Educ Psychol Rev (2008) 20:445–461
DOI 10.1007/s10648-008-9081-8

REVIEW ARTICLE

The Role of Teacher Epistemic Cognition, Epistemic Beliefs, and Calibration in Instruction

Liliana Maggioni · Meghan M. Parkinson

Published online: 11 July 2008

Abstract This review examines the literature on teacher epistemic cognition, epistemic beliefs, and calibration to consider the relation between these constructs and instruction that emerged from empirical studies. In considering how this body of literature can enhance understanding of how students become masters of their learning processes, we will briefly review how different theoretical frameworks have conceptualized the relation between epistemic cognition, epistemic beliefs, calibration and metacognition, self-regulation, and self-regulated learning. Implications for research include a more nuanced conceptualization of epistemic beliefs and a theoretical integration of these constructs. Implications for practice regard the reciprocal relations between teachers' knowledge, experience, epistemic cognition, epistemic beliefs, and calibration and their effects on pedagogical practices. The role of teachers' education and professional development is discussed.

Keywords Epistemic cognition · Epistemic beliefs · Calibration · Instruction · Teachers

In a recent review of current investigations on self-regulation of academic learning and performance, Zimmerman (2008) characterized the question driving this body of research as a quest for understanding "how students become masters of their own learning processes" (p. 167). We believe that a key aspect of this progress is the development of critical abilities that help learners to search for the meaning of what is learned, hence allowing them to be responsible actors in the learning process. Evaluating the quality of the information available in a particular learning context, reflecting on the nature of knowledge obtainable in a certain situation, and choosing what strategies to activate in order to get to know a specific aspect of reality are fundamental aids to enable learners to think critically.

Electronic supplementary material The online version of this article (doi:10.1007/s10648-008-9081-8) contains supplementary material, which is available to authorized users.

L. Maggioni (✉) · M. M. Parkinson
College of Education, University of Maryland, 3304 Benjamin Building, College Park, MD 20742-1131, USA
e-mail: lilianaumd@hotmail.com

A first step in this direction is the awareness that such questions actually need to be asked. It is precisely at this level that we believe that the literature on epistemic cognition, a term referring to the processes in which individuals engage in order to consider the criteria, limits, and certainty of knowing (Kitchener 1983), and the literature on epistemic beliefs—beliefs regarding the stability, structure, and source of knowledge (Schommer 1990)—can contribute to this special issue, by exploring the influence that different kinds of questions about the nature and justification of knowledge (or lack thereof) can have on the cognitive processes that characterize a learning experience (Radigan 2002). In addition, the literature on calibration, the match between confidence judgments and actual process or performance (Nietfeld and Schraw 2002), can illuminate how these epistemic considerations may influence cognition, by investigating a mechanism through which individuals evaluate their knowledge and thus regulate their cognition while learning.

The relations between epistemic cognition, epistemic beliefs, and calibration and metacognition, self-regulation, and self-regulated learning have evolved over time. Space constraints do not allow us to include a full examination of these developments within this article. However, a brief review of how different theoretical frameworks have conceptualized these relations is available as Supplementary Theoretical Material (see Supplementary Theoretical Material).

Although our ultimate goal is to foster understanding of how students can become masters of their learning, we decided to focus on the role that *teacher* epistemic cognition, epistemic beliefs, and calibration may have in instruction. This choice was based on research findings suggesting that formal schooling influences student beliefs about knowledge and how learners build knowledge, particularly when dealing with problems that cannot be solved by the application of an algorithm (Hofer and Pintrich 2002; Jehng *et al.* 1993; King and Kitchener 2004; Maggioni *et al.* 2006; Paulsen and Wells 1998; Perry 1970). In addition, analyses of the features of classroom discourse in various academic domains shed light on the processes that may foster the development of specific epistemic beliefs in students (Johnston *et al.* 2001; Lampert and Blunk 1998), suggesting that the way in which teachers conceptualize the nature and justification of their subject-matter knowledge and their ideas about students' learning influence the features of classroom discourse. In the section "Findings" of this paper, we have summarized how the literature focusing on teachers has characterized epistemic constructs and described their influence on instruction.

A Few Terms from Epistemological Research

Before delving into the analysis of the literature on teacher epistemic cognition, epistemic beliefs, and calibration, some conceptual clarifications are necessary. First, although a comprehensive review of each individual epistemological construct and of the philosophical roots of epistemic beliefs emerged in empirical investigations exceeds the purpose of this article, a note about terminology may be useful, because different terms usually signal variations in what is actually studied. The aim is to sketch the main differences present in the field and to convey a flavor of the various theoretical and methodological approaches to the psychological study of epistemology. In the rest of the article, we will refer to this body of literature in its generality as literature about individual epistemology to distinguish it from the philosophical literature on epistemology. We will also use the term *individual epistemology* to refer to a combination of the different epistemic constructs we are briefly describing in this section (i.e., epistemic cognition, epistemic beliefs, and cognitive resources).

The term *epistemic cognition* has been defined as the cognitive process in which people engage while considering the nature and the justification of knowledge and has mainly been

used by researchers focusing on the developmental aspects of cognitive processes (Kitchener 1983). As such, it refers to something that people *do* when they are prompted to reflecting on the nature of what they regard as knowledge and on the warrants for calling these ideas about the world knowledge. The investigation of teacher epistemic cognition in relation to instruction shaped our initial question because we wanted to capture as much as possible teachers' thinking in action; however, we found that most of the studies addressing our question focused on beliefs about the nature and justification of knowledge that people *entertain* at a certain moment in time (e.g., Blanco and Niaz 1997; Hashweh 1996; Maor and Taylor 1995).

These beliefs characterize the way in which individuals look at the world (the external, physical reality, themselves, or ideas) in order to gain knowledge and have been found to influence teachers' choice of pedagogical practices; they have been referred to as epistemic (epistemological) beliefs, personal epistemologies, or other beliefs or system of beliefs about how knowledge is generated in a specific disciplinary field or learning context (e.g., constructivist beliefs, positivist beliefs, or transmissionist beliefs). Finally, a few researchers have hypothesized that individuals "have a range of cognitive resources for understanding knowledge" (Louca *et al.* 2004, p. 58) that are activated according to the context in which people operate in the specific moment.

Overall, although researchers focusing on epistemic cognition tend to view individual epistemology as a unified set of ideas about the nature of knowledge and knowing that develop in time, researchers studying epistemic beliefs hypothesize that individual epistemology is composed of different, quite stable, semi-independent dimensions (e.g., certainty of knowledge and simplicity of knowledge). The components of individual epistemology are hypothesized to be even more independent by researchers focusing on fine-grained cognitive resources, since in this case, it is hypothesized that individuals can access different views of knowledge according to the specific context.

