Fall 10-20-2010

Expertise3: Outcomes of Instructor Collaboration on Elementary Teacher Education in Mathematics

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Paper Presented at

Northeastern Educational Research Association

41st Annual Conference

Rocky Hill, CT

October 20-22, 2010

Abstract

This research grew from two university faculty members' and one doctoral student's collaboration across different academic fields (mathematics and education) to better serve elementary preservice teachers (PSTs). The collaboration resulted in shared expertise and an ongoing investigation of confidence of mathematical content knowledge (M-CK) and mathematics pedagogical content knowledge (M-PCK) of PSTs who participated in math content coursework designed for elementary teachers. Findings suggest that PSTs who take one or more of these content courses, along with a mathematics methods course, have higher M-CK and M-PCK than PSTs who take only traditional mathematics courses along with a mathematics methods course.

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Purposes of the Study

What mathematical coursework is needed for preservice elementary teachers to grasp the mathematical concepts underlying the mathematics they teach to their students? Educational research has not yet found a clear answer to this question; the literature consistently demonstrates that content knowledge and pedagogical content knowledge (Shulman, 1987) play vital roles in effective teaching, and in elementary school mathematics teaching in particular (Ball, Lubienski, & Mewborn, 2001; NCTM, 2003), however, there is not a consensus on which courses best support mathematical content knowledge (M-CK) that translates to effective mathematical pedagogical content knowledge (M-PCK) and, in turn, student learning (Kirtman, 2008).

Aligned with the theme of NERA 2010, *building research partnerships*, our reported research grew from collaboration across the fields of mathematics, education, and cognition and instruction. The first two authors, one an instructor of mathematics content in the College of Liberal Arts and Sciences, and the other an instructor of mathematics methods in the University's School of Education, had shared conversations over several years about their courses in relation to their common students, elementary preservice teachers (PSTs). These informal discussions led to a more formal commitment to engage in collaborative research that would support the PSTs with whom they work. The third author, a Ph.D. student in Cognition, Instruction, and Learning Technology joined the research collaborative after the initial planning stages, bringing to the group a learning theory perspective. Since fall 2009 this research collaborative has been working on a study investigating preservice teachers' Math Content Knowledge (M-CK) and Mathematics Pedagogical Content Knowledge (M-PCK).

In this paper, we report on a quantitative piece of the larger study that investigates participant perceptions of the mathematics coursework designed specifically with PSTs in mind. We also reflect on the role of researcher collaboration throughout the research process, from the study conception through the interpretation of results. We end with a discussion of implications and future directions of this exploratory research.

Theoretical Framework and Researcher Backgrounds

From a dialogical perspective, collaborative research is an inherently recursive process. "Participants own individual thoughts are not the only sources of meaning for their utterances; instead, they exploit their co-conversationalist's contributions. In dialogical terms we could say that parties appear as *'coauthors' of each other's contributions*" (Linell, 2009, p. 73).

Paulus, Woodside, and Ziegler (2008) investigated and reported on their collaborative process as researchers, a perspective seldom addressed in the literature. In this paper, we draw from their perspective that research is "a group process of active meaning-making through dialogue rather than a 'discovery' of new knowledge" (p. 231). This process is compatible with ideas of reflective practice and its recognition that the way we look at and solve problems is influenced by our disciplinary backgrounds, past histories, interests, etc. (Schön, 1987). In our case, we came to the "problem" of research from different disciplinary backgrounds, as well as different research backgrounds. These differences, when combined with a "collaborative dialogic process" (Paulus, Woodside & Ziegler, 2008, p. 229), allowed us opportunities to develop new and richer ways of approaching the research. In order to do this, we relied on the idea of "cogenerative dialoguing" (Tobin & Roth, 2005) – that is, reflection where all members refer to the same set of events with understanding and explanations cogenerated. Cogenerative dialogues can allow people with different expertise to work together to articulate and design improvements.

Prior to delving more deeply into the research, we provide perspectives on our individual research backgrounds.

The Research Team

Fabiana Cardetti – mathematician. I am a research mathematician with an assistant professor position in the Mathematics Department within the College of Liberal Arts and Sciences. My research interests are in Control Theory on Lie Groups as well as Partial Differential Equations that model biological processes. In recent years my interests have grown to include Mathematics Education. I have always been involved in activities to enhance the mathematical learning experiences of students at the college level but I am now approaching these activities with the same rigor and discipline that I apply to my other research areas. Among my current research priorities are efforts to improve the preparation of teachers. I believe that their work is the most influential in shaping children's future interest and curiosity in mathematics.

