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Changing preservice teachers' epistemological beliefs about teaching and learning in mathematics: An intervention study

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Abstract

We investigated a theoretical model including an instructional intervention and systematic processing to account for change in preservice teachers' epistemological beliefs about teaching and learning in mathematics. General and subject-specific epistemological beliefs and systematic processing were assessed in 161 preservice teachers, randomly assigned to an experimental group whose epistemological beliefs about mathematics were activated and challenged through augmented activation and refutational text or to a control group who read a traditional expository text. The model was partially supported. The treatment group receiving the instructional intervention demonstrated greater change in implicit epistemological beliefs than the control group, and partial support for systematic processing as a mediator of the relationship between general epistemological beliefs and change in specific epistemological beliefs was obtained.

Keywords: Epistemological beliefs; Conceptual change; Mathematics; Refutational text; Augmented activation; Systematic processing

1. Introduction

Changing strongly held prior beliefs about academic concepts is difficult when those beliefs conflict with instruction. This difficulty has been particularly evident

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in numerous studies (e.g., Ball, 1990; Peterson, 1990; Williams & Baxter, 1996) of preservice and inservice teachers' efforts to align their teaching with the standards promulgated by the National Council of Teachers of Mathematics (NCTM, 1989, 2000). These standards advocate an emphasis on understanding and problem solving in the teaching of mathematics. Many teachers, however, have been unable to adopt this emphasis in their teaching, despite their enthusiasm for reform (e.g., Hiebert & Stigler, 2000; Gregoire, 1999). Several researchers (e.g., Schoenfeld, 1992) have proposed that teachers' *domain-specific* (hereafter referred to as specific) epistemological beliefs, that is, their beliefs about the nature of knowledge and teaching and learning in mathematics, contribute to their difficulties in changing their teaching practices. If these researchers are correct, helping pre- and inservice teachers develop more sophisticated specific epistemological beliefs may be an important initial step in enabling them to improve their students' understanding and achievement in mathematics. To contribute to the achievement of that goal, the first objective of this study was to test the effectiveness of an intervention designed to change teachers' specific epistemological beliefs about mathematics.

Other researchers (e.g., Cooney & Shealy, 1997; Spillane & Zeuli, 1999) have attributed mathematics teachers' difficulties in changing their teaching practices to their *domain-general* (hereafter referred to as general) epistemological beliefs about knowledge and knowing. Similarly, researchers who have attempted to change students' strongly held naive beliefs about science (e.g., Qian & Alvermann, 1995) have suggested that students' general epistemological beliefs, specifically that knowledge is simple and certain, contribute to their resistance to change. If these general epistemological beliefs influence resistance to belief change, it is important to address the question of how general epistemological beliefs influence this resistance.

A potential answer to the question of how general epistemological beliefs influence resistance to belief change has emerged. Several researchers (e.g., Chinn & Brewer, 1993; Dole & Sinatra, 1998; Gregoire, 2003) have suggested that systematic processing is a critical mechanism in inducing change. Systematic processing refers to high cognitive engagement in and elaboration of instruction (Dole & Sinatra, 1998). Mason (2002) proposed that systematic processing is the mechanism by which general epistemological beliefs influence changes in beliefs about subject matter. She reasoned that students who hold general epistemological beliefs that knowledge is changing and tentative are likely to see potential value in new knowledge and will work diligently to determine whether it warrants rejecting their prior beliefs. In contrast, she contended that general epistemological beliefs in knowledge as unchanging and certain limit students' engagement in processing of instruction. In sum, Mason hypothesized that systematic processing mediates the relationship between students' general epistemological beliefs and changes in subject-specific beliefs. To advance understanding of the process of changing specific epistemological beliefs, the second objective of this study was to test Mason's hypothesis.

As the context for achieving our two objectives, we studied the process of belief change about mathematics in preservice teacher education. By investigating belief change in this context, we hoped to identify effective teaching strategies for promoting change in preservice teachers' epistemological beliefs and to offer theoretical insights useful in advancing understanding of the relationship between general and specific epistemological beliefs.

2. A theoretical model of change in epistemological beliefs about mathematics

On the basis of the research and theory on general and specific epistemological beliefs, we constructed a theoretical model to account for the development of epistemological beliefs about the nature of mathematics and learning and teaching in mathematics. This model is presented in Fig. 1. As indicated in the model, we hypothesized that (a) general epistemological beliefs, systematic processing, and an instructional intervention designed to motivate change in specific epistemological beliefs about mathematics would predict change in preservice teachers' specific epistemological beliefs and (b) systematic processing would mediate the relationship between general epistemological beliefs and change in specific epistemological beliefs as well as the relationship between the treatment and change in specific beliefs. A review of research supporting the theoretical model follows.

3. Research support for the theoretical model

3.1. The nature of epistemological beliefs

3.1.1. General epistemological beliefs

Although researchers have proposed several competing models of the nature of epistemological beliefs, they have agreed that general epistemological beliefs refer to "individuals' beliefs about the nature of knowledge and the processes of knowing" (Hofer & Pintrich, 1997, p. 117; Schraw, 2001). Numerous epistemological beliefs have been proposed, but, of those beliefs, the core belief that knowledge is simple and certain is the strongest predictor of less sophisticated reasoning (Qian &

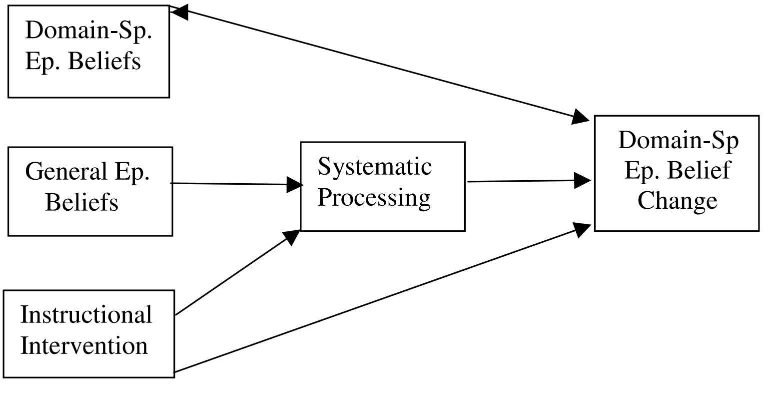

Fig. 1. Theoretical model of change in epistemological beliefs about teaching and learning in mathematics.