Different conceptualizations tend to suggest different research methods. For example, studies focusing on epistemic cognition and cognitive resources tend to use qualitative methodologies, while studies of epistemic beliefs make a larger use of quantitative data. However, studies of the relation between teachers' domain-specific epistemic beliefs and pedagogical practices also tend to use a qualitative approach. These differences in conceptualization and research methodology made the task of summarizing research results particularly challenging. For example, a major problem regards the fact that different researchers use different terms to identify a specific belief or set of beliefs, although a considerable overlapping emerged among these constructs. On the other hand, we found that this diversity had also the potential of contributing a richer and more nuanced understanding of the relation between teachers' individual epistemology and instruction. A complete inventory of the terms cannot be proffered here. Rather, we preferred to look at the content of the beliefs investigated by the different studies (e.g., by looking at the questions asked to participants) and to cluster them around a few common features that have emerged as factors affecting instruction. We review these features in the section dedicated to "Findings."

Review Parameters and Criteria for Inclusion

The initial search of relevant literature was limited to publications included in *PsycINFO*. The choice of this database and the exclusion of other databases more pedagogical in orientation were guided by the goal to target studies having an explicit psychological focus and a solid theoretical grounding in the educational psychology literature. The database was searched for

publications including the words "epistem*" and "teacher*." Results were limited by subject "epistemology." This initial search provided 133 entries. All abstracts were examined, and we retained publications that addressed the relation between some aspects of teachers' individual epistemology and instruction. Thirty-one documents were retained for full review. The remaining 102 publications were dropped from further examination because they focused on students, either preservice teachers or other students (40), consisted of commentary and book reviews (11), examined teachers' beliefs but did not consider eventual implications for instruction (7), or were theoretical discussions about pedagogical and epistemological issues that did not regard the relation between teachers' individual epistemology and instruction (44).

Since this search provided studies mainly regarding the sciences, in an attempt to broaden the review to other academic domains, we also searched *PsycINFO* for documents including the words "historical thinking" (given its strong epistemic component) and "teacher*." Fifteen documents fit these parameters; abstracts were reviewed using the same criteria applied in the previous search. Only three articles were retained for full review; the remaining 12 were dropped because they focused on students or student teachers.

The same database was used to search for publications including the words "calibrat*" or "accuracy" and "epistem*." Only one relevant article was retained from this search after excluding an editorial, five articles, and one dissertation unrelated to cognitive or educational psychology, and two more articles that did not study adults. A search including the words "calibrat*" and "teach*" yielded 53 results, most of which were related to test validity or measurement models. Two of the abstracts linked calibration to either self-regulation or metacognition. Finally, a search of "monitoring" and "accuracy" or "calibrat*," narrowed by "judgment," yielded 125 results, and eight were appropriate for the current review of calibration research. After reading all 125 abstracts, most were discarded because they dealt with either calibration of perception (i.e., visual tasks) or calibration of behavior (i.e., judgments of shock intensity). Further, 17 results were excluded because they focused on children or adolescents.

Additional relevant publications were identified through the references of the fully reviewed articles and of relevant chapters in the *Handbook of Educational Psychology* and in the *Handbook of Research on Teaching*. Also, the journal *Metacognition and Learning* was searched, as it is not included in the EBSCO research database. Thirteen theoretical articles and 39 empirical studies were incorporated in this review. The subset of empirical studies focusing on the relation between teachers' individual epistemology, calibration, and pedagogical practices is summarized in the Supplementary Appendix, available online (see Supplementary Appendix). It provides a brief description of the study designs, methods, participants, and subject matter.

Findings

Aspects of teachers' individual epistemology investigated

The study of teachers' individual epistemology is relatively young, and the amount of research available for this population is considerably less abundant than the research focusing on students. Although the *Handbook of Research on Teaching* (1986) dedicated one chapter to a review of the literature on teachers' thought processes for the first time (Clark and Peterson 1986), that document made no mention of teachers' individual epistemology. In the late 1980s and increasingly in the 1990s, researchers began to study teachers' beliefs about their subject matter (Calderhead 1996). The domain-specific focus that characterizes most of the studies of teachers' individual epistemology did not surprise us, since the

literature supports the hypothesis that epistemic beliefs have a domain-specific component (Buehl and Alexander 2001; Muis *et al.* 2006) and every discipline is characterized by a specific mode of thought and by particular terms of proof (Beers 1988). In addition, instruments commonly used to measure student and student teacher epistemic beliefs (e.g., the Epistemic Beliefs Inventory, Schraw *et al.* 1995) failed to produce the same factor structure once used to measure teacher epistemic beliefs (Wadsworth 2007).

As noted in the previous section, the terms used to identify emerging epistemic beliefs varied across studies, although their descriptions often emphasized the contrast between a view of knowledge driven by the knower and a view of knowledge driven by the object of knowledge (on this point, we have found an interesting parallel to the interpretive framework used by Fox and Riconscente 2008). In particular, studies focused on one or more of the following aspects of teachers' individual epistemology: teachers' beliefs about the constructed or discovered nature of their specific disciplinary knowledge, teachers' beliefs on the constructed or transmitted nature of learning, and fine grained components of individual epistemology triggered by contextual factors.

The complexity of the particular epistemic terrain in which the teachers operate has been explored with the aid of a few case studies by Lyons (1990), who found that teachers' epistemic evaluations simultaneously consider the status of the discipline taught (i.e., how knowledge is produced), the interpretation and presentation of a specific body of knowledge, and the evaluation of the nature of students' learning experience. The terrain is made even more complex because teaching happens within a relationship with students who, in turn, contribute their unique view of knowing and learning, views that teachers cannot ignore in deciding what pedagogical course of action better fits their overall educational goals (Radigan 2002). Although studies predominantly focused on specific aspects of this terrain, this complexity surfaced from several investigations and became evident in the description of teachers' individual epistemologies, which often contained ideas not only about the epistemic nature of the discipline but also beliefs about the development of learning. For example, some researchers (e.g., Hashweh 1996; Tsai 2006; Yerrick *et al.* 1998) examined teachers' beliefs about the nature of scientific knowledge and about learning, classifying them as constructivist (e.g., scientific knowledge is theory-driven and tentative; learning science often requires conceptual change) or empiricist (e.g., scientific knowledge is discovered and definitive; learning science is mainly acquisition of information).