Mary Truxaw – mathematics educator. I am a mathematics educator with an assistant professor position in the Department of Curriculum and Instruction in the School of Education. My research focuses primarily around discourse in mathematics classes, specifically, targeting middle and elementary school teaching and learning. Additionally, I am interested in teacher education issues more generally. My research interests related to discourse support the collaborative dialogic nature of our research work – namely, I recognize that dialogic processes are integral to creating new meaning.

Cindy Bushey – research assistant and learning theorist. I came into this project as a Research Assistant through the Teachers for a New Era Project, and I am currently pursuing my Ph.D. in Cognition and Instruction. My research interests include collaborative learning environments, specifically the affordances of learning through discussion. Situated Cognition is a primary theoretical lens through which I view my own work, and it enters easily into this conversation about the emergence of meaning within researcher conversations.

Background of the Research Process

The collaborative aspect of our research led us initially to ask the following research question:

RQ 1) What are outcomes of faculty collaboration across the disciplines of mathematics and education?

As an outgrowth of our focus on collaboration, we considered investigating issues that overlapped our areas of expertise – in particular, mathematics content and pedagogy for elementary preservice teachers. As noted earlier, researchers and professional organizations (e.g., Ball, Lubienski, & Mewborn, 2001; NCTM, 2003) recognize that both M-CK and M-PCK are necessary for teachers to effectively teach elementary school students; however, it is not clear exactly what that knowledge entails or the best way to obtain it. Renowned mathematics educator Deborah Ball said 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*. Further, Ball remarked that few mathematics courses offer opportunities that would produce knowledge that is appropriate for elementary school teachers. She urged, "ongoing research in this area is crucial" (p. 9).

In light of this call for research related to developing appropriate content knowledge for elementary school teachers, we developed a collaborative research study to examine the influences of mathematics courses designed specifically with elementary preservice teachers in mind that emphasize both M-CK and M-PCK.

In this study, as a vehicle for investigating M-CK and M-PCK, we considered measures of confidence (Gable & Wolf, 1993) and efficacy (Bandura, 1986) because they have been tied to *teacher efficacy* (Tschannen-Moran, Woolfolk Hoy, & Hoy, 1998) that, in turn, has been linked to positive teacher behavior and student performance (Henson, 2001). Indeed, NCTM (2003) notes, "Candidates' comfort with, and confidence in, their knowledge of mathematics affects both what they teach and how they teach it" (p. 4). We conjectured that measuring confidence toward M-CK and M-PCK could provide indicators of impact on PSTs' teaching efficacy and, in turn, their future mathematics teaching practices. Therefore, we investigated related 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 reasonable base from which to build an instrument to measure PSTs' confidence related to M-CK and M-PCK.

Our collaboration and the review of related research literature led us to ask two additional research questions, as follows:

RQ 2) How does completion of math content courses that are designed for elementary school teachers influence elementary PSTs' confidence in M-CK both before and after completing a mathematics methods course?

RQ 3) How does completion of math content courses that are designed for elementary school teachers influence elementary PSTs' confidence in their M-PCK both before and after completing a mathematics methods course?

Methods

We consider ourselves participants of this study with respect to our collaborative work (RQ 1). We met regularly to share our individual views and generate collective meaning from the data. These discussions and exchanges of ideas influenced the development of RQs 2 and 3, the research design to investigate these questions, and our interpretation of the findings related to them. In what follows, we describe the methods related to RQs 2 and 3 – the study of the preservice teachers' confidence with respect to M-CK and M-PCK.

Context

Participants. Related to RQs 2 and 3, the participants were elementary PSTs enrolled in our teacher preparation program (TPP). For the larger study, participants included elementary education PSTs in their junior and senior years in the TPP. These students were predominantly female (90-95%), white (80-90%), and typically ranging in age from 20 to 25 years old. For this paper, we focused on data from surveys administered during the fall of the PSTs' senior year, prior to and after completion of a required mathematics methods course.

Target coursework. In addition to this mathematics methods course, all elementary education PSTs at our institution are required to take at least three "quantitative" content courses (e.g., mathematics, statistics, or physical sciences) outside the School of Education. The Department of Mathematics offers two content courses specifically designed for elementary PSTs, which are currently recommended but not required as part of the TPP. We strategically targeted these two math content courses for this study.

These two 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 a required math methods course, are referred to here as the C-group (content). The participants who completed the math methods course, but neither of the identified content courses, are referred to here as the NC-group (non-content).

