Impact of Mathematics Content Courses on Elementary Preservice Teachers' Confidence in Teaching Mathematics

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Abstract

There is a general consensus that mathematical content knowledge (M-CK) is crucial for enabling elementary school teachers to effectively teach mathematics. However, it has been suggested that M-CK is not sufficient for elementary school teachers – it must be accompanied by math pedagogical content knowledge (M-PCK). In order to better identify coursework that may promote M-CK and M-PCK, this study investigates confidence of M-CK and M-PCK of elementary preservice teachers (PSTs) who have participated in math content coursework designed for elementary teachers. Findings from preliminary work in a larger study suggest that PSTs who take one or more of these content courses, along with a mathematics methods course, have greater confidence related to M-CK and M-PCK than PSTs who take only traditional mathematics courses along with a mathematics methods course. The research is ongoing.

Current research suggests the importance of mathematical content knowledge to enable elementary school teachers to teach mathematics effectively (Ball, 2003; Ball, Lubienski, & Mewborn, 2001; Fennema & Franke, 1992; NCTM, 2003). However, there is not a consensus on how best to prepare elementary preservice teachers (PSTs) in order to achieve mathematical content knowledge (M-CK) that translates to effective mathematical pedagogical content knowledge (M-PCK) and, in turn, student learning (Kirtman, 2008). For example, Ball (2003) notes that "increasing the quantity of teachers' mathematics coursework will only improve the quality of mathematics teaching if teachers learn mathematics in ways that make a difference for the skill with which they are able to do their work. The goal is not to produce teachers who know more mathematics. The goal is to improve students' learning" (p. 1). In other words, more content area mathematics courses, while they may support increased M-CK, may not translate to M-PCK.

Investigating confidence of M-CK and M-PCK of PSTs related to specific course experiences during a teacher preparation program may allow researchers and teacher educators to better identify course experiences that may enhance M-CK and M-PCK of PSTs. This research investigated influences of mathematics coursework that has been *designed specifically with elementary PSTs in mind*—mathematics content courses taught in the Math Department, but with M-PCK as an emphasis. Confidence with respect to M-CK and M-PCK was investigated – comparing PSTs who participated in the specific math content courses with those who did not participate.

Perspectives

Research connected to self-efficacy (Bandura, 1986) and teacher efficacy (Henson, 2001; Tschannen-Moran, Woolfolk Hoy, & Hoy, 1998) provides a framework for this study. Self-efficacy can be described as belief that one is capable of accomplishing certain tasks or goals (Bandura, 1986). Teacher efficacy relates to the teacher's belief in his/her capability to accomplish particular teaching-related tasks or goals (Tschannen-Moran et al., 1998). Teacher efficacy has been found to influence teachers' persistence and willingness to try new ideas; additionally, it has been linked to student outcomes such as achievement (Henson, 2001; Tschannen-Moran et al., 1998). Experts in instrument development, such as Gable and Wolf (1993), provide examples showing that self efficacy can be measured by rating confidence of specific beliefs about behaviors. This suggests that an instrument that measures confidence levels with respect to M-CK and M-PCK should provide indicators of self-efficacy with respect to these constructs. Indeed, NCTM (2003) noted, "Candidates' comfort with, and confidence in, their knowledge of mathematics affects both what they teach and how they teach it" (p. 4). Thus, assessing changes in PSTs' confidence toward M-CK and M-PCK may provide indicators of

self-efficacy that may impact future mathematics teaching practices.

In order to measure confidence with respect to M-CK and M-PCK, we investigated instruments that have been used extensively and found to be trustworthy. The Fennema-Sherman Mathematics Attitude Scale (FSMAS) has been used for more than 20 years to investigate attitudes towards mathematics (Mulhern & Rae, 1998), providing a solid base from which to build an instrument to measure PSTs' confidence related to M-CK and M-PCK.

In addition to confidence, it is important to consider other indicators of M-CK and M-PCK. For example, Deborah Ball noted in remarks to the Secretary's Summit on Mathematics (2003) that teaching mathematics effectively in elementary schools requires that "teachers must know the same things that we would want any educated member of society to know, but *much more*" (p. 7). The "much more" (M-PCK) entails being able to ask and answer *why* about mathematical problems; fluency with and ability to strategically use representations; ability to inspect and make sense of and use students' mathematical methods; capacity to support mathematical language, and *much more*. Therefore, in addition to confidence items, we designed open-ended problems for the PSTs to complete that related to their own M-CK (solving and explaining mathematical problems) and their M-PCK (examining and commenting on non-routine student work). These provide additional data related to PSTs' M-CK and M-PCK that are aligned with ideas described by Ball (2003).