Other researchers focused more specifically on the teachers' view of the discipline taught. For example, in the domain of science, researchers (e.g., Blanco and Niaz 1997; Brickhouse 1990) examined teachers' characterizations of scientific theories and contrasted perspectives reflecting the philosophical position of Kuhn and Lakatos (e.g., scientific progress is characterized by conflicting frameworks, evaluated in light of new evidence) to views more consistent with logical positivism and logical empiricism (e.g., science is characterized by objective, experimental observations mainly independent from theory). In the domain of history, researchers tended to analyze the views of history that emerged from teachers' reading and use of primary sources, contrasting conceptions of history as construction of meaning, a story to be brought to life, and a collection of accurate facts (Yeager and Davis 1996). Another group of researchers cast the difference of epistemic beliefs among teachers in terms of viewing learning and teaching as transmission of knowledge or conceiving them as its construction (Johnston *et al.* 2001; Maor and Taylor 1995).

Finally, a different line of research chose to adopt a much finer-grained analysis of teachers' individual epistemology, hypothesizing that individuals, according to the context, can conceptualize different sources of knowledge (transmitted and fabricated), distinguish among various forms of knowledge (stories, rules, or facts), and adopt different stances toward

knowledge (acceptance, puzzlement, or doubt); these studies tended to focus on classroom interactions and on the effect that the pedagogical moves of teachers had on the epistemic resources activated by their students (Louca *et al.* 2004; Rosenberg *et al.* 2006).

The relation between individual epistemology, calibration, and instruction

In identifying broad trends in the findings of this body of literature, we clustered the results of the articles reviewed according to what facet of teachers' individual epistemology and calibration was investigated or emerged as related to specific pedagogical practices. As shown in the Supplementary Appendix available online (see Supplementary Appendix), research methods varied, although a preponderance of the studies adopted a qualitative approach. Whereas this occurrence discourages an unqualified generalization of the findings, we found that results generally corroborated well across studies, identifying trends whose features were clearly identifiable beyond the particularities dictated by the specific context.

Science as theory-driven versus science as accumulation of facts

A few case studies in the sciences showed that conceiving of theories as tools to solve problems, viewing the scientific process as theory-driven, and believing that scientific progress consists more in changes in theories than in accumulation of facts correlated with a problem-based teaching approach, centrality of prediction in experimental activities, and continuous reinterpretation of laws and concepts previously encountered. On the other hand, conceiving of theories as truth uncovered through rigorous experimentation, viewing the scientific process as purely inductive, and considering the progress in science mainly as the accumulation of facts correlated with a different set of teaching methods. Specifically, these methods displayed the following features: heavy reliance on memorization, focus on terminology, avoidance of content perceived as potentially contradicting students' religious beliefs (e.g., evolution), use of laboratory experiments to demonstrate the veracity of formulas or rules previously taught by the teacher, stress of procedural precision in experimental activities, a classroom discourse characterized by a routine constituted by teacher-initiated questions, student responses, teacher evaluation of alternative responses, and scarce attention given to the integration of knowledge (Brickhouse 1990; Duschl and Wright 1989; Gallagher 1991; Yerrick *et al.* 1998). In addition, Brickhouse (1990) noted that teachers who viewed scientific progress as purely inductive tended to interpret students' "wrong answers" as procedural failings and reacted by encouraging students to better follow directions in order to obtain the "right answers."

In the history domain, Yeager and Davis (1996) identified three main views of history that tended to correlate with different pedagogical approaches. Conceiving history as construction of meaning correlated to awareness and use of several heuristics typical of historical analysis and interpretation (e.g., consider author's perspective, context and purpose of the document, nuances in tone and language, compare with other sources). These strategies were also emphasized in using primary sources in the classroom. On the other hand, viewing history as a story in need to be brought to life correlated with conceiving of sources as providers of information, and preference was accorded to documents that were captivating and entertaining, although the textbook retained its authority as conveyor of an unbiased narrative of the events. The researchers found little evidence of use of the tools of historical analysis or of the intention to expose students to the features of historical thinking.

Quite similarly, also a focus on accuracy in the study of history correlated with an overall disregard of context and the transmission of a fixed narrative. Students' inquiry was limited to an accurate analysis of the sources in order to support specific conclusions; issues of perspective were considered, though limited to identifying the side taken by a specific source. Overall, the interpretation rested with the teacher, and the teaching of historical thinking was perceived as impractical, due to time constraints and to the belief that students were still unable to engage in historical analysis.

Learners as recipients of knowledge versus learners as constructors of knowledge

The epistemic nature of beliefs about learning has often been debated in the literature and found problematic by several researchers (Hofer and Pintrich 1997, 2002; Schraw 2001). Yet, given that knowledge about learning is a fundamental component of teachers' professional knowledge, this dimension surfaced in several studies and appeared to be deeply intertwined with ideas referring more closely to epistemological issues previously discussed. Further, the beliefs about learning that emerged had an explicit epistemic character since they regarded the *nature* and *justification* of learning; thus differing considerably from ideas about learning identified in the literature as beliefs in *quick learning* and *fixed ability* (Schommer 1990), whose epistemic nature has been found problematic.

In general, two different views emerged from the studies. Some teachers conceptualized learning as receiving a body of knowledge developed by experts (e.g., scientists or historians); others perceived learning as the actively constructed understanding of the world (Johnston *et al.* 2001; Maor and Taylor 1995). Teachers expressing the first view tended to prefer rigidly structured, teacher-centered practices, dominated class discussions, and overall did not provide opportunities for students to develop their own questions. In addition, these teachers were particularly concerned that students internalized a correct answer. Thus, they tended to emphasize conventions and following directions, viewed themselves as the only authority in the classroom, preferred discussion of noncontroversial topics, and often used a pattern of interactions characterized by teacher-initiated questions, students' response, and teacher evaluation of competing outcomes.

On the other hand, teachers adopting a constructivist view of learning tended to share authority with the students, encouraged positive and mutually supportive exchanges among the students, emphasized the formulation of meaningful questions over answers to other people's questions, focused on helping students develop effective ways to generate and validate knowledge, and underscored the personal relevance of the topics investigated. These teachers were also comfortable with leaving the outcome of students' investigation sometimes uncertain, a situation that not only stimulated discussion but also produced frustration in some students.

It is interesting to note that the same patterns were observed in high-school science classes and in elementary school language-art classes and that some evidence suggests that these trends are not affected by teachers' academic backgrounds (Wilson and Wineburg 1993; Yeager and Davis 1996) or instructional context (Hashweh 1996). On the other hand, Brickhouse's (1990) study and findings on research projects involving student teachers (Gillaspie and Davis 1998) suggest a positive correlation between teachers' domain knowledge and the use of teaching strategies compatible with the epistemic nature of the discipline taught. Although the limited number of cases analyzed in these studies restricts generalizations and methodological differences may explain differences across studies, these discrepancies in the role played by teacher disciplinary knowledge may also support the hypothesis that the relation between teachers' individual epistemology and their pedagogical practices is moderated by a complex

set of teachers' educational goals and contextual constraints (Johnston *et al.* 2001; Kang and Wallace 2004).