Data Collection and Analysis

A survey was administered to all participants that included Likert items adapted from the *Fennema-Sherman Mathematics Attitude Scale* (Mulhern & Rae, 1998) (see Appendix A), along with open-ended content problems designed to uncover both M-CK and M-PCK (available upon request from the authors). Data collection included pre- and post-surveys administered to the elementary PSTs at the beginning and end of the math methods courses in fall 2009. For this paper we focus on the Likert-scale scores (1=Strongly Disagree; 5=Strongly Agree) that were analyzed using paired t-tests to compare the differences between means (pre-score minus post-score – a negative difference indicating positive change). Additionally, confidence intervals (CI) were analyzed. 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). The results from paired t-tests (significant at the

.05 level) were in agreement with the results from the 95% CI analysis. Therefore, due to the small sample size, only the results from the confidence interval analyses are presented here.

Results

Research Question One

Through cogenerative dialogue (Tobin & Roth, 2005), we communicated expectations, challenges, and concerns about the content and methods courses – allowing us to refer to the same "set of events" as we moved forward with our research. The course-related issues discussed included topics covered in the courses, pedagogical approaches, expected learning outcomes and skills. As we moved into the research, again, we worked collaboratively with the design and implementation of the study, discussing key points along the way. These ongoing dialogues enriched our previously held understandings, thus resulting in the study reported in this paper (RQs 2 & 3). The third author joined the team and the three of us worked collaboratively as we refined the design and implementation of the study and analyzed and interpreted the data. The fact that each member comes from a different discipline provided a unique opportunity to view and analyze the problems and results from multiple angles. This in turn forced us to raise the dialogue to another level where our perspectives would build from each other and produce a richer overall result.

Research Questions Two and Three

To address the remaining RQs, we analyzed pre and post confidence scores for the two groups of PSTs (C- and NC-groups) related to M-CK and M-PCK (for the 19 participants who completed *both* pre- and post-surveys).

To answer RQ 2, data from the Likert items related to M-CK (items 1-4) were analyzed. These first items refer to the students' confidence in their *own* ability to do mathematics. Table 1 shows descriptive statistics along with 95% CI for the mean difference on these Likert item scores.

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

Given the small data set, it is difficult to discuss statistical significance; therefore, we focus this discussion on the mean differences instead. Figure 1 shows the graph depicting these differences. The range of mean scores for the Likert items (items 1-3) are shown along the y-axis; and the x-axis contains the two points in time, pre- and post-survey, at which the mean scores were calculated. It is important to note that this is not a continuous graph; rather, each line represents two points, a beginning (labeled Pre) and an ending point (labeled Post). The lines have been drawn to help visualize comparisons between pre and post mean scores.