Alvermann, 1995; Schraw, 2001). Consequently, in our research we focused on this general epistemological belief.

3.1.2. General vs. specific epistemological beliefs

The question of whether epistemological beliefs are general or specific to subject matter has been a matter of considerable interest (Hofer, 2000; Schommer & Walker, 1995). In the early studies researchers assumed that epistemological beliefs are general (Schommer, 1990); however, some researchers have identified subject-specific epistemological beliefs. For example, in a review of the literature on teachers' beliefs, Calderhead (1996) noted that each academic subject includes epistemological issues regarding what knowing means in the subject and how knowledge in the subject should be developed. Buehl and Alexander (2001) synthesized these perspectives into a conception of epistemological beliefs as both general and specific. In commenting on their synthesis, Schraw (2001) called for research to clarify the relationship among the two types of epistemological beliefs. More relevant to this study, De Corte, Op 't Eynde, and Verschaffel (2002) emphasized the need for research on the relationship between mathematics-related beliefs and more general epistemological beliefs. To provide evidence on this issue, we explored the relationship between general and mathematics-specific epistemology beliefs.

The distinction between general and specific epistemological beliefs has been particularly well developed in research on mathematics instruction. Some researchers (Cooney & Shealy, 1997) have identified general epistemological beliefs as crucial to the development of teaching practices that focus on the development of students' understandings in mathematics, and other researchers have emphasized the importance of specific epistemological beliefs in the subject matter (e.g., Schoenfeld, 1992). The NCTM (1989, 2000) standards reflect a concern for the development of both general and specific epistemological beliefs in their emphasis on the development of a *constructivist* epistemological perspective. Constructivism as adopted in the standards is based on the general epistemological belief that knowledge is complex and uncertain and the domain-specific epistemological belief that knowledge in mathematics is developed not through passively learning rules and procedures but rather through actively constructing understanding in the process of solving problems (Hiebert et al., 1996). Controversy abounds regarding the nature of constructivism, but it was not within the scope of this paper to differentiate between conceptions of constructivism. Rather our purpose was to foster the development of a constructivist epistemology of mathematics that is consistent with the NCTM standards and with the general consensus regarding effective teaching held by most mathematics educators. In the hope of identifying strategies to enhance teachers' ability to adopt constructivist epistemological beliefs about teaching in mathematics, we turned to conceptual change theory.

3.2. Conceptual change theory

Conceptual change theory offers a model of concept acquisition that originated with science educators (Posner, Strike, Hewson, & Gertzog, 1982) who adapted the epistemological theories of Piaget (1980) and Kuhn (1970) to explain why students resist changing their conceptions about scientific phenomena when confronted with conflicting information. Posner et al. proposed that conceptual change occurs when instruction creates four psychological conditions in the learner: the learner experiences dissatisfaction with the current conception and finds the new conception intelligible, plausible, and fruitful. Numerous studies have demonstrated the effectiveness of science instruction that focuses on creating those four conditions in learners (see Guzzetti, Snyder, Glass, & Gamas, 1993, for a review). Considerable research indicates that the model can also be effective in inducing conceptual changes in other academic domains, including teacher education (e.g., Salisbury-Glennon & Stevens, 1999).

Although Posner et al. (1982) proposed the conceptual change model to explain knowledge acquisition, they noted that it could be applied to belief change as well. In a review of ways in which students resist changing their conceptions in response to contradictory evidence, Chinn and Brewer (1993) also proposed that the conceptual change model would be effective in inducing change in beliefs as well as knowledge. Consequently, we adopted the conceptual change model as a potentially appropriate model for motivating change in preservice teachers' specific epistemological beliefs. In the next section we identify two strategies that seemed promising for (a) promoting preservice teachers' dissatisfaction with their current specific epistemological beliefs and (b) convincing them that more sophisticated epistemological beliefs are intelligible, plausible, and fruitful.

3.3. Augmented activation and refutational text as motivators of conceptual change

In a meta-analysis of research on conceptual change, Guzzetti et al. (1993) evaluated the effectiveness of numerous interventions for promoting conceptual change in reading science texts, including discussion, demonstration, belief activation, augmented belief activation designed to challenge preconceptions, nonrefutational text, refutational text, Socratic questioning, concept mapping, labs, lectures, and worksheets. Their meta-analysis suggests that augmented activation and refutational text might be effective strategies in promoting change in preservice teachers' epistemological beliefs about mathematics.

3.3.1. Augmented activation

Alvermann and Hynd (1989) developed the technique of augmented activation to focus students' attention on salient information in instructional text that conflicts with their own beliefs. The technique consists of written directions (a) alerting readers that the information they are about to read may contain information that conflicts with their own beliefs and (b) directing them to pay attention to the ideas that differ from their own. The following example illustrates the use of augmented activation prior to students' reading of a text refuting their naive beliefs about motion:

> If you thought that the path the marble would take would be straight down, straight out and then straight down, or straight out and then curved down, your ideas may be different from what the laws of physics would suggest. As you read the following text, be sure to pay attention to those ideas presented that may be different than your own. (Alvermann & Hague, 1989, p. 199)

When Guzzetti et al. (1993) analyzed comparisons of a single intervention with a control, separately by grade, the intervention that had the largest effect on conceptual change in undergraduates was augmented activation (effect size = .80). Further, in seven studies with undergraduates, Guzzetti et al. found that conceptual change was much greater (effect size = .76) in groups receiving augmented activation than in groups whose prior beliefs were activated but were not instructed to pay attention to ideas in the text that contradicted their own beliefs.