In Ball's remarks to the Secretary's Summit, she noted that few mathematics courses offer opportunities that would produce knowledge that is appropriate for elementary school teachers. Further, she urged that "ongoing research in this area is crucial" (p. 9). With these important issues in mind, we asked: Does elementary preservice teachers' confidence in M-CK and M-PCK change before and after completing the math methods course? If so, do the math content

courses influence this change? In particular, in this article we explore the following research questions:

1. How does the change in confidence towards mathematical content knowledge (M-CK) before and after completion of a mathematics methods course compare between students who take math content courses designed for elementary school teachers and those who do not take these courses?
2. How does the change in confidence towards math pedagogical content knowledge (M-PCK) before and after completion of a mathematics methods course compare between students who take math content courses designed for elementary school teachers and those who do not take these courses?

An earlier paper (Truxaw, Cardetti & Bushey, 2010) reported on the collaborative process across the disciplines of mathematics and mathematics education that initiated these questions. This article builds from that work, focusing on the research questions themselves rather than the collaborative process.

Methods

Data for this paper are drawn from a larger research study that uses mixed methods (Creswell, 1998; Johnson, & Onwuegbuzie, 2004) to investigate influences of math content courses geared toward elementary PSTs. In order to examine confidence related to M-CK and M-PCK, a survey was administered that includes Likert items adapted from the *Fennema-Sherman Mathematics Attitude Scale* (Mulhern & Rae, 1998), along with open-ended content problems designed to uncover both M-CK and M-PCK. Additionally, the larger study includes interviews with a subset of the PSTs to provide supporting data related to the influence of the content courses.

Context

Participants are elementary PSTs enrolled in the teacher preparation program (TPP) at a large public research university in the northeastern United States. For the larger study, participants include elementary education PSTs in their junior and senior years in the TPP. These students are predominantly female (90-95%), white (80-90%), and typical ages range from 20 to 25 years old. For this paper, we focus on participants during the fall of their senior year, prior to and after completion of the required math methods course.

At our institution, all elementary education PSTs are required to take a mathematics methods course within the School of Education, along with at least three "quantitative" content courses (e.g., mathematic or statistics) outside the School of Education. The Department of Mathematics offers two content courses (recommended but not required by the TPP) for elementary PSTs. The courses have been created to develop an advanced perspective on and profound understanding of concepts, structures, and algorithms constituting the core of K-8 math curriculum. The topics of the course are chosen to support and extend the expectations set forth by the Mathematical Standards, K-8 (NCTM, 2000). The class meetings are structured to provide students with the experience of developing their own mathematical ideas. The instructor acts as a facilitator providing guidance to lead students toward understanding of concepts behind familiar concepts as well as new ones. Special attention is given to exploring and communicating the ideas and reasons behind the mathematical manipulations. Participants who completed either of these courses, along with the math methods course, are referred to here as the C-group (content). The participants who completed the math methods course, but did not complete either of the content courses recommended for elementary PSTs are referred to here as the NC-group (non-content).

Data Collection and Analysis

Data collection included pre- and post-surveys administered to the elementary PSTs in the math methods courses in fall 2009. Surveys included demographic items; Likert-type items to measure confidence in M-CK and M-PCK; and open-ended response items to gauge PSTs' facility to accurately complete and explain content problems, as well as to interpret and explain student work samples. Overall, 23 PSTs (11 C, 12 NC) completed the pre-survey, 32 PSTs completed the post-survey (16 C, 16 NC), and 19 PSTs (9 C, 10 NC) completed both pre- and post-surveys. Analysis focuses on the 19 participants who completed both pre- and post-surveys. It is important to note that the pre and post designations relate to the *methods course*, not the content course. Related to the research questions, we wondered if the C-group would begin the methods course with different levels of confidence in M-CK and/or M-PCK than the NC-group; *and* we wondered if the C-group would demonstrate different levels of *change in confidence* in M-CK and/or M-PCK than the NC-group (from pre to post methods course). In other words, we were interested in the impact of the specific content courses on confidence relative to the methods course.

For this paper we focus on the Likert-scale scores (1=Strongly Disagree; 5=Strongly Agree). The Likert-scale items were organized according to confidence in mathematical content (M-CK, items 1-4) and confidence in teaching mathematics (M-PCK, items, 5-8), as follows:

1. Generally, I feel secure about attempting mathematics.
2. I have a lot of self-confidence when it comes to math.
3. Mathematics is enjoyable and stimulating to me.
4. I would rather figure out a math problem myself than to have someone give me the solution.

