparation programs are requiring mathematical content courses specifically focusing on the mathematics taught at the elementary level. This study considers what impact two such courses (one course focusing on Arithmetic, and the other course focusing on Geometry and Measurement) had on the mathematical content knowledge and attitude towards mathematics by comparing a group of pre-service elementary teachers who took these courses to a group of pre-service elementary teachers who took only a more general mathematics course (such as College Algebra). Results indicated that those teachers who took the specialized content courses had significantly higher mathematical content knowledge compared to those pre-service elementary teachers who took more general mathematics courses, but not significantly better attitudes towards mathematics.*

Keywords: Mathematical content knowledge, attitude toward mathematics, pre-service teachers, elementary teachers, pre-service elementary teachers, content courses

## Introduction

*Content Knowledge of Teachers.* In 1986, Shulman presented the notion that content knowledge needed for teaching also involves knowing "why" something is so, not just that it "is" so, and specifically in mathematics, more than being able to simply compute something. Since this seminal work, the content knowledge preparation of elementary teachers has been a major topic in the research, with most studies reporting major shortcomings in pre-service and in-service elementary teachers' content knowledge in mathematics. For example, Ball (1990) found that pre-service teachers understanding of division was based on relatively simplistic and internalized rules and unconnected to other mathematical operations. Stoddart, Connell, Stofflet, and Peck (1993) found that the pre-service teachers demonstrated from 37% to 98% accuracy among questions on procedural skills, but only 5% to 10% accuracy among more conceptual based questions.

This need for a deeper understanding of mathematics for elementary teachers is found in a wide variety of studies involving a diverse set of mathematical topics and settings. For example, Quinn (1997) found that less than ½ of the pre-service teachers in his study could solve problems involving geometric concepts. Adams (1998) found that less than 1/3 of the pre-service teachers in her study could describe how the number systems (reals, integers, whole numbers) were related with diagrams or descriptions. Van Dooren, Verschaffel, and Onghena (2002) found that pre-service elementary teachers may struggle with problems that are more algebraic in nature. Stacey, Helme, Steinle, Baturo, Irwin, and Bana (2001), found that 20% of the pre-service elementary teachers did not have a good grasp of concepts related to decimals. Ever more current studies are confirming these alarming insights, as Tsao (2006) reported that most pre-service teachers studied have poor number sense, estimation skills and poor abilities to solve problems mentally that should be accessible mentally. Matthews and Seaman (2007) reported that the pre-service teachers in their study struggled when asked to analyze arithmetic algorithms. Pickreign (2007) asked pre-service elementary teachers to write a definition of rectangles and rhombi. Of the 40 teachers surveyed, only 9 wrote an acceptable definition for rectangles and only 1 wrote an acceptable definition for rhombi.

A growing body of research has validated the seemingly intuitive idea that content knowledge of teachers is directly related to their students' mathematical performance (Rowan, Chiang, and Miller, 1997; Rowland, Martyn, Barber, and Heal, 2000; Goulding, Rowland, and Barber 2002; Hill Rowan, and Ball, 2005; Van Dooren, Verschaffel, and Onghena, 2002). As these research findings have become well known, addressing the shortcomings in teacher's content knowledge has become an increasing priority in the United States and linked to larger challenges in STEM Education (Coppola and Malyn-Smith, 2006; National Science Foundation, 1996).

In the earlier part of this decade, some major organizations concerned with mathematics education began to propose that content courses in mathematics for pre-service teachers should be a standard part of their preparation (Conference Board of the Mathematical Sciences, 2001; Kilpatrick, Swafford, & Findell, 2001). In particular, the Conference Board of Mathematical Sciences (CBMS, 2001) published a document entitled "The Mathematics Education of Teachers" which contained specific recommendations for the mathematical preparation of teachers. The report recommended at least 9 semester-hours on fundamental ideas of elementary school mathematics. The main areas suggested were numbers and operations, algebra, geometry, and data analysis. The goal of such recommended courses for elementary pre-service teachers is to not only develop an understanding of the mathematics taught, but to also develop "the habits of mind of a mathematical thinker…" Additionally, after completing these courses, elementary teachers would enter the classroom recognizing a more intuitive network of mathematical concepts that extend to other grades. As these new CBMS guidelines are implemented, it would seem that a systematic investigation of their relative impact of these specialized content courses on elementary pre-service teacher understanding of mathematics would be appropriate.