3.3.2. Refutational text

Refutational text is designed to stimulate conceptual change by fostering students' dissatisfaction with their current beliefs through rebuttal of those beliefs using scientific evidence (Guzzetti et al., 1993). Most scientific text is expository, that is, a straightforward explanation of the concept under study. In their meta-analysis Guzzetti and her colleagues reported that refutational text had a greater effect on conceptual change than did nonrefutational text (average effect size = .22). Consistent with the conceptual change model, students have reported that refutational text is more interesting and more plausible than nonrefutational text and challenges them to question their prior conceptions (Guzzetti, 2000).

Two studies relevant to the present study examined the use of refutational text with preservice teachers. In the first, Salisbury-Glennon and Stevens (1999) found that using a refutational text to challenge prospective teachers' beliefs about motivation engendered greater conceptual change than reading a typical textbook passage about motivation (effect size = .71) A smaller but still significant effect of .54 in favor of the refutational text was found 1 week later. Building on the work of Salisbury-Glennon and Stevens, Kutza (2000) found that prior beliefs about motivation interacted with text type and reward structure in influencing change. Kutza also found that conceptual change persisted after a 1-week delay. These two studies offer strong support for the efficacy of refutational text in promoting conceptual change in preservice teachers and preliminary evidence of its persistence over time.

To achieve the objectives of this study, a strong intervention was required for two reasons: First, we needed a strong test of the hypothesis that preservice teachers' epistemological beliefs could be enhanced on the basis of the conceptual change model, and second, we needed to obtain change in preservice teachers' specific epistemological beliefs in order to test the hypothesis that systematic processing mediates the relationships between general epistemological beliefs and change in specific epistemological beliefs and between the treatment and epistemological change. Therefore, we combined the two techniques of augmented activation and refutational text in one intervention in the hope that it would have a strong effect on preservice teachers' specific epistemological beliefs in mathematics.

3.4. General epistemological beliefs and conceptual change

Considerable evidence suggests that general epistemological beliefs play an important role in conceptual change. In Pintrich's (1999) model of conceptual change, for example, general epistemological beliefs function as a resource or constraint on conceptual change. Specifically, Pintrich proposed that adopting more sophisticated (i.e., constructivist) epistemological beliefs promotes conceptual change. Research in several academic domains supports his proposition. For example, Rukavina and Daneman (1996) found that understanding of scientific text was most strongly predicted by two epistemological beliefs: whether knowledge is simple or complex and whether it consists of facts or integrated ideas. Similarly, Qian and Alvermann (1995) found that the general epistemological belief that knowledge is simple and certain, compared to beliefs in quick knowledge or innate ability, had the largest impact on conceptual change (Qian & Alvermann, 2000). With regard to students' reading performance, Schommer (1990) found that the belief in certain knowledge predicted inappropriately absolute conclusions to an open-ended text. In mathematics, Cooney and Shealy (1997) offered the theoretical argument that it is unlikely that teachers will adopt constructivist principles if they maintain the general epistemological beliefs that there is only one way to solve a problem and that the teacher is the sole authority on what that way should be. Thus, on the basis of the substantial evidence demonstrating a relationship between general epistemological beliefs and conceptual change, and Cooney and Shealy's theoretical rationale, we included general epistemological beliefs in our study as a potential influence on specific epistemological belief change in mathematics.

3.5. Systematic processing

The lack of research to identify mechanisms that account for changes in beliefs is a serious limitation in our understanding of the process. Chinn and Brewer (1993) suggested that systematic processing, the effortful cognitive processing that focuses on the core argument of a passage rather than on its more superficial features, might influence belief change. Empirical research on attitude change in social psychology offers strong support for systematic processing as a mechanism of belief change, at least in the context of persuasion (Dole & Sinatra, 1998). The central premise of systematic processing models is that more effortful processing, because of its focus on understanding the semantic content of messages, forms extensive networks of cognitions and thus is more likely to lead to lasting attitude change than less effortful modes of processing (Dole & Sinatra, 1998; Eagly & Chaiken, 1993; Petty & Wegener, 1999). In a synthesis of the literature on conceptual change and social psychological research on persuasion, Gregoire (2003) proposed that systematic processing is a key mediator of accommodation, or lasting belief change. Given the strong theoretical basis for systematic processing as a mechanism of conceptual change, we hypothesized that it mediates the relationship between the instructional intervention and change in specific epistemological beliefs.

Mason's (2002) recent theoretical analysis suggesting that systematic processing may mediate the relationship between general epistemological beliefs and change in specific epistemological beliefs further emphasizes the need to investigate the mediational role of systematic processing in change in specific epistemological beliefs. Therefore, we investigated the role of systematic processing as a mediator of changes in beliefs.

3.6. Summary

Our overview of the literature provides support for the following predictions represented in the conceptual model in Fig. 1: (a) the instructional intervention would have direct and indirect effects on change in specific epistemological beliefs; (b) systematic processing would mediate the relationship between the instructional intervention and specific epistemological beliefs; and (c) systematic processing would mediate the relationship between general epistemological beliefs and specific epistemological belief change.

4. Method

4.1. Participants

One hundred sixty-one undergraduate students enrolled in seven sections of a child development course during their first semester of their elementary teacher education program at a large, southern state university participated in this study. The sample was typical of elementary education majors at this university: predominantly white (81%), female (90%), with minority representation typical of the larger university population (Hispanic 9%, Black 5%, and 4% self-identified as "other") with the exception of fewer Asian students than typical for the university.