5. Generally, I feel secure about teaching elementary school mathematics.
6. I have a lot of self-confidence when it comes to teaching elementary school mathematics.
7. Teaching elementary school mathematics is enjoyable and stimulating to me.
8. I would rather if my elementary school student could figure out a math problem rather than having me give them the solution.

Although items 4 and 8 relate to M-CK and M-PCK respectively, they deal less with overall confidence and more with a stance toward problem solving. Therefore, when items were aggregated for certain analyses, items 1-3 and items 5-7 were grouped and items 4 and 8 were considered independently.

A preliminary analysis focusing *only* on the change in mean differences of the Likert-scale scores was presented in Truxaw, Cardetti & Bushey (2010). In this study, we analyze the results of paired *t* tests (significant at the .05 level) using SPSS software (Green, Salkind, & Akey, 2000) comparing these mean differences (pre-score minus post-score – a negative difference indicating positive change). Due to the small sample size, we report a 95% confidence interval (CI) of the paired *t* test analysis rather than the *p*-values. If zero did not fall within the range of a 95% CI, it indicated 95% confidence that the difference between the pre- and post-survey means was not zero and, therefore, the mean difference was significant (Shavelson, 1996).

As the larger study progresses, results are being triangulated through analysis of the open-ended content problems and interviews. The open-ended content problems are being scored using rubrics that have been developed, refined, and tested for inter-rater reliability (90% or higher). The interview data is being coded and analyzed thematically (e.g., Creswell, 1998; Strauss & Corbin, 1990). This paper reports on findings from the Likert-items, along with some preliminary findings from the open-ended items.

Results and Discussion

In this section we present results of analysis used to answer the research questions (RQs) along with related explanations and discussion. We present descriptive statistics, mean differences, and the 95% CI for a mean difference for the corresponding Likert item scores, along with explanations and discussion of these results. Our analysis and discussion focus on the statistical significance of each individual item, as well as on the aggregated data for groups of items corresponding to different constructs.

RQ 1: Comparison of elementary PSTs' Confidence in Mathematical Content Knowledge

To answer the first RQ, data from pre- and post-scores of the Likert items related to M-CK (items 1-4) were analyzed. Table 1 summarizes the changes in pre- and post-scores for each of the M-CK-related items for the C- and NC-groups.

Table 1

Confidence Toward Math Content

	Pre		Post		*Mean Difference pre-post*	*95% CI Mean Difference*
	Mean	*SD*	*Mean*	*SD*		
Content Group, *n = 9*						
Item 1	4.44	.53	4.33	.50	.11	(-1.00, .20)
Item 2	4.44	.73	4.00	.50	**.44**	**(.04, .85)****
Item 3	4.33	1.00	4.22	.44	.11	(-.60, .824)
Item 4	4.22	.67	4.44	.53	-.22	(-.86, .42)
Non-Content Group, *n=10*						
Item 1	3.40	.97	3.80	.63	-.40	(-1.00, .20)
Item 2	3.10	.87	3.40	.84	-.30	(-.78, .18)
Item 3	3.20	.79	3.50	.71	-.30	(-.65, .05)
Item 4	4.00	.47	4.00	.47	.00	

**Significant at the 95% CI level

Before making pre and post comparisons, it should be noted that mean scores for *every item*

related to M-CK, both pre and post, were higher for the C-group than for the NC-group. In terms of pre and post comparisons, for the C-group, only one item (item 2 - *I have a lot of self-confidence when it comes to math*) showed significant change at the 95% level from pre-to post-survey (*95% CI*, (.04, .85)). A large effect size of .72 was found for this item when comparing pre- and post-survey scores. Interestingly, the change was a *negative* one – that is, the C-group reported significantly *less confidence* for this item than prior to participating in the methods course. Although not significant, mean scores for items 1 and 3 decreased from pre to post; for item 4, mean scores increased from pre to post. For the NC-group, although no single item showed significant changes, the mean scores showed *increases* in reported confidence for three out of the four content-related items (items 1-3) and *no change* for item 4.