The two sides of the coin: theories of knowledge and theories of learning

A few studies simultaneously considered teachers' epistemic views of knowledge and of learning and found overall similar patters of relations with pedagogical strategies use. In a multiple case study, Kang and Wallace (2004) focused on science teachers' use of labs. The researchers found that conceiving of science as a body of true factual knowledge and viewing students as consumers of scientific information correlated with using labs in order to convince students of the veracity of what was taught. Students were physically involved in the demonstrations. However, their cognitive involvement was limited to voting on predictions, listening to the abundant teacher's explanations, and writing down the (correct) results of the labs. The relation with labs' use was more complex in the case of a teacher who viewed science as true factual knowledge and also as a way to answer questions through problem solving; his use of lab activities varied markedly according to the specific aspect of science he intended to foster in a particular lesson. Specifically, structured labs were used to demonstrate specific processes, with no room left for discussion of results, while open-ended lab activities encouraged students to tackle concrete problems and build their own answers.

Teachers' views of knowledge and learning also influenced teachers' interpretation and consequent response to students' "wrong answers." Hashweh (1996) found that teachers holding constructivist beliefs (e.g., scientific knowledge is theory-driven and tentative; learning science often requires conceptual change) tended to be more sensitive in detecting the presence of alternative conceptions in students' answers than teachers holding empiricist beliefs (e.g., scientific knowledge is discovered and definitive; learning science is mainly acquisition of information). Constructivist teachers were therefore more likely to address the misconceptions, facilitating the overall integration of knowledge. They also tended to use a wider array of teaching strategies, such as refutation (use of counterexamples or anomalies), persuasion (using representations aiming at convincing the student), and solicitation of further questioning. Empiricist teachers tended instead to rehearse the "correct answer," offering further explanations.

The role of context: cognitive resources and classroom discourse

Louca *et al.* (2004) proposed a different framework for studying individual epistemology in science learning. In particular, they proposed that consistent and conscious epistemic beliefs evolve from cognitive resources that, activated by the context, enable individuals (including novices) to understand knowledge. Particularly in novices, these views may appear unstable and contradictory. For example, children may think of knowledge as transmitted when they say that they know what they will be eating for dinner because their parents told them so, but they may think of knowledge as constructed when they say that they know that their mom bought them a present since it is their birthday. It is only when individuals manifest the same response across different contexts that these researchers infer the development of an epistemic belief.

In the case of teachers, the influence of context in activating different resources is used to explain differences between the views of knowledge that the teachers verbalize and the beliefs that one would infer by observing classroom's interactions. It is also used to explain how teachers can help students to activate resources more adaptive to learning science by

temporarily move the discussion to familiar contexts in which the adaptive resource is more likely to be turned on.

The study of teachers' epistemological moves (i.e., discursive practices that teachers use to direct students' attention toward what counts as knowledge and appropriate ways of obtaining that knowledge in the specific situation) is a promising step in understanding how teachers' individual epistemology influence instruction. For example, Lidar *et al.* (2005) analyzed the interchanges between students and teachers in science classrooms and characterized teachers' epistemological moves as utterances that bring attention to what is important to notice in a particular situation (e.g., under what conditions does saltpeter dissolve in water). Yerrick *et al.* (1998) studied how a science teacher and three of his students confronted epistemological differences about the nature of scientific knowledge, suggesting that differences at this level may prompt student disengagements and skepticism toward school authority, if not openly acknowledged as such by the teacher. Similarly, Radigan (2002) found that students responsible for bringing epistemic issues to the forefront tended to be risk takers, who did not receive the highest grades in class, willing to voice minority points of view and to defy school rules. She also found that sequences in classroom discourse having an epistemic content happened only when ill-structured problems were discussed (although teachable moments happened also during the discussion of well-structured problems), the expression of different views was encouraged, the teacher was not placing herself as the only legitimate evaluator of knowledge claims, and the dialogue included questions encouraging reflection on knowledge beliefs (e.g., What do you think about that?).

Examples of pedagogical practices enacted by experts (both in education and in the subject matter taught) can be found in a few studies nested in the sciences and in history (Bain 2000; Elby 2001; Hammer 1995; Lampert 1990; VanSledright 2002; Osborne 1998). Although these case studies offer clear descriptions of the relation between teachers' individual epistemology and instruction, they are in many ways atypical, since research strongly suggests that teachers do not usually exhibit the same degree of epistemic consistency, nor do teachers with different kinds and levels of expertise appear to calibrate in the same degree (Cunningham *et al.* 2004; Johnston *et al.* 2001).

Disciplinary knowledge versus school knowledge: a double epistemic standard

A particular case of epistemic contextualization emerged in the case of a few teachers who acknowledged the constructed nature of the scientific explanations produced by scientists but viewed the science taught in school as the explanation of knowledge already existing. Thus, science "done" by scientists was conceived as a human and incomplete (albeit valid) explanation of natural phenomena that might be disproved; however, the "learning" about science occurring in the classroom was perceived as receiving accepted knowledge. This sort of "epistemic double standard" may explain what could appear as a contradictory pedagogical practice. For example, one of the teachers in the Kang and Wallace's (2004) study explicitly acknowledged the constructed and tentative nature of science but viewed school science as learning about knowledge that already existed. Although he acknowledged in class that the scientific approach was not the only one possible, his labs were structured so that students could experience how rigorous handling and evaluation of data conduced to support a given theory; this approach never allowed students to pursue alternative ways of thinking about the data.

Another example emerged in the case study of an elementary teacher, who characterized science as the study of anything in the surroundings through the perception of the senses but

saw scientists as more capable but distant individuals able to explain to "ordinary folks" what was happening (Laplante 1996). Thus, while she appeared aware that the work of scientists is theory-driven, she saw herself and her students as consumers of scientific knowledge. In teaching science, she elicited but then left unanswered children's questions about the specific topic. Seeing the object of school science as self-evident, she did not address children's alternative conceptions and used the books as final arbiters in deciding about the outcome of class discussions. Similarly, Hartzler-Miller (2001) found that a teacher who was well aware of the interpretive component of historical knowledge and of the importance of introducing his students to the practice of historical inquiry tended to adopt a recitation style, convinced that first students needed to become acquainted with the themes of historical scholarship and acquire a coherent historical narrative. As a teacher, he felt the responsibility to use his disciplinary knowledge for selecting the best conceptual tools for his students.