4.2. Measures: Predictors

Assessment of epistemological beliefs has typically involved self-report or interviews. Self-reports and interviews, however, are particularly susceptible to the social desirability bias. To address this possibility, we used two types of measures: (a) the CGI survey, a self-report measure of domain specific epistemological beliefs in mathematics that we refer to as a measure of *explicit epistemological mathematics beliefs* and (b) scenarios we designed to assess underlying epistemological beliefs about mathematics teaching and learning without relying on self-reports of beliefs. We refer to the scenarios as measures of *implicit epistemological mathematical beliefs*.

4.2.1. Explicit epistemological mathematics beliefs

We used the first and third subscales of the Cognitively Guided Instruction Belief Survey (referred to here as the CGI), developed by Peterson, Fennema, Carpenter, and Loef (1989) to measure preservice teachers' explicit epistemological beliefs about mathematics learning and teaching. The measure was derived from a review of the cognitive psychological literature on how children learn and is based on a constructivist view of learning and teaching of mathematical skills in the context of problem solving and a focus on understanding. Half of the items on each subscale are worded to favor a cognitively based perspective. A high score on the first subscale, concerned with how children learn mathematics, indicates agreement with the constructivist view of learning. A sample item is "Most young children can figure out a way to solve simple word problems.'' The third subscale assesses teachers' beliefs about their methods of instructing addition and subtraction. Higher scores indicate greater willingness to allow students to solve problems independently and with a greater degree of cognitive effort. A sample item is ''Teachers should allow children to figure out their own way to solve word problems.''

Peterson et al. (1989) obtained important validity evidence for a draft of the CGI completed by 39 first-grade teachers in the Midwest. In contrast to teachers with the lowest scores on the CGI, teachers with the highest scores were more likely to report teaching practices consistent with a constructivist approach to teaching; that is, they were more likely to build upon children's intuitive mathematical strategies; they were less likely to use written symbolism when introducing addition and subtraction to their students; and they were more likely to use manipulatives to help children form a conceptual understanding of arithmetic.

To determine whether the CGI would be appropriate for use with preservice teachers, Gregoire (2001) administered the CGI to 84 undergraduate elementary education majors. To reduce the time devoted to assessment in our experiment, we used the Gregoire data to select 30 items equally divided between Subscales 1 and 3. Two criteria were used to select items: (a) retain items with the largest item-subscale correlations and (b) eliminate items with duplicate phrasing while keeping the number of negatively and positively worded items balanced. Scores could range from 1 (*strongly disagree*) to 6 (*strongly agree*). Approximately half of the items in each subscale represent procedural views, and half represent constructivist views of problem solving. Cronbach's α for preservice teachers' total scores on the CGI in this study was .87.

4.2.2. Implicit epistemological mathematics beliefs

Eight mathematics teaching scenarios designed to reveal preservice teachers' underlying understandings of the nature of teaching and learning in mathematics were created (see Appendix A for two of the scenarios). (Copies of all eight scenarios are available from the first author.) Participants were asked to rate, on a scale of 1–10, the degree to which eight scenarios of a lesson on fractions represented excellent mathematics teaching. To create the scenarios, half of which represent constructivist teaching and the other half procedural teaching, the distinction between surface characteristics and structural characteristics of problems was used (Schoenfeld, 1985; see also Quilici & Mayer, 1996). Structural differences in the problems were based on changes in instructional emphasis advocated by the creators of the NCTM standards (1989, 2000). Specifically, the constructivist scenarios included the following structural characteristics, as described in the NCTM standards: The teacher gives students time to think on their own, the subject matter is problem-based; nonroutine problems are given; multiple solutions or graphing solutions are encouraged; and students are empowered to construct understandings based on their own thinking and experiences. The procedural scenarios contained the following structural characteristics as delineated in the NCTM standards: Word problems are given in isolation from real experience; procedures are straightforward and easily processed; routine, one-step problems are given; problems are categorized by types; and adherence to the algorithm is stressed over conceptual understanding. Surface characteristics of the problems were manipulated so that half of the constructivist and half of the procedural items each contained surface similarities from the opposing viewpoint. The remaining scenarios were both structurally and superficially consistent. Beginning teachers often adopt the surface features of constructivist teaching but not the structural features (Ball, 1990; Peterson et al., 1989); therefore, the goal of incorporating both structural and surface differences of these two teaching epistemologies was to unearth deeper and more accurate beliefs than is usually obtained by self-report.

A professor of mathematics education reviewed the scenarios for content validity and categorized the scenarios as constructivist or procedural. Then her categories were compared to those of the first author of this study. They disagreed on only one the scenarios, which the professor said did not provide enough information. After reading a revision of that scenario, the professor's decision agreed with the author's. Cronbach's α for the prospective teachers' scores on the pretest constructivist scenarios was. 58 and for the procedural scenarios, .47.

4.2.3. General epistemological beliefs

Schommer's (1990) Epistemological Beliefs Questionnaire (EBQ) is the most frequently used measure of general epistemological beliefs (Duell & Schommer-Aikins, 2001), but methodological and conceptual problems are associated with the EBQ (Hofer & Pintrich, 1997). Qian and Alvermann (1995) addressed some of the methodological problems, yielding a revised 32-item measure composed of three subscales named from a naive perspective: (a) learning is quick, (b) knowledge is simple and certain, and (c) ability to learn is innate. Items are scored on a 6-point Likert-type scale ranging from (1) *strongly disagree* to (6) *strongly agree*. For this study, we used their general epistemological belief in simple and certain knowledge subscale (11 items) because Qian and Alvermann found it to be the strongest predictor of conceptual change. Cronbach's α for the preservice teachers' scores on this subscale in this study was .73.