There were interesting, although not statistically significant, observations of the data related to item 4 (*I would rather figure out a math problem myself than to have someone give me the solution*). While the mean scores for the C-group on item 4 increased (pre, M=4.22; post, M=4.44), these were not significantly different at the 95% CI level. For the NC group there were no changes for this item in means or standard deviations (pre and post, M=4.00, SD=0.471). However, these results show that both groups reported consistently high expectations for allowing themselves to struggle when working through mathematical problems, with the C-group reporting slightly higher levels and slight increase from pre- to post. These results will be discussed further in comparison to a similar item (item 8) related to M-PCK.

Additionally, to further understand changes in pre- and post-scores for each group related to this RQ, three Likert items constituting a single construct, confidence toward M-CK, were identified (items 1-3). The aggregate scores' mean differences and CIs were analyzed for the two groups separately. The analysis yielded no significant change at the 95% level for the C-group

(Mean difference, .22; *95% CI*, (-.12, .56)). However, a significant (positive) change was noted for the NC-group (Mean difference, -.33; *95% CI*, (-.65, -.02)). A medium effect size of .48 was found for this construct when comparing pre- and post-survey scores. These results suggest that the NC-group of PSTs showed significant growth in confidence toward M-CK after completing the math methods course. One may conjecture that NC-group's lack of exposure to the M-CK courses may have impacted their need to focus on the mathematical content while in the methods course.

RQ 2: Comparison of elementary PSTs' Confidence in Mathematical Teaching

To address the second research question, data from the pre- and post-scores of the Likert items related to M-PCK (items 5-8) were analyzed. Table 2 summarizes the changes in pre- and post-scores for each of the M-PCK related items for the C- and NC-groups.

Table 2

Confidence Toward Teaching Math

	Pre		Post		*Mean Difference pre-post*	*95% CI Mean Difference*
	Mean	*SD*	*Mean*	*SD*		
Content Group, *n=9*						
Item 5	3.33	.50	3.78	.67	**-.45**	**(-.85, -.04)****
Item 6	3.22	.67	3.78	.67	**-.56**	**(-.96, -.15)****
Item 7	3.67	.87	4.00	.71	-.33	(-.72, .42)
Item 8	4.89	.33	4.89	.33	.00	
Non-Content Group, *n=10*						
Item 5	3.70	.48	3.20	.79	.50	(-.11, 1.11)
Item 6	3.10	.57	2.80	.79	.30	(-.46, 1.06)
Item 7	3.30	.48	3.10	.74	.20	(-.46, .86)
Item 8	4.50	.53	4.50	.71	.00	(-.48, .48)

**Significant at the 95% CI level

Before reporting results of the CI analysis, it is worth noting general trends related to

confidence toward teaching mathematics. Although the results were less definitive than for M-CK, the mean scores related to M-PCK suggest greater confidence by the C-group than the NC-group. For example, prior to taking the math methods course, the C-group reported greater confidence than the NC-group on three of the four items (items 6, 7 & 8). After completing the math methods course, the C-group reported greater confidence than the NC-group *on every item* related to M-PCK.

For the C-group, the analyses of the CIs for mean differences showed significant increases at the 95% level from pre- to post-survey for items 5 (*95% CI*, -.85, -.04) and 6 (*95% CI*, (-.96, -.15)). Large effect sizes of 0.88 and 0.84, respectively, were found when comparing pre- and post-survey scores for these items. For item 7, the C-group showed an increase in mean scores, but the change was not significant at the 95% level; for item 8, there was no change in mean scores or standard deviations (pre and post, M=4.89, SD=0.333). For the NC-group, although there were decreased mean scores on three of the four items (items 5, 6 & 7), none of the changes were significant. For item 8, the NC-group showed no change from pre- to post-survey in the mean scores (pre, M=4.50, SD=.527; post, M=4.50, SD=.707). These results show that both groups reported consistently high expectations for allowing their students to struggle when working through mathematical problems, with the C-group reporting slightly higher levels.

Additionally, to further understand changes in pre- and post-survey scores for each group related to M-PCK, three Likert items constituting a single construct: confidence toward M-PCK were identified (items 5-7). The confidence intervals for aggregate means differences on pre- and post-scores for this construct were analyzed for the two groups separately. The analysis yielded a *positive* significant change at the 95% level for the C-group (*Mean difference*, -.44; *95% CI*, (-.76, -.13)). A moderately large effect size of .68 was found for this construct when comparing

pre- and post-survey scores. However, no significant change was noted at the 95% level for the NC-group (*Mean difference*, .33; *95% CI*, (-.24, .91)). These results suggest that the C-group of PSTs showed significant growth in confidence toward M-PCK after completing the math methods course. One may conjecture that the C-group of PSTs' prior exposure to M-CK courses may have provided them content knowledge that allowed them to focus on the pedagogical content while in the methods courses, thus increasing their confidence with teaching mathematics while participating in the math methods course.