*Level of Implementations of the recommended guidelines* .Some research studies that have investigated how widely the CBMS guidelines are being adopted are finding wide variability among teacher preparation institutions. For example, in 2007, Matthews and Seaman reported that of a random sample of 48 higher education institutions that grant degrees in elementary education (out of 1,297 higher education institutions classified at The Chronicle of Higher Education website, http://chronicle.com/), a total of 14 institutions did not require any specific content course opting instead to only require a general mathematics course such as Intermediate or College Algebra. Further, NCTQ (National Council on Teacher Quality, 2008) found that in the United States, there is extreme variability in what is required in mathematics courses for pre-service elementary teachers. Specifically, NCTQ found that 15 out of 77 of the education schools sampled required no specialized mathematics courses, 11 schools required only one course, 42 schools require two courses, and only 9 schools required at least 3 courses as the CBMS guidelines suggested.

*Impact of Content Courses on Teachers' Knowledge Research.* Although limited, some content courses have been relative mainstays in a few institutions' teacher preparation curricula dating back before the CBMS guidelines. Early research into the impact of these courses has been mixed. Leapard (2000) found significant decreases in mathematical anxiety but no increases in the content knowledge among pre-service teachers. Leonard and Joergensen (2002) used a continuous diagnostic tool, post-test data, interviews, and journals and found overall improvement in content knowledge, with some subtopics, like area and perimeter problems, were still relatively misunderstood by the pre-service teachers in their study. In an interesting and more blended approach, Burton, Daane, and Giesen (2008) replaced 20 minutes of a traditional methods class instruction with elementary mathematics content instruction. They concluded that even a limited amount of time spent on elementary mathematics content can increase the mathematics knowledge of pre-service teachers. Finally, Matthews and Seaman (2007) found that students who took a single content course had significantly higher content knowledge, approximately 1-2 semesters later, then when compared to students who took a more general mathematics course.

*Mathematics Attitudes.* In general, research on elementary teachers' attitudes toward mathematics has shown that these teachers have relatively negative attitudes toward mathematics. Kolstad and Hughes (1994) found that 34% of the K-4 teachers in their study had strong negative attitudes toward mathematics, a significantly higher percentage than other educators. Pre-service elementary teachers have been shown to have the most negative attitude toward mathematics when compared to all other college majors (Hembree 1990).

Attitude towards mathematics is no doubt a complex idea that interacts with other important belief structures of a teacher. Research studying attitudes toward mathematics is associated with research on beliefs, anxiety, and efficacy towards mathematics (Beswick, 2006; Beswick & Dole, 2001; McGinnis et al., 2002). Bandalos, Yates, & Thorndike-Christ (1995) define anxiety partially in terms of attitude. Efficacy has also been shown to be related to attitude toward mathematics (Randhawa, Beamer, & Lundberg, 1993). Furthermore, attitude toward mathematics has been shown to be negatively correlated with anxiety toward the subject (Brady & Bowd, 2005).

Finally, the content knowledge of elementary teachers also appears to be a significant consideration in their mathematical attitudes. Gleason studied the relationship between prospective teachers' mathematics anxiety and numerical anxiety with mathematical knowledge for teaching (2008). Gleason found the variables were significantly correlated, but that the correlation between teachers' numerical anxiety and mathematical knowledge for teaching was relatively weak. Matthews and Seaman (2007) found that pre-service teachers who took one content course designed along the CBMS guidelines had significantly better attitudes than those pre-service teachers who only took more generalized mathematics courses.