4.2.4. Systematic processing

We assessed the degree to which students systematically processed the refutational and nonrefutational texts with a thought-listing task often used in the social psychological research literature. Eagly and Chaiken (1993), in their review of the literature on systematic processing, concluded that thought-listings provide valid measures of participants' cognitive processing, particularly because of their correlation with physiological evidence, such as increased heart rate and pattern of facial EMG activity. Students were given 3 min to list their ideas, attitudes, thoughts, and feelings about the passage they read. The number of their message-based thoughts (TLs) were counted as a measure of systematic processing. Two trained raters coded the TLs without knowing whether the respondent was a member of the experimental or control group. The correlation between ratings contributed by the two raters was .73. To estimate interrater reliability, we calculated ICC $(3, k)$ (Shrout & Fleiss, 1979). This intraclass correlation coefficient is appropriate because both raters coded every thought listing and, for each participant, the average of the two raters' scores was used in the analysis (Crocker & Algina, 1986). ICC $(3, k)$ was .84.

4.3. Outcome measures

4.3.1. Epistemological belief change

To assess changes in epistemological beliefs after reading the texts, the preservice teachers responded to the scenarios again, re-arranged to reduce the likelihood of a pretest effect. Internal consistency coefficients for their' scores on the constructivist scenarios were .65 for the experimental group and .61 for the control group, and for the procedural scores, .61 for the experimental group and .56 for the control group. Principal components analyses were conducted separately on the covariance matrices of the scores on the posttest scenarios for the experimental and control groups. Inspection of the eigenvalues indicated that for each group the first two eigenvalues were substantially larger than the others (1.92 and 1.75 for the control group and 2.07 and 1.82 for the experimental group). A two-factor obliquely rotated solution in each group indicated that scores on the four constructivist scenarios loaded on one factor and scores on the four procedural scenarios loaded on the second factor.

4.3.2. Teachers' explicit belief change

To determine if change occurred on the measure of explicit epistemological beliefs about mathematics, the prospective teachers completed the CGI again after rating the scenarios. Internal consistency estimates for the posttest CGI scores were .92 for the experimental group and .93 for the control group.

4.4. Manipulation checks

Three Likert items were used as manipulation checks. Participants were asked to rate (a) the degree to which the passage challenged their views of mathematics, (b) the degree to which the passage distinguished between constructivist and procedural instruction, and (c) how useful and/or important the information in the passage was for teaching.

4.5. Procedure

We collected pretest data early in the semester, before students had been introduced to constructivism. First, students completed a pretest questionnaire that included the 30 CGI items, the 11 general epistemology questions, and the 8 teaching scenarios. About a week later, depending upon the instructor's schedule, we administered the treatment and posttreatment measures. Participants were randomly assigned to the treatment or a control condition. They were given 15 min to read the experimental or control passage. Then, they completed the posttreatment measures, including the 3 items to check the effectiveness of the manipulation, the 8 teaching scenarios, and the 30 CGI items.

4.5.1. Experimental treatment

The treatment group read the following augmented activation message designed to induce recall of the epistemological beliefs underlying their responses on the CGI and to challenge them:

Augmented activation message

You are about to read a passage that will most likely challenge the way you think about mathematics teaching and learning. To understand why this might be so, try to remember how you rated the following items (on a scale from strongly disagree to strongly agree) from the [CGI] questionnaire you completed the first day of this study:

1. Teachers should demonstrate how to solve simple word problems before children are allowed to solve them.
2. Children learn mathematics best from a teacher's demonstrations and explanations. If you agreed with these statements, you are not alone: A great majority of ... students (between 75 and 85%) just like yourself agreed with these statements last semester. The problem is that these statements reflect underlying beliefs about mathematics that are opposed to what most mathematics educators would consider good mathematics teaching, as reflected in the national standards for the teaching of mathematics.

In the selection you are about to read, the type of instruction represented by statements 1 and 2 above is called procedural teaching. As you read the following text, see if you can clarify your own beliefs about mathematics. Be sure to pay attention to how your beliefs might differ from the material presented in the following text. Also, notice what implications your beliefs have for instruction.

Then the participants read a refutational text that presented (a) a rationale for the adoption of a constructivist epistemology and teaching practices and (b) direct challenges of their traditional beliefs about effective mathematics teaching (see Appendix B for an excerpt in which the differences between the refutational text read by the experimental group and the expository text read by the control group are indicated; copies of the full texts of the refutational text and the expository text are available from the first author.) The criteria used to construct the refutational text were based on a review of the literature on reading research (Kardash & Scholes, 1995; Kintsch & van Dijk, 1978), conceptual change (Dole & Sinatra, 1998; Guzzetti et al., 1993), and social psychological research on persuasion (Eagly & Chaiken, 1993; Petty & Wegener, 1999). The refutational text includes causal arguments (Dole & Sinatra, 1998), presents individuals with unfamiliar premises with positive implications for the conclusion and assertions with which the individual already agrees (according to the guidelines established by Wyer as cited in Eagly and Chaiken); and uses multiple sources (see Anderson, as cited in Eagly and Chaiken)—all criteria that are related to persuasion and change in attitudes or beliefs. More important, in the tradition of conceptual change research in science (Posner et al., 1982), to cause cognitive conflict in the reader, the refutational text was constructed to provide a direct refutation of procedural instruction. The text was written on a 12th-grade reading level, according to the Flesch-Kincaid Readability scale given in Microsoft Word's text editor.

Control condition. Participants in the control condition completed a brief word scramble designed to call to mind words related to the passage they were about to read (e.g., problem solving) to activate, but not challenge, their beliefs. This task was a minimal activation intended to occupy students while the treatment group read through the augmented activation message. Then, instead of a refutational text, the control group read a standard expository text (available from the first author) written to reflect typical textbook writing. The text presented a rationale for the adoption of a constructivist epistemology and teaching practices in mathematics similar to the rationale in the refutational text without the direct challenges of procedural beliefs and practices. It was consistent in length and grade level with the refutational text.