The role of calibration

A different and perhaps complementary perspective on the discrepancy between teachers' beliefs and their pedagogical practice may be offered by research on calibration. Although few studies have investigated teachers' calibration, it is reasonable to assume that findings from general adult populations should generalize to teachers. Initial empirical support of the generalizability of these findings to teachers is provided by a study investigating the role of teachers' calibration in pedagogical approaches to reading curriculum (Cunningham *et al.* 2004). These researchers hypothesized that teachers' calibration of their knowledge of varying conceptual approaches to a domain is a metacognitive skill crucial to how teachers use their already-held knowledge to gain new knowledge. Specifically, well-calibrated teachers know what they do and do not know and can therefore seek knowledge in areas that need improvement.

To test this hypothesis, Cunningham *et al.* tested 722 teachers of kindergarten through third grade on their knowledge of children's literature, phonological awareness, and phonics. Participants were also asked to rate their current knowledge of those areas. The correspondence between test responses and knowledge ratings was deemed calibration of domain knowledge. The only area where teachers were relatively well-calibrated as to their knowledge was children's literature. Teachers performed poorly on the knowledge measures of phonological awareness and phonics and were very poorly calibrated in these pedagogically more complex areas, suggesting that they knew little and were unaware that they knew so little. As posited by Lichtenstein and Fischhoff's earlier work (Lichtenstein and Fischhoff 1977), this was true regardless of how much experience (i.e., years teaching) teachers reported.

In their study investigating the influence of intelligence, expertise, and item difficulty on calibration, Lichtenstein and Fischhoff (1977) found that undergraduate and graduate students who knew more about the given questions usually demonstrated better calibration. However, very high levels of knowledge appeared to decrease calibration, since participants who answered more than 80% of the questions correctly were more poorly calibrated than the group that only got 70% correct. They also found that people tended to be overconfident regardless of intelligence or expertise. Therefore, we might assume that teachers who are experts in their content area and pedagogical knowledge are still prone to misrepresenting their own understanding of this knowledge. If this was the case, addressing teachers' beliefs without improving their calibration would not be very effective.

However, is training in calibration feasible? Lichtenstein and Fischhoff (1980) found that individuals increased the accuracy of their probability judgments after just one training ses-

sion that provided participants with feedback and opportunities for reflection and discussion. This suggests that calibration training could be implemented to help teachers become more aware of their beliefs and whether or not their instructional practices match those beliefs. More recent research, however, suggests a more complex picture since calibration, in turn, appears to be influenced by epistemic beliefs.

For instance, in their model, Stahl *et al.* (2006) assumed that epistemic beliefs indirectly affect whether individuals are poorly or well calibrated for a specific learning task. They hypothesized that learners who believed that knowledge is certain, simple, and transferable (so called "naïve beliefs") are more poorly calibrated to complex tasks than they are to simpler learning tasks. They also hypothesized that learners with these beliefs would be more poorly calibrated on complex tasks than learners who viewed knowledge as contextual, complex, and constructed (so called "sophisticated beliefs"). Stahl *et al.* found that those who believed that knowledge was contextual, complex, and constructed were better able to calibrate their goal setting and planning to the difficulty of the task. Given the exploratory nature of this study, participants did not actually complete the tasks; therefore, it is unknown whether or not they would have used the aspects of metacognition they rated as important for the specific tasks. In other words, they were demonstrating calibration of knowledge of task difficulty but not of perceived versus actual use of metacognitive monitoring and control.

This exploratory look at the link between epistemic beliefs and calibration suggests that the quality of epistemic cognition has an impact on individuals' adaptive use of metacognitive regulation, as defined by Baker and Brown (1984). If this holds true for teachers, adaptive metacognitive regulation may be needed for instructional practice of varying depth and complexity. In other words, teachers who view knowledge as complex would be expected to set more appropriate goals and engage in planning for more complex aspects of pedagogy than teachers who viewed knowledge as simple. However, it is necessary to study these processes specifically with teachers in order to determine the effects on instructional practice.

If teachers entertaining certain epistemic beliefs are better calibrated in their approach to instructional tasks, then it might be desirable to promote such beliefs. Would it be feasible? Muis (2007) indicated that change in epistemic beliefs is an incremental process that occurs over many encounters with conflicting information. Further, she indicated that for individuals to calibrate their held epistemic beliefs to epistemic beliefs necessary for a particular teaching paradigm, they must be explicitly aware of those beliefs. Thus, it is recommended that teachers engage in reflection and receive feedback in order to become better aware of their epistemic beliefs and better trained in how to calibrate them to different situations, a suggestion compatible with previous findings (Lichtenstein and Fischhoff 1980). In conclusion, it seems that calibration training could improve the process of making epistemic evaluations and change in beliefs. This possibility is worth exploring given that studies have reported discrepancies between teachers' beliefs and their practices (Schraw and Olafson 2003).

Discussion

Even if the majority of these studies cannot claim causality, a few consistent relations between teachers' individual epistemology and the tendency to adopt specific pedagogical practices emerged. Thus, these findings lend support to the hypothesis that, by affecting instruction, teachers' individual epistemology and calibration may play a role in fostering those conditions that enable students to become "masters" of their learning. At the same time, the findings also suggest that these relations are complicated by at least two factors. First, most of the studies

focused on describing and contrasting cases of teachers whose epistemic beliefs were captured by one side of the dichotomies we also used in summarizing the findings (e.g., constructivists vs. empiricists) because the main purpose of the researchers was the exploration of relations between epistemic beliefs and pedagogical practices. However, a few researchers also reported that a greater number of teachers who participated in the studies (or at least in earlier phases of the research projects) manifested beliefs belonging to both sides of this characterization (Blanco and Niaz 1997; Hashweh 1996; Johnston *et al.* 2001; Tsai 2006). For example, a teacher in Tsai's (2006) study believed that "[s]ome scientific knowledge is discovered, but some is invented." (p. 229). He then offered Kepler's laws as an example of the former and Einstein's relativity theory as an example of the latter.

A second factor increasing complexity is the school context in which teachers operate, since teachers need to consider not only the nature of scientific or historical knowledge but also the kind of knowledge construction they may want to foster in students, the curricular and institutional constraints they may face, and student contributions (or lack thereof) to the classroom exchange (Hartzler-Miller 2001; Laplante 1996; Lyons 1990; Rosenberg *et al.* 2006; Tirri *et al.* 1999; Webb and Blond 1995). In the following sections, we offer a few reflections on how this more nuanced appreciation of teachers' individual epistemology and calibration can foster our understanding of the conditions that may help students to become masters of their own learning and suggest a few implications for future research and practice.