Previous research has also examined the mathematics anxiety of practicing and prospective elementary teachers and its effect on student achievement. Various studies suggest that elementary education majors are typically highly math-anxious and particularly when they have low content knowledge (Becker, 1986; Kelly & Tomhave, 1985). Alarmingly, such teachers may inadvertently transmit these attitudes to their students, although such research is mixed. Two studies that focused on the transmission of the teacher's mathematics anxiety to their students had mixed results (Sovchik, 1996, Wood, 1988), but both researchers considered this unfortunate transfer to be a real possibility.

It appears that more research should be conducted to ascertain the impact of additional mathematics coursework on the teacher content knowledge of pre-service teachers. As additional mathematics coursework has been added to the undergraduate curriculum for elementary teachers, it is imperative to decipher whether the impact of these courses is indeed an increased content knowledge that is needed to teach elementary school mathematics. Since the University of Nebraska at Omaha had just implemented such additional coursework for pre-service elementary teachers, it seemed like the appropriate time to investigate such impact. The study procedures for this investigation are now described.

## Methodology and Data Description

*Subjects.* Over a two-year period, data was collected on students enrolled in mathematics methods for elementary teachers course or engaged in student teaching. Students were considered as being in one of two groups, depending upon their enrollment in at least one of two new mathematics content courses for elementary teachers. Students who had never taken, nor were currently enrolled in, a mathematics content course designed for elementary teachers were considered part of the control group (n = 19). Students who had taken at least one of the courses, or were currently enrolled in one of the mathematics courses for elementary teachers were considered members of the experimental group (n = 39). The first content course was designed to enhance the teacher's mathematical knowledge of numbers, place value, fractions, and number sense. The second course included topics in geometry. Both mathematics courses focused on instruction that would increase the future teachers' ability to fully explain mathematics and to develop a thorough understanding of these topics. The content courses also modeled some pedagogical strategies (such as the use of manipulatives) that might also be used in their later instruction of elementary students.

Demographics-related information was gathered on the prospective teachers using the following descriptive variables: ACT Math subscore, ACT composite score, high school grade point average, age, ethnicity, gender, and university grade point average. These variables were selected to ascertain whether the subjects' demographics were relatively similar between groups. A t-test was performed on each variable, comparing the control and experimental groups. The null hypothesis, that no difference existed on the mean scores of the groups on the demographic variables, was confirmed in every case. The two groups were statistically the same on all variables. The summary of the descriptive variables is given in the table below. The coded values for the variables are as follows: ACT Math subscore and ACT composite range 0 – 36, high school and university grade point average have a range of 0 – 4, ethnicity was coded as 1 = Caucasian, 2 = other, gender was indicated as 0 = male and 1 = female. Both groups consisted of primarily Caucasian females in their early twenties.

**Table 1. Descriptive variables**

| Variable | Grouping | N | Mean | St. Dev. | Significance (2-tail) t-test |
|---|---|---|---|---|---|
| ACT Math | Control | 18 | 21.889 | 4.588 | $p < 0.926$ |
| | Experimental | 39 | 21.769 | 4.338 | |
| ACT | Control | 18 | 22.056 | 3.686 | $p < 0.941$ |
| | Experimental | 39 | 22.128 | 3.302 | |
| HS GPA | Control | 17 | 3.354 | 0.643 | $p < 0.601$ |
| | Experimental | 33 | 3.436 | 0.445 | |
| Age | Control | 23 | 26.391 | 8.923 | $p < 0.116$ |
| | Experimental | 52 | 23.962 | 4.356 | |
| Ethnicity | Control | 23 | 1.174 | 0.650 | $p < 0.717$ |
| | Experimental | 52 | 1.250 | 0.905 | |
| Gender | Control | 23 | 0.960 | 0.200 | $p < 0.287$ |
| | Experimental | 52 | 0.885 | 0.323 | |
| Univ GPA | Control | 23 | 3.383 | 0.394 | $p < 0.275$ |
| | Experimental | 52 | 3.474 | 0.299 | |