5. Results

The means and standard deviations of the pre- and posttest measures are presented in Table 1. To test the equivalence of the experimental and control groups on the pretest measures, independent samples t tests were conducted. Although the participants were randomly assigned to experimental treatment and control conditions, a significant difference between the groups on the CGI was found, $t = -2.24$, $p < .05$. Nevertheless, this difference does not present a problem for the subsequent hypothesis testing for treatment effects on the posttest because the control group had the higher mean pretest score (3.56 vs. 3.38). If anything, this difference strengthened the robustness of the hypothesis tests, because it was in the opposite direction of the expected treatment effects. All other pretest differences were nonsignificant.

Table 1
Means and standard deviations for the pre- and posttreatment measures

Measure	Control			Treatment		
	M	*SD*	*N*	*M*	*SD*	*N*
Pretreatment measures						
CONST	6.39	1.35	84	6.33	1.45	77
PROC	6.28	1.26	84	6.40	1.24	77
CGI	3.56	.49	84	3.38	.49	77
EB	2.41	.58	84	2.27	.59	77
Posttreatment measures						
Challenge	4.10	2.31	79	6.07	2.41	74
Distinct	6.79	2.10	79	7.70	1.98	74
Useful	7.51	1.89	79	7.80	1.75	74
CONST	6.84	1.36	79	7.35	1.34	74
PROC	6.34	1.36	79	6.06	1.30	74
CGI	3.73	.65	79	3.80	.63	74
SP	.43	.27	80	.48	.24	74

Note. CONST, constructivist teaching scenarios; PROC, procedural teaching scenarios; CGI, CGI Beliefs Survey; EB, naive epistemological beliefs in simple and certain knowledge; SP, proportion of message-based thought-listings (a measure of systematic processing).

5.1. Manipulation checks

To determine whether the experimental manipulation was effective, one-way ANOVAs were computed on the participants' ratings on three Likert items (see Table 1 for means and standard deviations). If augmented activation had the desired effect, the experimental group should have rated the text as more challenging to their beliefs than did the control group. The null hypothesis of no treatment differences was rejected, $t(151) = 5.16$, $p < .01$. (Unless otherwise noted, the Type I error rate was set at 5% for all hypothesis tests. One-tailed t tests were conducted when a directional alternative hypothesis was specified.) The effect size, using Cohen's d, was .84. The second manipulation check assessed whether the experimental group rated the text as making a clearer distinction between constructivist and procedural instruction than did the control group. As expected, the null hypothesis of no treatment differences between the groups was rejected, $t(151) = 2.77$, $p < .01$, $d = .45$. A third manipulation check assessed the discriminant validity of the treatment. No difference due to treatment was expected between the groups on how useful or important they thought the text was for teaching, and none was found, $t(151) = .98$, $p > .05$. Thus, the experimental group perceived that the text provided a greater challenge to their beliefs and made a clearer distinction between the two teaching epistemologies than did the control group, but the two groups did not differ in their perceptions of the usefulness of mathematics. These results support the validity and efficacy of the treatment.

5.2. Path analysis

Our conceptual model (see Fig. 1) specifies that the treatment directly affects change in specific epistemological beliefs, and general epistemological beliefs and the treatment directly affect systematic processing, which in turn directly affects epistemological change. We used a simultaneous equation model to estimate the effects. The model contained four endogenous variables: systematic processing, implicit constructivist beliefs, explicit constructivist beliefs, and procedural beliefs. Two approaches were considered for measuring the last three endogenous variables: using change scores and using posttreatment scores as the endogenous variables. The latter approach was selected. In regard to direct effects, indirect effects, and goodness of fit results, both approaches yield the same results except for the direct effect of pretreatment status on the endogenous variable. When posttreatment scores are used as the endogenous variable, the direct effect for the pretreatment variable addresses the question of whether pretreatment status is related to posttreatment status. If change scores were used as the endogenous variables, the direct effect for the pretreatment variable would address the question of whether pretreatment status is related to change. However, this effect has a serious flaw that tends to result in the misleading conclusion that pretreatment status is negatively related to change. The flaw has two sources: First, ceiling effects can preclude participants with high pretreatment scores from exhibiting large positive change and therefore pretreatment status will tend to be negatively related to change. Second, change scores and pretreatment scores have negatively correlated measurement errors (Lord, 1963). As a result, participants with spuriously high pretreatment scores due to measurement error tend to exhibit small or negative gain. Because using change scores as the dependent variable has the potential to be misleading about the effect of pretreatment status on change, posttreatment scores were used as the dependent variable. Because in our estimated model the pretest effect is the effect on posttest rather than on change, we excluded the effects of pretest from our results.

The model contained four endogenous variables: systematic processing and the three posttest measures of domain-specific beliefs: implicit constructivist beliefs, explicit constructivist beliefs, and procedural beliefs. Residuals for the last three endogenous variables were allowed to correlate. The model contained five exogenous variables: a treatment indicator, general epistemological beliefs, and the pretests on implicit constructivist beliefs, explicit constructivist beliefs, and procedural beliefs. Full information maximum-likelihood was used to estimate the path model because 31 of the 1449 (161 participants on 9 variables) scores were missing due to nonresponse and/or attrition. Listwise deletion was used as a check and the pattern of significant effects was the same for both methods of estimation. The goodness of fit index was nonsignificant, $\chi^2(12) = 19.51$, $p = .71$, and the CFI was .98, indicating good fit. The results of tests of the model are presented below for each of the three measures of epistemological change.

For implicit epistemological belief change, as measured by the constructivist scenarios, the standardized direct effect (SDE) of treatment was significant (SDE = .18, Cohen's $d = .36$), $z = 2.75$, $p < .01$, and the direct effect of systematic processing (SDE = .15) was also significant, $z = 2.29$, $p < .025$. The model posits indirect effects of treatment and general epistemological beliefs, but only the indirect effect of general epistemological beliefs was significant (SDE = .03), $z = -1.73$, $p < .05$.