Implications for the development of theoretical frameworks and epistemological research

Considered in the broader context of the research on metacognition, self-regulation, and self-regulated learning, we believe that findings from this review highlight the importance of integrating the dimensions of individual epistemology and calibration in theoretical models trying to capture the relation between these constructs and instruction. The case for integrating these constructs in models of metacognition (Flavell 1979; Hofer 2004; Kitchener 1983; Kuhn 1983), self-regulation (Hofer 2004), and self-regulated learning (Muis 2007; Pieschl *et al.* 2008; Winne and Hadwin 1998) has been made in the literature in regard to learners and briefly reviewed in the Supplementary Theoretical Material. How these models may capture teachers' metacognitive and self-regulatory processes is a question open to empirical research.

However, teachers with different beliefs about knowledge and knowing demonstrated a different understanding of which cognitive strategies would better foster students' understanding of the discipline taught (e.g., Brickhouse 1990; Duschl and Wright 1989; Gallagher 1991; Hashweh 1996; Tsai 2006). These teachers also differently asked (or failed to ask) questions about the trustworthiness of the available information and the method to generate knowledge in the specific domain. In regard to the effects on pedagogical practices, these variations generated a different set of questions offered to students and fostered different kinds of classroom discourse that are likely to influence students' metacognitive and self-regulatory processes (e.g., Johnston *et al.* 2001; Kang and Wallace 2004; Laplante 1996; Maor and Taylor 1995; Yerrick *et al.* 1998). Within these frameworks, calibration offers a possible explanation of the mechanism that links individual epistemology to self-regulation, suggesting viable research methodologies and instructional approaches.

On the other hand, the qualitative nature of many studies focusing on teachers' epistemic beliefs and the finer-grained analyses of classroom discourse showed a nuanced and contextualized view of individual epistemology that escapes the naïve/sophisticated dichotomy (e.g., Blanco and Niaz 1997; Johnston *et al.* 2001; Lidar *et al.* 2005; Louca *et al.* 2004; Tsai 2006). These findings suggest that this popular characterization may be an artifact of questionnaires that measure epistemic sophistication mostly along the dimensions of certainty

and simplicity of knowledge, with no reference to how individuals believe knowledge claims should be justified in a given situation and within a particular domain.

Thus, the distinction between beliefs reflecting an overall relativistic stance and beliefs reflecting the acquisition of criteria that enable the individual to build knowledge even under conditions of uncertainty is blurred, and the likely differences in terms of metacognition, self-regulation, and self-regulated learning get lost. In addition, the naïve/sophisticated dichotomy does not provide space for acknowledging the role that context plays in the use of specific epistemic criteria and in their convenience in regards to learning a specific content in a certain domain. For example, their individual system of epistemic beliefs notwithstanding, we expect that very few people ever doubted their date and place of birth, although such knowledge has probably been transmitted to them by some authority. Finally, teachers' epistemic beliefs appear to include a few unique components, such as beliefs regarding the characteristics of knowledge imparted in school and beliefs about the role of the learner in the process of knowledge building.

The focus on teachers' individual epistemology naturally favored a domain-specific approach, nesting this body of research within knowledge domains. Although some common traits emerged across teachers of different subject matters, several features of individual epistemology were linked to the specificity of the domain; thus supporting the hypothesis that epistemic beliefs are both general and domain specific (Buehl and Alexander 2001; Muis *et al.* 2006). From a methodological point of view, the studies also offered a diverse set of methods that may increase understanding of this complex and somewhat elusive terrain.

Walking across the borders of different bodies of literature

In exploring the topic of this review, a lack of dialogue between bordering bodies of literature emerged. Given the limits of this review, we are far from claiming generality. However, we found it particularly noteworthy that the research on teaching hardly mentioned the work done on teachers' epistemic cognition and epistemic beliefs (Munby *et al.* 2001). On the other hand, research on teaching can provide many insights about the context in which teachers operate that might influence teachers' individual epistemology and inform the somewhat limited educational psychology literature in this area.

Similarly, research focusing on a particular domain seemed unaware of parallel research done with regard to a different disciplinary area, although we found several common trends emerging from the findings. In this regard, it seems that electronic databases may be a mixed blessing; although they greatly facilitate researchers' access to a vast array of resources and may give the illusion of broad coverage, slight differences in vocabulary and the selection of journals included in the databases may keep apart bodies of literature that shares much in terms of substance. In preparing this review, we were surprised that a few studies we thought very pertinent were not directly retrieved by our searches; however, this epistemic question greatly surpasses the scopes of this contribution.

The role of teacher disciplinary knowledge and professional experience

The influence of professional experiences and disciplinary knowledge on teachers' individual epistemology and on their pedagogical practice is unclear. In studies of preservice teachers, deep knowledge of the discipline usually correlated with beliefs in the constructed nature of knowledge and learning. Studies of practicing teachers did not include specific measures of teachers' disciplinary knowledge. Yet, these studies reported that beliefs about the nature of the discipline do not necessarily extend to the subject matter taught in school

(e.g., Kang and Wallace 2004). Moreover, teaching experience seems to play an ambivalent role in regard to how teachers' beliefs are translated into practice (e.g., Kang and Wallace 2004). In a longitudinal study, Cady *et al.* (2006) found that novice teachers tended to revert to traditional beliefs and pedagogical practices at the beginning of their career; with experience, most of them embraced a more relative view of truth and their beliefs about teaching and learning became more cognitively based. However, the influence of these beliefs on their pedagogical practice seemed to depend on their overall individual epistemology, suggesting that educational intervention may affect teachers' beliefs about learning without translating into changes in pedagogical practice whenever they conflict with the teachers' epistemic beliefs. Given the high numbers of studies focusing on preservice teachers that we found in our search, it is important to note that the outcome of this review does not support the extension of findings in the preservice teacher population to experienced teachers. Clearly, more classroom-based research is necessary to address this issue.

Teaching teachers

Considered as a whole, these findings suggest that there are no "teacher-proof" curricular innovations or "ready for use" pedagogical strategies likely to foster per se students' epistemic development and thus facilitate mastering of the learning process. In other words, pedagogy is only as effective as a means to learning as teachers are clear on what they wish that their students learn. Including the development of epistemic cognition among the explicit goals of teachers' education curricula and professional development programs may look like a long-term project; yet, it is fundamental for fostering effective teaching practices across all school levels. Alternatively, formalism (i.e., the tendency to apply abstract principles without considering the real context) tends to be a likely outcome (Pajares and Graham 1998).

In addition, research suggests that it may be possible to train teachers to calibrate the accuracy of their epistemic cognition and teaching practices for a specific discipline through providing feedback on the difference between believing and doing, thus improving both epistemic and metacognitive monitoring and subsequent strategy use. As highlighted by a few case studies, such education is a crucial requisite especially when the constraints of the school system and the inevitable tradeoffs between breadth and depth defy the pursuing of goals of epistemic development that require time and effort. Without it, teachers will hardly have the necessary resilience and creativity to face the challenge.

