MATHEMATICS TEACHERS' EPISTEMIC DISPOSITIONS AND THEIR RELATIONSHIP WITH TEACHER INSTRUCTION AND STUDENT LEARNING: A SYSTEMATIC RESEARCH SYNTHESIS

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Some research suggests that teachers' beliefs and thoughts about the nature of mathematical knowledge and knowing (broadly termed epistemic dispositions*) comprise an important factor that influences their practice. However, to date, there is no systematic review of the empirical literature on mathematics teachers' epistemic dispositions. The purpose of this systematic research synthesis was to assess the existing empirical literature in order to (a) describe mathematics teachers' epistemic dispositions, (b) to identify whether such dispositions correlate with teacher's use of constructivist teaching practices, and (c) correlate with student learning outcomes. A systematic assessment of 30 relevant studies suggest that teachers, on average, hold constructivist epistemic dispositions regarding mathematics, which are positively correlated with constructivist teaching practices*

Keywords: epistemic cognition, epistemic beliefs

Cognitive processes involved in constructing and evaluating arguments—called *epistemic cognition*—has been well studied in the educational psychology literature. Epistemic cognition concerns itself with the thinking that people do about what they know and how they know it (Chinn, Rinehart, & Buckland, 2014; Sandoval, Greene, Bråten, 2016). For example, a learner engages in epistemic cognition when they explain "how they know" that a mathematical assertion is true or justified. A common object of investigation in epistemic cognition research is people's beliefs about the nature of mathematics, mathematical knowledge, and processes of knowing—sometimes termed *epistemic beliefs* (e.g., Cooney, 1985; Ernest, 1989; Muis, 2004; Thompson, 1984). Existing research syntheses suggest that students' epistemic beliefs support their motivation, selection of productive problem solving strategies, and achievement outcomes in mathematics (e.g., Muis, 2004) and are involved in teachers' lesson planning, evaluation of student work, and instructional techniques (e.g., Maggioni & Parkinson, 2008). Yet, despite several decades of research consistently confirming that epistemic cognition plays a crucial role in facilitating teaching and learning in many disciplines, little to no research focuses on synthesizing findings regarding teachers' epistemic cognition in the domain of mathematics.

The purpose of this systematic review was therefore to synthesize the existing work on epistemic cognition in mathematics teaching in order to specify teachers' epistemic dispositions and identify whether epistemic dispositions are associated with instructional practice and student achievement. Specifically, we sought to answer three central questions: (a) *What are teachers' epistemic dispositions towards mathematics?* (b) *To what extent are epistemic dispositions associated with teacher instruction? (c) To what extent are epistemic dispositions associated with student learning?*

Theoretical Framework

Epistemic cognition can be defined as the thinking that people do about knowledge and knowing (Greene et al., 2016). A common focus in epistemic cognition research is on the beliefs that people hold about knowledge and knowing—or epistemic beliefs—which are studied both as both a domain-general and domain-specific construct. Three decades of research from various

disciplines have yielded multiple domain-general models of epistemic cognition that broadly fall into three categories: developmental, multidimensional, and philosophically informed models (e.g., Sandoval et al., 2016). *Developmental models* of epistemic cognition investigate how people's views of knowledge progress through a series of levels over time (e.g., Kuhn, 1991; Moshman, 2015; Perry, 1970). *Multidimensional models* explore epistemic cognition as a set of multiple, relatively independent dimensions of beliefs (e.g., Hofer & Pintrich, 1997; Schommer, 1990). *Philosophically informed models* more broadly conceive of epistemic cognition as encompassing not only beliefs, but cognitive processes that take into account motivation, emotion, and practices that dynamically interact with beliefs in context (e.g., Chinn et al., 2014).

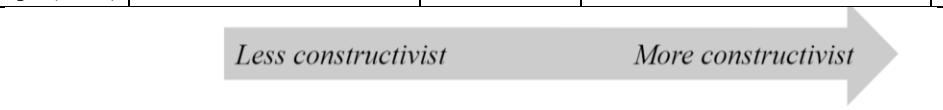
Theoretical Models of Epistemic Cognition Specific to Mathematics

Much of the literature on mathematical epistemic cognition focuses on individuals' beliefs about mathematics and the nature and acquisition of mathematical knowledge (e.g., epistemic beliefs; Ernest, 1989; Thompson, 1984). The most commonly cited model of teachers' beliefs about mathematics is that of Ernest (1989). Ernests' model posits that teachers' beliefs about what mathematics is impacts their beliefs about how students learn, how teachers should teach, and subsequently impact their enacted model of how students learn (e.g., their teaching practices and how they utilize classroom resources like textbooks). Ernest proposes three categories of epistemological beliefs that increase in their level of sophistication: instrumentalist, platonist, and problem-solving. Individuals that hold an *instrumentalist* perspective believe that mathematics is a set of unrelated rules and facts. Instrumentalists view mathematical statements as mere consequences of a set of arbitrary mathematical rules. Math teachers that adopt an instrumentalist perspective might view math statements as "just a collection of disconnected formulas" to be memorized and reproduced that are ultimately disconnected from our experience in the world. *Platonists* hold the view that mathematics is a unified body of objective mathematical knowledge and that mathematics is discovered. This can be illustrated by the teacher who believes that that mathematical knowledge is highly interconnected, builds upon itself, and exists in an unchanging almost transcendent world of objective mathematical knowledge. A platonist teacher might believe that the best way to communicate mathematical knowledge to their students is to expose students to math knowledge in a logically consistent way. The *problem-solving* perspective holds that mathematics is dynamic, expanding, and is a human invention. This perspective stems from the view that mathematics is essentially a human invention constructed from subjective experience in the world. Teachers that hold a problem-solving perspective might believe that mathematical knowledge is a construction used to describe individual experience of the world (e.g., numbers and arithmetic is one way to describe our experience of countable objects), that math is a language to describe the world around us, and that the best way for students to learn mathematics is to co-construct knowledge is through engaging in situations that demand mathematics, through discussion, and interaction in the classroom.