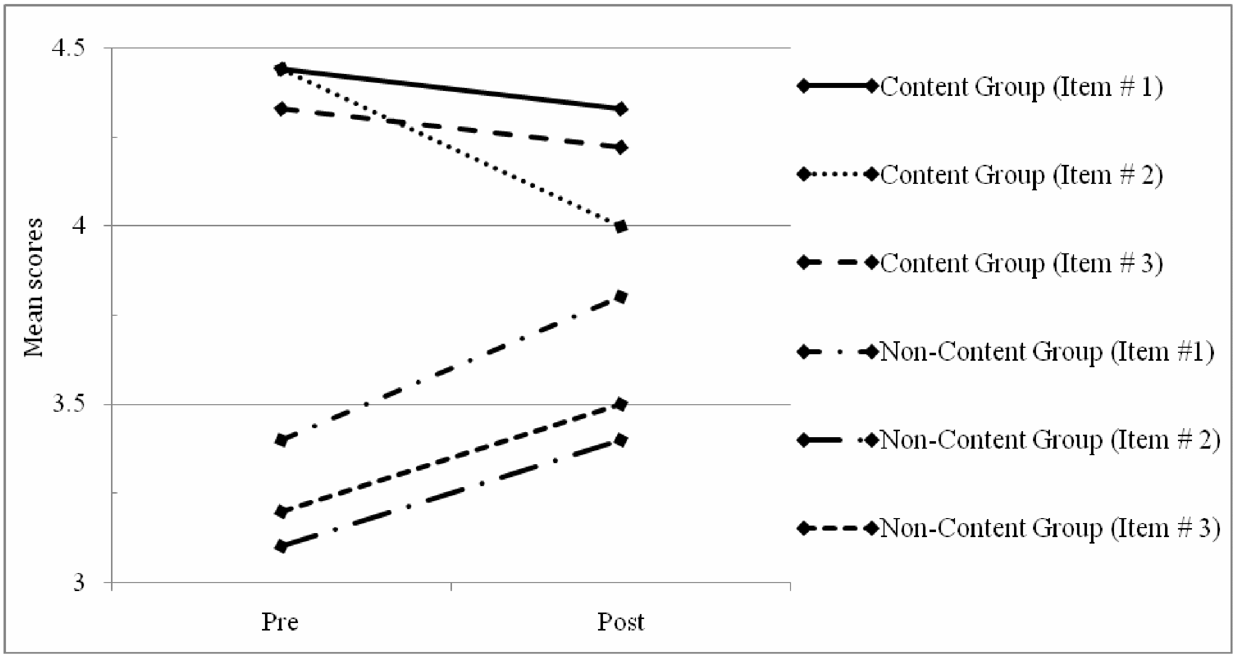

Figure 1 M-CK pre and post mean scores.

It is clear from Figure 1 that the C-group began with higher confidence in their ability to do mathematics than the NC-group. The C-group's means decreased, and the opposite is true for the NC-group. These data represent their confidence pre- and post-*methods* course. Those students who did not have the benefit of the content course (NC-group) prior to taking math methods course increased their confidence in their ability to do mathematics; however, this confidence never reached the point—anywhere—pre or post—of those who had taken the content course (C-group).

To answer RQ 3, data from the Likert items related to M-PCK (items 5-8) were analyzed. These questions related to the students' pedagogical confidence—their ability to teach. In Table 2 we present the descriptive statistics along with 95% CI for the mean difference corresponding to these Likert item scores.

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

Once again, given the small data set, it makes more sense to look at the mean differences in graphical form than statistical significance. Figure 2 contains the graph depicting the mean differences pre and post survey for items 5-7. The range of the mean scores for these Likert items are shown along the y-axis; and the x-axis contains the two points in time, pre and post survey, at which the mean scores were calculated. As with the previous figure, Figure 2 does not represent a continuous graph, but it represents only the beginning (labeled Pre) and an ending (labeled Post) points. The lines have been drawn to help visualize comparisons between pre and post mean scores.

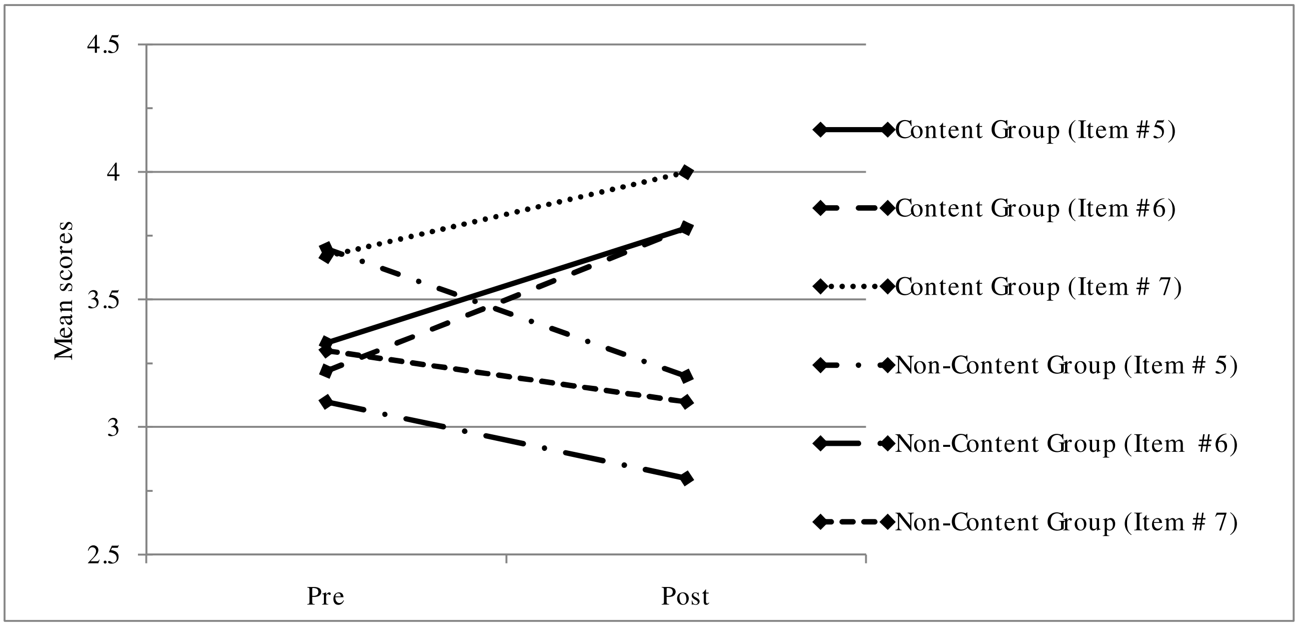

Figure 2. M-PCK pre and Post mean scores.