*Instruments.* Near the end of an academic semester, study participants took two exams designed to specifically measure the mathematical content needed for teaching (as drawn from Hill, Schilling, & Ball, 2004), known as the Content Knowledge for Teaching Mathematics (CKT-M). This assessment process consisted of two instruments: 1) Elementary Number Concepts and Operations – Content Knowledge and 2) Elementary Geometry – Content Knowledge. Both of these instruments were drawn from the 2004 versions. These assessment tools were developed by the Learning Mathematics for Teaching (LMT) Project at the University of Michigan and were designed to assess teachers' mathematical knowledge needed for teaching (Hill, Schilling, & Ball, 2004). Content validity for the CKT-M was established by multiple interviews and input from mathematicians and elementary mathematic educators (Hill et al., 2004).

The attitude towards mathematics was measured by administration of the Aiken's Revised Mathematics Attitude Scale (1974). This 20-item 5-choice Likert-scaled instrument was designed to measure enjoyment of mathematics and the value of mathematics and has been shown to have high internal-consistent reliability. The instrument had reliability and validity measures established using a population of young women. Given the make-up of the subjects of this study, that increased the appropriateness of this instrument. The scores on the instrument range from -40 to 40, with more negative values associated with negative attitudes towards mathematics and positive values associated with positive attitudes.

*Analysis.* To assess whether enrollment in the mathematical content courses made a significant difference on the pre-service teachers' scores on the content assessments for teaching mathematics, independent samples t-tests were performed on the results of the Content Knowledge for Teaching Math instruments. The subjects' raw scores were converted to z-scores using item response theory (IRT) models, which use a common person and common item equations conversion table (Hill et al, 2004). The converted IRT scores were used for the independent samples t-test. The raw scores or percentage correct are not reported due to the nonlinearity of the measure. The range of scores possible using the IRT is from -3.0 to 5.0, with higher scores indicating teachers with more mathematical knowledge for teaching. As Gleason (2009) has recently reported, when using the LMT measures with pre-service teachers, the individual instruments scores are possibly not reliable enough for the results to be considered valid. However, as a combined measure, the LMT measures are reliable enough to be a decent measure of mathematical content knowledge of preservice teachers. Thus, we will report the overall score and interpret individual instruments' results with caution.

*Results.* The results of the independent samples t-test on the group statistics are presented in Table 2. The overall mean IRT of the combined number operations and geometry scores was -0.609 for the control group and 0.1789 for the experimental group. The t-value for the comparison of these scores is -2.56, with a corresponding p-value of 0.013. Thus, the control group performed significantly better, at the .05 level, than the experimental group when considering the overall score of both instruments. The effect size for this finding is 0.28, suggesting a small moderate effect (Sprinthall, 2000).

**Table 2: Comparison of Mathematical Content Knowledge for Teaching**

| | N | Mean IRT | SD | t | Significance (p-value) |
|---|---|---|---|---|---|
| Number Concepts & Operations | | | | | |
| Experimental | 39 | -0.374 | 0.732 | -1.90 | .062 |
| Control | 19 | -0.778 | 0.806 | | |
| Geometry Concepts | | | | | |
| Experimental | 39 | 0.060 | 0.607 | -2.93 | .005** |
| Control | 19 | -0.433 | 0.588 | | |
| Combined | | | | | |
| Experimental | 19 | -0.609 | 0.596 | -2.56 | .013* |
| Control | 39 | -0.178 | 0.606 | | |

* represents significance at $p < .05$
** represents significance at $p <.01$

The mean IRT score on the number concepts instrument for the control group was - .778 and - .374 for the experimental group. The t-value for this comparison was - 1.90, with a corresponding p value of .062. The mean IRT scores on the geometry instrument for the control group was - .433 and .060 for the experimental group. The t-value for this comparison was -2.930, with a corresponding p value of .005. This result seems to indicate that on the instrument measuring geometry concepts, those in the experimental group performed significantly better. However, as Gleason reported, the LMT instrument is possibly not reliable enough to trust any individual instruments' score when using the instruments with pre-service teachers.