Acknowledgment We would like to acknowledge with gratitude the valuable guidance and insights offered by our developmental reviewers, Krista R. Muis and P. Karen Murphy.

References

Bain, R. (2000). Into the breach: Using research and theory to shape history instruction. In P. N. Stearns, P. Seixas, & S. Wineburg (Eds.), *Knowing, teaching and learning history: National and international perspectives* (pp. 331–352). New York: New York University Press.

Baker, L., & Brown, A. L. (1984). Metacognitive skills and reading. In P. D. Pearson, M. Kamil, R. Barr, & P. Mosenthal (Eds.), *Handbook of reading research* (vol. 1, (pp. 353–394)). White Plains, NY: Longman.

Beers, S. E. (1988). Epistemological assumptions and college teaching: Interactions in the college classroom. *Journal of Research and Development in Education*, *21*(4), 87–94.

Blanco, R., & Niaz, M. (1997). Epistemological beliefs of students and teachers about the nature of science: From 'baconian inductive ascent' to the 'irrelevance' of scientific laws. *Instructional Science*, *25*, 203–231. doi:10.1023/A:1002992204311.

Brickhouse, N. W. (1990). Teachers' beliefs about the nature of science and their relationship to classroom practice. *Journal of Teacher Education*, *41*(3), 53–62. doi:10.1177/002248719004100307.

Buehl, M. M., & Alexander, P. A. (2001). Beliefs about academic knowledge. *Educational Psychology Review*, *13*, 385–418. doi:10.1023/A:1011917914756.

Cady, J., Meier, S. L., & Lubinski, C. A. (2006). Developing mathematics teachers: The transition from preservice to experienced teacher. *The Journal of Educational Research*, *99*(5), 295–305. doi:10.3200/JOER.99.5.295-306.

Calderhead, J. (1996). Teachers: Beliefs and knowledge. In D. C. Berliner, & R. C. Calfee (Eds.), *Handbook of educational psychology* (pp. 709–725). New York: Macmillan.

Clark, C. M., & Peterson, P. L. (1986). Teachers' thought processes. In M. C. Wittrock (Ed.), *Handbook of research on teaching* (pp. 255–296). New York: Macmillan.

Cunningham, A. E., Perry, K. E., Stanovich, K. E., & Stanovich, P. J. (2004). Disciplinary knowledge of K-3 teachers and their knowledge calibration in the domain of early literacy. *Annals of Dyslexia*, *54*(1), 139–167. doi:10.1007/s11881-004-0007-y.

Duschl, R. A., & Wright, E. (1989). A case study of high school teachers' decision making models for planning and teaching science. *Journal of Research in Science Teaching*, *26*(6), 467–501. doi:10.1002/tea.3660260602.

Elby, A. (2001). Helping physics students learn how to learn. *Physics Education Research: American Journal of Physics, Supplemental*, *69*(7), 54–64.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive-developmental inquiry. *The American Psychologist*, *34*(10), 906–911. doi:10.1037/0003-066X.34.10.906.

Fox, E., & Riconscente, M. M. (2008). Metacognition and self-regulation in the theories of James, Piaget, and Vygotsky. *Educational Psychology Review* (this issue).

Gallagher, J. J. (1991). Prospective and practicing secondary school science teachers' knowledge and beliefs about the philosophy of science. *Science Education*, *75*(1), 121–133. doi:10.1002/sce.3730750111.

Gillaspie, M. K., & Davis Jr., O. L. (1998). Historical constructions: How elementary student teachers' historical thinking is reflected in their writing of history. *The International Journal of Social Education*, *12*(2), 35–45.

Hammer, D. (1995). Epistemological considerations in teaching introductory physics. *Science Education*, *79*(4), 393–413. doi:10.1002/sce.3730790404.

Hashweh, M. (1996). Effects of science teachers' epistemological beliefs in teaching. *Journal of Research in Science Teaching*, *33*(1), 47–63. doi:10.1002/(SICI)1098-2736(199601)33:1<47::AID-TEA3>3.0.CO;2-P.

Hartzler-Miller, C. (2001). Making sense of "best practice" in teaching history. *Theory and Research in Social Education*, *29*, 672–695.

Hofer, B. K. (2004). Epistemological understanding as a metacognitive process: Thinking aloud during online searching. *Educational Psychologist*, *39*(1), 43–55. doi:10.1207/s15326985ep3901_5.

Hofer, B. K., & Pintrich, P. R. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research*, *67*(1), 88–140.

Hofer, B. K., & Pintrich, P. R. (2002). *Personal epistemology: The psychology of beliefs about knowledge and knowing*. Mahwah, NJ: Lawrence Erlbaum.

Jehng, J. J., Johnson, S. D., & Anderson, R. C. (1993). Schooling and Students' Epistemological Beliefs about Learning. *Contemporary Educational Psychology*, *18*, 23–35. doi:10.1006/ceps.1993.1004.

Johnston, P., Woodside-Jiron, H., & Day, J. (2001). Teaching and learning literate epistemologies. *Journal of Educational Psychology*, *93*(1), 223–233. doi:10.1037/0022-0663.93.1.223.

Kang, N., & Wallace, C. (2004). Secondary science teachers' use of laboratory activities: Linking epistemological beliefs, goals, and practices. *Science Education*, *89*(1), 140–165. doi:10.1002/sce.20013.

King, P. M., & Kitchener, K. S. (2004). Reflective judgment: Theory and research on the development of epistemic assumptions through adulthood. *Educational Psychologist*, *39*(1), 5–18. doi:10.1207/s15326985ep3901_2.

Kitchener, K. S. (1983). Cognition, metacognition and epistemic cognition: A three-level model of cognitive processing. *Human Development*, *26*, 222–232.

Kuhn, D. (1983). On the dual executive and its significance in the development of developmental psychology. In D. Kuhn, & J. A. Meacham (Eds.), *On the development of developmental psychology* (pp. 81–110). Basel, NY: Karger.

Lampert, M. (1990). When the problem is not the question and the solution is not the answer: Mathematical knowing and teaching. *American Educational Research Journal*, *27*(1), 29–63.

Lampert, M., & Blunk, M. L. (1998). *Talking mathematics in school: Studies of teaching and learning*. New York: Cambridge University Press.

Laplante, B. (1996). Teachers' beliefs and instructional strategies in science: Pushing analysis further. *Science Instruction*, *81*, 277–294.

Lichtenstein, S., & Fischhoff, B. (1977). Do those who know more also know more about how much they know? *Organizational Behavior and Human Performance*, *20*, 159–183. doi:10.1016/0030-5073(77)90001-0.

Lichtenstein, S., & Fischhoff, B. (1980). Training for calibration. *Organizational Behavior and Human Performance*, *26*, 149–171. doi:10.1016/0030-5073(80)90052-5.