Figure 2 shows a very different picture than Figure 1. Whereas before the C-group and NC-group data were clearly separated, in this case, it is not as simple to distinguish between the two groups at the beginning point (Pre). Given that these data related to how confident participants felt in *teaching* math, and none of them had experience with teaching mathematics, it is not surprising that the pre-survey means show intermingled values across the two groups. However, the post survey data points are clearly separated, as was the case on Figure 1. The post survey means on all three items for those who had taken the content course (C-group) increased. And, the post survey means on all three items, for those who had not taken the content course (NC-group) *decreased*.

The findings related to items 4 and 8 and the open-ended items are described and discussed in Cardetti, Truxaw, and Bushey (manuscript in progress, 2010).

Discussion and Implications

We have each learned much from this ongoing collaborative work that has benefited not only our individual and collective growth, but also that of the research study itself, as evidenced by the following excerpts taken from our personal reflections on the process.

With regards to the impact of this collaboration in our individual roles as educators, Mary wrote:

> As we have delved into the research, not only have I learned from the research process and results, but I have learned more about what my elementary education students may learn within the Math Department that may support my work with them in the School of Education. (Mary, personal reflection, 2010)

Contemplating our collective growth as members of an interdisciplinary research group, Cindy commented:

> As the three of us have engaged in this community of practice (Lave & Wenger, 1991), I have experienced movement from the outer edge of this little community towards taking on a more central role. When I first joined the research team, I knew little about the research Mary and Fabiana were conducting. Their egalitarian approach to their research and their willingness to include me in the dialogue has promoted a shared ownership over the project. (Cindy, personal reflection, 2010)

With respect to the influence of the cogenerative dialogue in the research study, Fabiana wrote:

> At the same time the original problem has expanded and become more interesting and richer than where I could have brought it by myself--or with others within my discipline. (Fabiana, personal reflection, 2010)

In summarizing the benefits of this collaborative effort, Mary emphasized the working dynamics as a major contributor to success as follows:

> Again, as we worked to develop rubrics, make sense of interview data, document our results, etc., having another perspective and another member of the dialogic collaborative process has been invaluable. It means that ideas get vetted from a variety of perspectives and the "end result" is truly dialogic – that is, new meaning is created. (Mary, personal reflection, 2010)

The collaborative work is allowing us to think and reason collectively and build on our different perspectives, while helping us uncover possible influences of mathematics content courses designed for elementary PSTs. The results of the study suggest not only that taking these math content courses may be important for enhancing M-CK, but also that the timing of the coursework matters for the development of M-PCK. The PSTs going into the methods courses with greater M-CK (the C-group) may have been able to focus more on pedagogy than those who did not go into the course with strong mathematics content knowledge. Those with less M-CK experience (NC-group) may have felt the need to focus their attention on the mathematical *content*, thus, diluting their focus on teaching methods. As Ball and others have suggested, we know that teachers need both; they need to know the content and they need to know how to teach the mathematics. Timing – that is, when the PSTs take the specific content and methods courses – may be important.

One means of supporting elementary PSTs as they work to become effective mathematics teachers may be participation in mathematics content courses that are designed specifically for them. 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 may be on their own mathematical content knowledge. It will be important to further investigate the influences of such courses on M-CK and M-PCK.

We are continuing our collaborative work – collecting and analyzing data including the Likert-items, open-ended items, and interviews, across at least two cohorts of students. We anticipate that continuing to analyze these data will provide us with evidence related to particular content mathematics courses and how their timing (i.e., if PSTs take the courses prior to or after math methods courses) may impact PSTs' confidence with respect to M-CK and M-PCK. The results may influence recommendations for our teacher preparation program and others as well.

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Endnotes

1. We gratefully acknowledge the support of the *Teachers for a New Era* Project at the university for supporting this endeavor.

Appendix A

The Likert-scale items used in this study were adapted from Fennema-Sherman Mathematics Attitude Scale (FSMAS) 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.