An examination of the instrument and results revealed that questions could be categorized into subgroups of (a) properties of polygons, (b) hierarchical relationships among polygons, (c) area problems, spatial visualization, (d) place value, (e) fraction multiplication and division, (f) ordering of rational numbers, and (g) understanding nonstandard algorithms. Among the control and experimental groups, members of the experimental group answered more questions correctly on the problems that involved hierarchy of polygonal shapes, ordering of rational numbers and fraction multiplication. In fact, if questions from these three areas were removed from the analysis, no difference would have existed between the two groups. These more detailed results should not be considered significant. Rather these results should be considered merely suggestive and worthy of further exploration.

Regarding attitude toward mathematics, the results indicated no significant difference on the responses of the experimental and control groups. Given the range of scores from -40 to 40, the reported scores of 3.111 for the experimental group and 0.804 for the control group indicate overall rather neutral attitudes toward mathematics among both groups. The results of this analysis are summarized in Table 3.

**Table 3. Comparison of Attitudes toward Mathematics**

| Group | N | Mean | SD | t | Significance |
|---|---|---|---|---|---|
| Experimental | 19 | 3.111 | 21.4775 | 0.378 | 0.707 |
| Control | 39 | 0.804 | 22.1586 | | |

## Discussion

The results from our study appear to indicate that content courses are indeed an effective way of enhancing the mathematical knowledge that elementary teachers might require for their own classroom instruction of mathematics, as measured by the LMT instruments. These results would seem to indicate that teacher preparation programs without such courses should seriously consider adding some specialized mathematics content courses, consistent with the CBMS guidelines, to their elementary teacher preparation programs.

The study participants performed significantly better than the control group on the CKT-M and specifically on the instrument that contained questions from geometry topics. In the area of number concepts and operations, two of the authors have taught these courses and spent countless hours examining and modifying their presentations and expectations to specifically address certain topics like fraction division. To find no real difference in understanding this topic between elementary pre-service teachers who took the specialized mathematics content courses and those pre-service elementary teachers who took a class like college algebra is relatively disappointing and provides our institutional team with an important future goal. Further research needs to be done on developing instruments to measure individual class impact as effectively as possible for specific mathematical concepts so that we can undertake instructional strategies that are as targeted and as successful as possible.

Some limitations in our study should be mentioned as we conclude our discussion on content knowledge. First, it should be noted that the LMT measures are limited in the scope of material that is covered. Several topics, like dividing fractions, have multiple questions associated with the topic, while other vital concepts to elementary mathematics are missing. The reliability of the LMT instruments, while established for in-service teachers, may warrant more study for use with pre-service teachers.

Many studies have considered the mathematics attitudes of teachers and some studies have indicated negative attitude were possessed by elementary teachers, specifically. However, among this sample, the attitudes evidenced by all participants, were overall neutral. There was no significant difference between the measures of attitudes toward mathematics; therefore enrollment in the mathematics for elementary teachers course did not impact the prospective teachers' attitudes toward mathematics.

There is little doubt that the preparation of elementary teachers in mathematics is an increasingly critical topic for teacher preparations programs. As these new courses have been developed and taught, there has been concern about the very limited mathematics background that some elementary teachers bring into these courses. A significant amount of instructional work is required to support these students in their learning of the material in these content courses. However, our data would suggest that these courses, and our ongoing efforts, can indeed make a difference. We believe that such content courses can help new teachers, to become more solid in their mathematical backgrounds, and to thus become more prepared to teach and represent the increasingly important discipline of mathematics to their students.