For implicit epistemological belief change as measured by the procedural scenarios, the standardized direct effect (SDE) of treatment was significant (SDE = −.14, $d = -.27$), $z = -1.86$, $p < .05$. No other significant direct or indirect effects were obtained.

For explicit epistemological belief change, as measured by the CGI, the standardized direct effect (SDE) of treatment was significant (SDE = .16, $d = .31$), $z = 2.46$, $p < .01$. No other significant direct or indirect effects were found.

6. Discussion

6.1. Treatment effects

This study provides strong support for the hypothesis that the instructional intervention of augmented activation and refutational text promotes greater change in prospective teachers' epistemological beliefs about mathematics than exposure to a traditional text. All three of the hypotheses were supported: The treatment group receiving the augmented activation of their prior beliefs and the refutational text had higher scores on the CGI measure of constructivist beliefs and on the scenario measure of beliefs in constructivist teaching and lower scores on the scenarios endorsing procedural teaching than the control group. Although the reliability coefficients for scores on the constructivist and procedural scenarios were modest, ranging from .47 to .65, the effect of low reliability was to make it more difficult to demonstrate significant treatment effects and to reduce the magnitude of the effect sizes (Maxwell, Cole, Arvey, & Salas, 1991). A longer instrument would likely yield higher reliability coefficients and larger effect sizes. The finding of treatment effects on both implicit and explicit measures of beliefs, even though the effect sizes were modest, is notable because the treatment lasted only 15 min and mathematics beliefs are particularly difficult to change (Hiebert & Stigler, 2000). Of course, the questions of whether the treatment effect was due to augmented activation or refutational text and whether the preservice teachers have maintained the effects of the instructional intervention across time remain, but evidence from other studies suggest that refutational text is likely to have a more permanent effect than other conceptual strategies that have been studied. From her review of studies of instructional strategies used in conceptual change research, Guzzetti (2000) reported that only refutational text has shown effects lasting a month or more. Hynd (2001) has suggested that the powerful effect of refutational text is likely to be due to its effectiveness in meeting the four conditions Strike and Posner (1992) described as essential to conceptual change. That is, it creates dissatisfaction with existing beliefs and effectively demonstrates that the new belief is intelligible, plausible, and useful. Our participants' responses to the manipulation checks support Hynd's claim. The treatment group reported that the refutational text provided a greater challenge to their beliefs and made a clearer distinction between the two teaching epistemologies than did the control group in their evaluation of the expository text.

This study is the first study of epistemological belief change with preservice teachers to include a quantitative measure of implicit epistemological beliefs. If the prospective teachers merely assimilated constructivist beliefs into their existing system of thought, they may still have chosen the constructivist responses on the self-reported CGI; however, it would have been much harder for them to rate the scenarios as excellent teaching without significant belief change. When individuals read a passage and then report that their beliefs are more in line with what they have read—as they did on the CGI, their responses may simply reflect a response to the demands of the situation and not a belief change; however, when they respond to complicated teaching scenarios, they are providing a more ecologically valid response that reflects their ability to analyze instructional methods and identify those most likely to promote student learning. For example, Hiebert and Stigler (2000) found that most teachers in the US endorsed the NCTM standards, but their instruction reflected predominantly traditional instruction. The teaching scenarios are a first step in examining belief change that more accurately reflects preservice teachers' underlying beliefs than self-report. In sum, this study provides support for the idea that accommodation rather than assimilation occurred in the treatment group because treatment effects were found on both explicit and implicit measures of epistemological belief change.

6.2. Systematic processing as a mechanism of change

Our second hypothesis was that systematic processing mediates the relationship between the instructional intervention and change in preservice teachers' epistemological beliefs. The path analyses indicated that systematic processing does not mediate the relationship. Perhaps a more sensitive measure of systematic processing is needed to detect its role as a mediator or perhaps the failure to find evidence of mediation may be due to one or more individual difference variables that moderate the effect of the intervention on systematic processing. Our third hypothesis was that systematic processing mediates the relationship between preservice teachers' general epistemological beliefs and change in their specific epistemological beliefs. The path analyses indicated that systematic processing does mediate the relationship but only for epistemological belief change as measured by the constructivist scenarios. This finding suggests that preservice teachers who hold beliefs in knowledge as simple and certain are less likely to engage in deep thinking about the ideas presented in the refutational text and in turn are less likely to develop sophisticated beliefs about the nature of mathematics and how understanding of mathematics is developed. This result provides initial support for systematic processing as a mechanism for specific epistemological belief change. However, systematic processing did not mediate the relationship between the treatment and epistemological belief change or the relationship between preservice teachers' epistemological beliefs and change in their specific epistemological beliefs as measured by the procedural scenarios or the CGI. Thus, further research is needed to clarify why systematic processing did not mediate these relationships. One possibility is that limitations in the measure of systematic processing reduced the likelihood of finding an effect. Consequently, research that investigates alternative approaches to the measurement of systematic processing is needed.

6.3. Implications for policy and practice

In their synthesis of the literature on learning to teach, Wideen, Mayer-Smith, and Moon (1998) found that the most productive approach to promoting learning in novice teachers included (a) creating a teacher education program that builds on the beliefs they hold when they enter the program and (b) beginning the program by having them examine those beliefs. The effectiveness of the intervention in this study provides empirical support for the use of augmented activation and refutational text together to increase prospective teachers' awareness of their specific epistemological beliefs. By activating and challenging their original beliefs and providing logical arguments and challenges to those beliefs, augmented activation and refutational text appear to create the dissatisfaction and the intelligible, plausible, and useful evidence that Posner and Strike (1992) proposed as necessary for inducing belief change. Targeting and challenging preservice teachers' beliefs is clearly more effective than providing them with straightforward expository text. This study, and previous ones in teacher education (Hynd, Alvermann, & Qian, 1997; Kutza, 2000; Salisbury-Glennon & Stevens, 1999) and science education (Guzzetti, Snyder, & Glass, 1992), provide strong empirical support for this conclusion. At the very least, writers of textbooks—in educational psychology and in specific subject areas—should accommodate this growing body of research. Ultimately, such changes in teacher education programs should help teachers adopt more sophisticated epistemological beliefs and teaching practices for the benefit of their students, especially if such changes enable teachers to identify and challenge their students' epistemological subject matter beliefs.