Additional mathematics-specific theoretical models of epistemic cognition are similar to Ernest's. Felbrich and colleagues (2012) and Daepepe and colleagues (2016) also posit categorizations of teachers' epistemic dispositions that lie on a continuum of less to more constructivist (scheme-related, formalism, and process-related). Two of Blömeke's three categories are similar, with the third category, the application perspective, being somewhat unique in that it represents a teacher with the perspective that math is a tool that can be applied to accomplish various tasks.

Table 1: Four Developmental Models of Teachers' Beliefs about Mathematics.

Ernest (1989)	Instrumentalist	Platonist	Problem Solving	
Felbrich (2012)	Math is Static Science		Math is a Dynamic Process	Application
Blömeke (2008)	Scheme-Related	Formalist	Process-Related	
Daepepe (2016)	Absolutist		Fallibilist	



Teachers' mathematical beliefs are predicted to shape their perceived role in the classroom, intended outcomes, and enacted instructional practices. Ernest's (1989) model predicts that teachers' epistemic beliefs inform their espoused and enacted models of teaching and learning mathematics as well as their use of classroom materials (see Figure 1). For example, teachers who hold platonist beliefs that mathematics is an objective and unified body of knowledge are expected to view their role in the mathematics classroom as that of the "explainer" and that students learn as "receptacles" of this knowledge, and thus structure their classrooms around this idea by emphasizing direct instruction and rote reproduction of mathematical procedures. In contrast, teachers who hold constructivist, problem-solving beliefs are expected to view their role in the mathematics classroom as that of the "facilitator" of students as they actively construct understanding in social environments, and therefore center their classroom around groupwork and student's individual perspectives of mathematical content. In this way, teachers' constructivist epistemic beliefs are expected to correspond with teaching practices that subsequently support student learning.

As it stands, the epistemic cognition frameworks reviewed here posit that teachers generally progress from less to more constructivist mathematical beliefs and that these views on the nature of mathematics shape teachers' espoused models for teaching and learning and their enacted practices. However, it should be noted that such developmental models of epistemic cognition concentrate on epistemic beliefs and are limited in that they do not consider the multi-dimensionality or context-sensitivity of epistemic cognition as proposed in the educational psychology literature (e.g., Hofer & Pintrich, 1997; Chinn et al., 2014). As such, we operationalized epistemic cognition to include multidimensional and philosophically informed models and cast a wide net for retrieving relevant information about the topic, despite there being no math-specific theoretical models that are widely used that take these perspectives.

Method

Inclusion Criteria

This review investigates empirical research on epistemic cognition of instructors within the domains of educational psychology and mathematics education. Studies were selected if they examined *teachers'* thinking about mathematical knowledge and knowing that could be identified as satisfying one or more of the components of the operational definition outlined above. These components included beliefs about the nature of knowledge in mathematics, justifications of knowledge in mathematics, sources of knowledge in mathematics including teachers' perspectives on the acquisition of mathematical certainties (i.e., proof).

Search Procedures

Relevant empirical literature was identified via the following procedure (see Figure 3). Two online databases PsychINFO and ERIC were first searched with the following search command: "(teach* OR instruct* OR profess* OR faculty) AND (epistem* OR proof* OR prove OR proving OR (math* NEAR/6 belief*)) AND (math*)," no additional restrictions were placed on

the search. This search resulted in a total of 810 items. All abstracts of the 810 items were scanned to identify potentially relevant articles, dissertations, reports, or book chapters published in English. Sixty six duplicates from the two search databases were automatically removed from the list using the duplicate identification procedure in Mendeley version 1.19.4. Seven hundred and three additional articles were removed based on the title or abstract: 33 were conference proceedings that have been set aside for more thorough screening in the near future, 670 were removed because they focused on students' beliefs but not teachers' epistemic cognition, focused on beliefs about a content domain other than mathematics, were nonempirical, were not printed in English, or did not relate to epistemic cognition or epistemic beliefs as operationalized in the sections above (e.g., pertained to teachers' self-efficacy beliefs, beliefs about teaching and learning, or beliefs about intelligence). Full texts for the remaining 41 items were then assessed more carefully for eligibility, at which point 11 were removed after closer screening. Of the initial 810 items identified from the search in the two databases, a total of 30 texts met the inclusion criteria and were selected for this review. Of these 30 texts, 12 were identified as qualitative, 16 were quantitative studies, and 2 were mixed methods.