**References**

Adams, T. L. (1998). Prospective elementary teachers' mathematics subject matter knowledge: The real number system. Action in Teacher Education, 20(2), 35-48.

Ball, D. T. (1990.) Breaking with experience in learning to teach mathematics: The role of a pre-service method course. International Journal of Mathematics Education, 10(2), 10-16.

Aiken, L.R. (1974). Two scale of attitude toward mathematics. Journal for Research in Mathematics Education, 5, 67-71.

Ball, D. L. (1990). The mathematical understandings that prospective teachers bring to teacher education. Elementary School Journal, 90, 449-466.

Bandalos, D. L., Yates, K., & Thorndike-Christ, T. (1995). Effects of math self-concept, perceived self-efficacy, and attributions for failure and success on test anxiety. Journal of Educational Psychology, 87(4), 611-623.

Begle, E. G. (1979). Critical variables in mathematics education: Findings from a survey of the empirical literature. Washington, D.C.: Mathematical Association of America & National Council of Teachers of Mathematics.

Becker, J.R. (1986). Mathematics attitudes of elementary education majors. Arithmetic Teacher, 33(5), 50-51.

Beswick, K. (2006). Changes in pre-service teachers' attitudes and beliefs: The net impact of two mathematics education units and intervening experiences. School Science and Mathematics, 106(1), 36-47.

Beswick, K. & Dole, S. (2001). Dispelling the myths: Influencing the beliefs of pre-service primary teachers. In J. Bobbis, B. Perry, & M. Mitchelmore (Eds.), Proceedings of the 24th annual conference of the Mathematics Education Research Group of Australia: Numeracy and beyond (pp. 90-97). Sydney, NSW: Mathematics Education Research Group of Australia.

Brady, P., & Bowd, A. (2005). Mathematics anxiety, prior experience and confidence to teach mathematics among pre-service education students. Teachers and Teaching: Theory and Practice, 11(1), 37-46.

Burton, M., Daane, C.J., Giesen, J., (2008). Infusing mathematics content into a methods course: Impacting content knowledge for teaching. Issues in the Undergraduate

Mathematics Preparation of School Teachers, 1. Retrieved October 15th, 2008 from http://www.k-12prep.math.ttu.edu/.

Coppola, R., Malyn-Smith, J. (2006). Preparing for the Perfect Storm—A Report on the Forum Taking Action Together: Developing a National Action Plan to Address the "T&E" of STEM. Reston, VA: International Technology Education Association.

Conference Board of the Mathematical Sciences. (2001). The mathematical education of teachers, part I. Retrieved September 8th, 2007, from www.cbmsweb.org/MET_Document/index.htm.

Gleason, J. (2009). Structure and reliability of the CKT-M instruments for pre-service teachers. Manuscript submitted for publication.

Gleason, J. (2008). Relationships between pre-service elementary teachers' mathematics anxiety and content knowledge for teaching. Journal of Mathematical Sciences and Mathematics Education, 3(1): 39-47.

Goulding, M., Rowland, T., & Barber, P. (2002). Does it matter? Primary teacher trainees' subject knowledge in mathematics. British Educational Research Journal, 28(5), 689-704.

Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety. Journal for Research in Mathematics Education, 21, 33-46.

Hill, H.C., Rowan, B., & Ball, D.L. (2005). Effects of teachers’ mathematical knowledge for teaching on students’ achievement. American Educational Research Journal, 42(2), 371-406.

Hill, H.C., Schilling, S.G., & Ball, D.L. (2004) Developing measures of teachers’ mathematics knowledge for teaching. Elementary School Journal, 105, 11-30.

Kelly, W.P., & Tomhave, W.K. (1985). A study of math anxiety/math avoidance in pre-service elementary teachers. Arithmetic Teacher, 32(5), 51-53.

Kilpatrick, J., Swafford, J., & Findell, B. (2001). Adding it up: Helping children learn mathematics. Washington, DC: National Academy Press.