Lidar, M., Lundqvist, E., & Ostman, L. (2005). Teaching and learning in the science classroom: The interplay between teachers' epistemological moves and students' practical epistemology. *Science Education*, *90* (1), 148–163. doi:10.1002/sce.20092.

Louca, L., Elby, A., Hammer, D., & Kagey, T. (2004). Epistemological resources: Applying a new epistemological framework to science instruction. *Educational Psychologist*, *39*(1), 57–68. doi:10.1207/s15326985ep3901_6.

Lyons, N. (1990). Dilemmas of knowing: Ethical and epistemological dimensions of teachers' work and development. *Harvard Educational Review*, *60*(2), 159–180.

Maggioni, L., Riconscente, M., & Alexander, P. A. (2006). Perceptions of knowledge and beliefs among undergraduate students in Italy and in the United States. *Learning and Instruction*, *16*(5), 467–491. doi:10.1016/j.learninstruc.2006.09.006.

Maor, D., & Taylor, P. C. (1995). Teacher epistemology and scientific inquiry in computerized classroom environment. *Journal of Research in Science Teaching*, *32*(8), 839–854. doi:10.1002/tea.3660320807.

Munby, H., Russell, T., & Martin, A. K. (2001). Teachers' knowledge and how it develops. In V. Richardson (Ed.), *Handbook of research on teaching* (pp. 877–904). Washington, DC: American Educational Research Association.

Muis, K. R. (2007). The role of epistemic beliefs in self-regulated learning. *Educational Psychologist*, *42*(3), 173–190.

Muis, K. R., Bendixen, L. D., & Haerle, F. (2006). Domain-generality and domain-specificity in personal epistemology research: Philosophical and empirical reflections in the development of a theoretical framework. *Educational Psychology Review*, *18*, 3–54. doi:10.1007/s10648-006-9003-6.

Nietfeld, J. L., & Schraw, G. (2002). The effect of knowledge and strategy training on monitoring accuracy. *The Journal of Educational Research*, *95*(3), 131–142.

Osborne, M. D. (1998). Teacher as knower and learner: Reflection on situated knowledge in science teaching. *Journal of Research in Science Teaching*, *35*(4), 427–439. doi:10.1002/(SICI)1098-2736(199804)35:4<427::AID-TEA12>3.0.CO;2-6.

Pajares, F., & Graham, F. (1998). Formalist thinking and language arts instruction: Teachers' and students' beliefs about truth and caring the teaching conversation. *Teaching and Teacher Education*, *14*(8), 855–870. doi:10.1016/S0742-051X(98)80001-2.

Paulsen, M. B., & Wells, C. T. (1998). Domain differences in the epistemological beliefs of college students. *Research in Higher Education*, *39*(4), 365–384. doi:10.1023/A:1018785219220.

Perry, W. (1970). *Forms of intellectual and ethical development in the college years: A scheme*. Troy, MO: Holt, Rinehart & Winston.

Pieschl, S., Stahl, E., & Bromme, R. (2008). Epistemological beliefs and self-regulated learning with hypertext. *Metacognition and Learning*, *3*, 17–37. doi:10.1007/s11409-007-9008-7.

Radigan, J. (2002). Personal epistemological beliefs in the high school classroom. *Dissertation Abstracts International*, *63* (2-A). (UMI no. 3042445).

Rosenberg, S., Hammer, D., & Phelan, J. (2006). Multiple epistemological coherences in an eight-grade discussion of the rock cycle. *Journal of the Learning Sciences*, *15*(2), 261–292. doi:10.1207/s15327809jls1502_4.

Schommer, M. (1990). Effects of beliefs about the nature of knowledge on comprehension. *Journal of Educational Psychology*, *82*, 498–504. doi:10.1037/0022-0663.82.3.498.

Schraw, G. (2001). Current themes and future directions in epistemological research: A commentary. *Educational Psychology Review*, *13*(4), 451–464. doi:10.1023/A:1011922015665.

Schraw, G., Dunkle, M. E., & Bendixen, L. D. (1995). Cognitive processes in well-defined and ill-defined problem solving. *Applied Cognitive Psychology*, *9*, 523–538. doi:10.1002/acp.2350090605.

Schraw, G., & Olafson, L. (2003). Teachers' epistemological world views and educational practices. *Journal of Cognitive Education and Psychology*, *3*, 178–235 (online).

Stahl, E., Pieschl, S., & Bromme, R. (2006). Task complexity, epistemological beliefs and metacognitive calibration: An exploratory study. *Journal of Educational Computing Research*, *35*(4), 319–338. doi:10.2190/1266-0413-387K-7J51.

Tirri, K., Jukka, H., & Kansanen, P. (1999). The epistemological stance between the knower and the known. *Teaching and Teacher Education*, 15, 911–922. doi:10.1016/S0742-051X(99)00034-7.

Tsai, C. (2006). Teachers' scientific epistemological views: The coherence with instruction and students' views. *Science Education*, *91*(2), 222–243. doi:10.1002/sce.20175.

VanSledright, B. (2002). *In search of America's past: Learning to read history in elementary school*. New York: Teachers College.

Wadsworth, L. M. (2007). Teachers' epistemologies: Beliefs, theories of intelligence and approaches to instruction. *Dissertation Abstracts International*, *68* (6-A). (UMI No. 3270626).

Webb, K., & Blond, J. (1995). Teacher knowledge: The relationship between caring and knowing. *Teaching and Teacher Education*, *11*(6), 611–625. doi:10.1016/0742-051X(95)00017-E.

Wilson, S. M., & Wineburg, S. S. (1993). Wrinkles in time and place: Using performance assessment to understand the knowledge of history teachers. *American Educational Research Journal*, *30*(4), 729–769.

Winne, P. H., & Hadwin, A. F. (1998). Studying as self-regulated learning. In D. J. Hacker, J. Dunlosky, & A. C. Graesser (Eds.), *Metacognition in educational theory and practice* (pp. 277–304). Mahwah, NJ: Lawrence Erlbaum.

Yeager, E. A., & Davis Jr., O. L. (1996). Classroom teachers' thinking about historical texts: An exploration study. *Theory and Research in Social Education*, *24*(2), 146–166.

Yerrick, R. K., Pedersen, J. E., & Arnason, J. (1998). "We're just spectators": A case study of science teaching, epistemology, and classroom management. *Science Education*, *82*, 619–648. doi:10.1002/(SICI)1098-237X(199811)82:6<619::AID-SCE1>3.0.CO;2-K.

Zimmerman, B. J. (2008). Investigating self-regulation and motivation: Historical background, methodological developments, and future prospects. *American Educational Research Journal*, *45*(1), 166–183. doi:10.3102/0002831207312909.