There were interesting observations of the data related to item 8 (*I would rather if my elementary school student could figure out a math problem rather than having me give them the solution*). This question was designed to parallel item 4 in the M-CK section (related to a similar stance toward their own problem-solving). As noted, neither group of PSTs reported changes related to item 8. Recall that for the NC-group there were no changes in mean scores for item 4 either – that is, the NC-group reported no change in stance toward problem-solving for themselves or for their students. For the C-group, there was a slight increase in expectations related to their own problem solving, but no increase in expectations toward preferences for their students' problem solving. It should be noted that both groups reported high expectations for both themselves and their students related to persistence with problem solving. Even so, it is interesting to observe that, for both C- and NC-groups, the mean scores for item 4 (expectations for self) were *lower* than the mean scores for item 8 (expectations for students) – suggesting that the PSTs may have different mathematical expectations for themselves than for their students.

Preliminary Findings from Open-Ended Content Items

Results from open-ended content items are being used to corroborate findings from the survey related to PSTs' M-CK and M-PCK. Analysis of these items is in progress. They are being scored using rubrics that have been developed, refined, and tested for inter-rater reliability (90% or higher). Preliminary results from analysis of a subset of the larger data set suggest that the C-group, as compared to the NC-group, of PSTs demonstrates stronger content knowledge for doing math, interpreting student work, attempting explanations, and providing reasonably accurate/appropriate explanations. This ongoing analysis will further support this research.

Limitations

One limitation of this study is its small sample size. However, the results demonstrate significant means difference at the 95% confidence level. This suggests that if hypothesis testing were performed that the results would likely reach statistical significance. We expect to confirm this statement as we continue to collect and analyze data over time. Another limitation may lie in the particular TPP where these data are collected. More research studies, both incorporating more participants and within other TPPs, could provide further evidence of the extent to which the findings reported here are representative of the experiences of other PSTs in other TPPs. Finally, this research investigates *confidence* rather than knowledge or observed teaching practices; while confidence provides a window into potential knowledge and practice, we recognize that there are limitations in using this approach. Future research investigating a link between confidence and performance will continue to grow the body of literature on preservice elementary preservice teachers' mathematics and pedagogical content knowledge.

Final Remarks

This study sought to uncover influences that mathematics content courses designed for

elementary PSTs may have on the PSTs' confidence toward M-CK and M-PCK. The findings indicate that the C-group showed greater gains than the NC-group in confidence towards M-PCK after taking the required math methods course. Interestingly, students in the NC-group reported greater gains than the C-group in confidence towards M-CK. These results suggest that PSTs going into the methods courses with greater M-CK may potentially increase their confidence in M-PCK, and that this increase could be to a greater extent than those with less M-CK experience. The NC-group's gains in M-CK and relative lack of gain in M-PCK from pre- to post-methods course may suggest that their attention was focused more on the mathematics content than the teaching methods or student learning.

An interesting additional result was that while both C- and NC-groups reported high expectations for allowing their students to struggle when working through mathematical problems, the expectations they reported for themselves, although also relatively high, were lower than for their students. In essence, they reported lower tolerance for personal persistence with problem solving for themselves than for their students.

Based on these preliminary findings, we are continuing to analyze the data and to expand the study to include: further analysis of open-ended items, administration of surveys to additional PSTs, and interviewing of selected PSTs. The analysis of the interviews will allow us to better interpret survey responses and to dig deeper into their thinking and perceptions related to M-CK and M-PCK.

Our findings corroborate others (e.g., Ball, 2003; Ball, Lubienski, & Mewborn, 2001; NCTM, 2003) who have noted the importance of both M-CK *and* M-PCK for elementary school teachers. Our results suggest that one means of supporting elementary PSTs as they work to become effective mathematics teachers is participation in mathematics content courses that are

designed specifically with elementary school teachers in mind. Indeed, these mathematical *content* courses may enhance learning outcomes of mathematics *methods* courses by providing sufficient M-CK to allow the PSTs to focus their attention, during *methods* courses, on the teaching methods and student learning related to the mathematics. Without these courses, the PSTs' attention toward student learning and mathematical teaching methods may be diluted while they are focusing on their own mathematical content knowledge. It will be important for future investigations to continue to investigate the influences of such courses on M-CK and M-PCK.

Endnotes

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