Kolstad, R.K. & Hughes, S. (1994). Teacher attitudes toward mathematics. Journal of Instructional Psychology, 21(1), 44-48.

Leapard, B. B. (2000). Affective, metacognitive, and conceptual effects of an emerging scholars program on elementary teacher preparation: An application of the Treisman workshop model. Dissertation Abstracts International, 61(10), 3958. (UMI No. AAT 9990658)

Leonard, J., & Joergensen, P. (2002). Empowering all elementary preservice teachers to teach children mathematics. Annual Conference of the Holmes Partnership. (ERIC Document Reproduction Service No. ED469957).

Matthews, M. & Seaman, W. (2007). The Effects of Different Undergraduate Mathematics Courses on the Content Knowledge and Attitude towards Mathematics of Pre-service Elementary Teachers. Issues in Undergraduate Mathematics Preparation of School Teachers: The Journal, 1. Retrieved October 15th, 2008 from http://www.k-12prep.math.ttu.edu/.

McGinnis, J.R., Kramer, S., Shama, G., Graeber, A.O., Parker, C.A., & Watanabe, T. (2002). Undergraduates' attitudes and beliefs about subject matter and pedagogy measured periodically in a reform-based mathematics and science teacher preparation program. Journal of Research in Science Teaching, 39, 713-737.

National Council on Teacher Quality. (2008). No common denominator: The preparation of elementary teachers in mathematics in America's education schools. Retrieved Aug, 1st, 2008 from http://www.nctq.org/p/publications/reports.jsp

National Science Foundation. (1996). Shaping the future: New expectations for undergraduate education in science, mathematics, engineering, and technology. Washington, D.C., 1996.

Pickreign, J. (2007). Rectangles and Rhombi: How Well Do Pre-service Teachers Know Them? Issues in the Undergraduate Mathematics Preparation of School Teachers, 1 Retrieved May 12th, 2008 from http://www.k-12prep.math.ttu.edu/.

Quinn, J., R. (1997). Effects of mathematics methods courses on the mathematical attitudes and content knowledge of pre-service teachers. The Journal of Educational Research, 91(2), 108-113.

Randhawa, B. S., Beamer, J. E., & Lundberg, I. (1993). Role of maths self-efficacy in the structural model of maths achievement. Journal of Educational Psychology, 85(1), 41-48.

Rowan, B., Chiang, F.-S., & Miller, R. J. (1997). Using research on employees' performance to study the effects of teachers on students' achievement. Sociology of Education, 70(4), 256-284.

Rowland T.S. , Martyn S., Barber P., and Heal, C. (2000). Primary teachers trainees' mathematics subject knowledge and classroom performance. Research in Mathematics Education, 2, 3-18.

Shulman, L.S. (1986). Those who understand: Knowledge growth in teaching. Educational Researcher, 15(2), 4-14.

Sovchik, R.J. (1996). Teaching mathematics to children. New York: Harper Collins.

Sprinthall, R. C. (2000). Basic statistical analysis (6th ed.). Boston: Allyn & Bacon.

Stacey, H., Steinle, B., & Irwin, B. (2001). Preservice teachers' knowledge of difficulties in decimal numeration. Journal of Mathematics Teacher Education, 4(3), 205-225.

Stoddart, T., Connell, M., Stofflett, R., & Peck, D. (1993). Reconstructing elementary teacher candidates' understanding of mathematics and science content. Teaching and Teacher Education, 9(3), 229-241.

Tsao, Y. (2005). The number sense of pre-service elementary school teachers. College Student Journal, 39(4), 647-679.

Van Dooren, W., Verschaffel, L., & Onghena, P. (2002). The impact of preservice teachers' content knowledge on their evaluation of students' strategies for solving arithmetic and algebra word problems. Journal for Research in Mathematics Education, 33(5), 319-351.

Wood, E.F. (1988). Math anxiety and elementary teachers: What does research tell us? For the Learning of Mathematics, 8(1), 8-13.