6.4. Directions for future research

It is important to investigate the effects of changes in teachers' epistemological beliefs on their teaching practice as well as on student outcomes. In addition, this study should be extended to studying epistemological belief change in parents and school administrators. As McLeod (1994) found in his review of mathematics research, the affective response of the community to mathematics reform influences whether reform-based practices are adopted. Moreover, these results need to be extended to teachers' specific epistemological beliefs in academic areas besides mathematics to provide evidence of the generalizability of the results. Finally, other intervention techniques to promote epistemological change should be investigated in addition to the two used in this study. In a recent paper, Guzzetti (2000) suggested that teacher-led discussions of refutational texts may have the largest impact on promoting conceptual change in students' science conceptions. Perhaps adding discussion to the experimental treatment and comparing it to other interventions would provide a better understanding of how to promote change in prospective teachers' specific epistemological beliefs.

In summary, the results of this study provide insight into two mechanisms for promoting change in prospective teachers' epistemological beliefs about mathematics: (a) increasing students' awareness of their specific epistemological beliefs and refuting them through sound, logical argument and (b) engaging students in systematic processing of text. The next step is to explore ways of promoting and sustaining change in the face of personal and institutional resistance to change. One way to accomplish this may be through targeting prospective teachers' general epistemological beliefs. Our finding that general epistemological beliefs predicted specific epistemological belief change indirectly through preservice teachers' systematic processing suggests that fostering the development of general epistemological beliefs may be a key to promoting the type of thinking and mature beliefs about knowledge in mathematics that we hope prospective teachers possess.

Appendix A. Mathematics teaching scenarios

1. Ms. J has students open their math textbooks to the lesson on fractions. She selects a problem from the page and writes it on the chalkboard: 1/3 + 1/2. She asks students to spend a few minutes trying to solve this problem. During this time, she walks around the room but when students ask her for help, she recommends that they just try to solve it on their own first, using whatever they need to use to help them solve it.

After 5 min pass, Ms. J asks students to come to the board and present their solutions, one at a time. She does not tell them if their answers are correct but allows students to debate each others' answers. After 10 min of discussing their solutions, most of the class decides that 5/6 is the correct answer but that there are numerous ways to get that answer. Two students, however, are still confused, so Ms. J asks them to share their solutions at the board, one at a time. The first student draws a picture and incorrectly divides a pizza into 5 slices, coloring in 2 of them. The other student agrees with this solution of 2/5.

Ms. J then asks the class if this method works for adding pizza slices, "Does 1/3 of a pizza and 1/2 of a pizza equal 2/5 of the entire pizza?"

Several students call out "No," so she asks one of them to come to the board and explain why not. That student explains the concept of equivalent slices using a paper circle cut into sixths and fifths. The two confused students now understand their errors. Satisfied that the class is in agreement, Ms. J assigns them more problems from the textbook to work on, noting that they are free to use any method they want to find the answer, as long as it is valid.

2. Mr. Q reviews with his class how to add fractions with unlike denominators by reminding his students that they first must find a common denominator. He then tells them to multiply the numerator by whatever number they used to multiply the original denominator by to get the common denominator. He models how it would be done with $1/3 + 1/2$.

First, he has them write these fractions in their notebooks. Then, he tells them to write the common denominator after the 'equals' sign, like so: $1/3 + 1/2 = ?/6$. Then, he shows them how to multiply the numerators by the factors 2 and 3, respectively, to get $2 + 3 = 5$, which he writes above the 6.

"So, your answer would be 5/6. Any questions?" he asks. Mr. Q then spends several minutes answering students' questions about how to add fractions with unlike denominators. He gives them time to work a couple of problems on their own, then he goes over their answers with them. Some students are still struggling, so Mr. Q tells the class to get started on their homework, but those who want extra assistance can meet him at the group table in the back of the room for individual tutoring.

Appendix B. Excerpt from the refutational text treatment condition[1]

Note that [*constructivist instruction*] is quite different from *procedural instruction*. For example, even if students are placed in groups, if the goal is to have them practice solving exercises without any critical thinking, cognitive struggle, or mathematical conversation on their part, then they are just being little math "factories" churning out the "correct" answer without deeper understanding of the underlying principles behind what they are doing. With a [constructivist] approach, **however**, students are given time to think, to make mistakes, to verbalize their thinking, to debate with their fellow students **without the teacher immediately interrupting and telling them whether**

[1] The material in bold was deleted in the control condition. Note that the distinction between the refutational text and the control text consists of direct contrasts between the constructivist and procedural approaches that emphasize the limitations of the procedural approach.

their answer is correct. Of course, the teachers job is to guide students thinking along fruitful mathematical paths, but it is not their job to do all the thinking for them...

[In a] classroom based on [constructivism]... students would attempt to solve real math problems *before* learning all the procedures and rules they might need to make the process more efficient. Students would be encouraged to create new and different ways of solving problems, and they would discuss their solutions with each other. Constructivist classrooms are filled with *student* discussion. The teacher's role is to select rich mathematical problems and activities for the class, to guide student participation so it is respectful and fruitful, and to probe student understanding. **You might say that procedural teachers are concerned with students listening to them and** constructivist teachers are concerned with listening to students in order to figure out how to provide appropriate tasks and problems to promote student understanding. What matters is that students experience mathematics in situations in which they come to view it as personally empowering. **Instead of being dependent upon the teacher for knowledge, they are encouraged to think critically about authentic problems.**

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