The 30 papers were then coded to capture characteristics of the theoretical framing, study setting, participants, internal validity, and external validity (codebooks available upon request; Cooper, 2016). Papers were broadly categorized by whether they addressed one or more of the three main research objectives to (a) describe teachers' epistemic cognition about mathematics, (b) identify whether there is a relationship between epistemic cognition and teaching practices, and/or (c) identify whether there is a relationship between epistemic cognition and student learning outcomes. Some texts were applicable to more than one category.

Preliminary analysis. For this preliminary analysis, we recorded the direction of effects—we noted whether each study found that teachers held constructivist dispositions or not, and whether these dispositions were positively or negatively correlated with reform-based instructional practices, and/or with student learning. We then tallied up the direction of effects across these studies. The secondary reference section presents a list of the articles cited in the review.

Preliminary Results

As with the theoretical literature on epistemic cognition in mathematics, the empirical literature used in this synthesis tended to centralize epistemic beliefs as the object of investigation. Of the 30 items pulled, all 30 of them appeared to be explicitly focused on assessing static epistemic beliefs using developmental or multidimensional conceptions of epistemic cognition (rather than philosophically informed models that take into account the context-sensitive nature of epistemic cognition). Most cited either Ernest's (1989) developmental model, though some cited Hofer & Pintrich's (1997) multidimensional model. Study samples ranged from pre-service K-12 teachers, and in-service teachers of preschool up through undergraduate and graduate instructors. As noted, of 30 texts, 12 were qualitative, 16 were quantitative, and 2 were mixed methods.

RQ1: What are teachers' epistemic dispositions towards mathematics?

To answer the first research question—*What are teachers' epistemic dispositions towards mathematics?*—We assessed sample means of teachers' beliefs about mathematics from quantitative studies to judge whether their epistemic dispositions towards mathematics were constructivist or not. Of the 17 studies presenting relevant means, 13 of them (76%) revealed that teachers on average held constructivist beliefs about mathematics knowledge and knowing.

RQ 2: To what extent are epistemic dispositions are associated with teacher instruction?

To answer the second research question—*To what extent are epistemic dispositions are associated with teacher instruction?*—we tallied the direction of effects of correlations between constructivist epistemic dispositions and teachers' reform-based teaching practices. Of the thirty papers, only four of them reported such correlations, all of which (100%) were positive and significant.

RQ3: To what extent are epistemic dispositions associated with student learning?

To answer the third research question—*To what extent are epistemic dispositions associated with student learning?*—we tallied the direction of effects of correlations between constructivist epistemic dispositions and student learning outcomes. Of the thirty papers, only two studies presented correlations between epistemic dispositions and student learning. Both correlations were positive, but only one was significant.

Discussion

We sought to assess the empirical literature on mathematics teachers' epistemic cognition to describe their epistemic dispositions and identify potential relationships with their practice and student learning outcomes. Initial findings from an analysis of 30 journal articles, book chapters, reports, and dissertations begin to suggest that teachers lean towards constructivist perspectives regarding mathematical knowledge and knowing. Such constructivist epistemic dispositions also appear to be correlated with the extent to which teachers employ or report employing constructivist teaching practices.

Another central finding is that much of the literature identified in this search conceived of and measured epistemic cognition as a unidimensional, static construct. Preliminary analyses suggests that teachers can hold different epistemic beliefs in different contexts, and may be more likely to advocate for a problem-solving perspective when considering mathematics outside of their day-to-day classroom preparation, but advocate for a more instrumentalist or platonic perspective when considering the gritty details and time constraints present in real classroom teaching. We therefore suggest that future research explore moderators, and to adopt theoretical models of epistemic beliefs that take context, motivation, emotions, and other situated aspects of mathematical beliefs into account (e.g., Chinn et al., 2014) because the literature currently lacks substantial empirical work in this regard.

Also, nearly absent from the literature are investigations into potential relationships between teachers' mathematical epistemic beliefs and race- and gender-disparities in student outcomes in the classroom. Existing research suggests that teachers' seemingly innocuous beliefs about the nature of mathematical ability are not gender-neutral (Copur-Gencturk, Thacker, & Quinn, 2019). Such evidence suggests that implicit racial and gender biases may belie the seemingly harmless beliefs about the nature of mathematics and mathematical knowing. Future research should explore potential relationships.

Conclusion

Our research synthesis suggests that literature on teachers' mathematics-specific epistemic cognition finds that teachers hold fallibilist (or constructivist) epistemic beliefs, and that fallibilist mathematical beliefs correspond positively with teachers' enacted practices. Teachers should thus be encouraged to adopt fallibilist perspectives. However, more research is needed. Future work should build from epistemic cognition models that centralize the role of context and frame epistemic cognition as a situated process—issues of race, gender, and class were all but absent from this body of literature, future work might explore links between teachers' epistemic dispositions and implicit biases (e.g., Authors, 2019).

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