PLEASE DO NOT DISTRIBUTE

Epistemic Cognition as a Psychological Construct:

Advancements and Challenges

Barbara K. Hofer

Middlebury College, USA

Revision submitted May 29, 2015, for *Handbook of Epistemic Cognition*. Please address correspondence to Barbara K. Hofer, Ph.D., Department of Psychology, Middlebury College 05753, bhofer@middlebury.edu.

Epistemic Cognition as a Psychological Construct:

Advancements and Challenges

What is knowledge? How do we know what we know? What influence might this set of beliefs have on how we think, reason, and learn? To offer a simple example, when I was seven my parents bought a set of encyclopedias and with giddy enthusiasm, I began reading the entries in sequence, motivated by the belief that if I were only to read each of these volumes, I would know all there was to know in the world. My beliefs about knowledge (my own folk epistemology) were that it was finite, constant, uncontested, existing as a discrete set of facts, conveyed by authorities through books. Knowing, I believed, came about by reading and remembering information, absorbing the knowledge of experts – a pure transmission model of learning that relied solely on memorization. It was not long, and much closer to A than Z, that I not only became bored with the process and returned to reading out of interest, but also knew I was not retaining all that I read, a substantial disappointment. Such realizations, however, have fueled a lifetime of interest in understanding how people learn, the role individual conceptions of knowledge and knowing play in the process, and how these perspectives change over time. This interest is shared by an ever-growing body of researchers, whose extensive knowledge on the topic is the subject of this handbook.

What individuals believe about knowledge and knowing and how they think and reason about the epistemological aspects of knowing are all part of a psychological construct now being called epistemic cognition. This set of cognitive processes has a deeply

influential role in learning, both formally and informally, throughout life, as well as in everyday encounters with new information and in the assessment of competing authorities. This matters not only during schooling but is also critical to an educated citizenry who have the competence to assess the abundance of information available on any complex topic. Recent examples of public confusion in the U.S. about such scientific topics as climate change, vaccinations, evolution and the teaching of creationism in the schools all suggest the difficulties posed when individuals have difficulty weighing epistemic claims (Bromme & Goldman, 2014; Sinatra, Kienhues, & Hofer, 2014), and the implications for communities, educational systems, and the planet. The need for clear thinking on these issues becomes ever more evident, and those who study epistemic cognition have a critical role to play in establishing and asserting the value of the construct and its role in education.

Beliefs about knowledge and knowing, their patterned development over time, and their relation to other cognitive processes have been studied by a wide array of researchers over the past five decades, with exponential growth in the past dozen or so years. Although philosophers have long been interested in epistemology, defined as the nature and scope of knowledge, and its origins, limits, and justification, psychologists are now making an important contribution in investigating how people actually think and reason about epistemic issues. This research broadly includes such concerns as what individuals count as a valid source of knowledge, the perceived certainty and simplicity of knowledge, and the processes by which individuals weigh competing truth claims, justify what they know, and validate their own knowing (Hofer & Bendixen, 2012).

With this volume, the editors stake a claim on a term that has previously had more limited meaning, and which might now serve to unite a somewhat disparate field of scholarship. Epistemic cognition is one of several attempts over the years to create an inclusive term that might encompass this wide-ranging set of research programs focused on a similar set of processes. This body of work has also been identified as *personal epistemology* (Hofer & Pintrich, 2002a), an umbrella term chosen for the first edited anthology on the topic (whose initial working title, ironically, was *Epistemic Cognition)*. The need for an inclusive term is critically important at this juncture in time, as it could help individuals from disparate fields (e.g., educational psychology, developmental psychology, higher education, science education, math education, learning sciences, etc.) more easily identify similar research lines and learn from one another's work.

Research on epistemic cognition has grown exponentially, from a body of work that could be comprehensively surveyed in a single review article less then twenty years ago (Hofer & Pintrich, 1997), to a sweeping array of articles, chapters, special issues of journals, and edited volumes, requiring a handbook such as this one to address. The engagement of new researchers entering the field from diverse graduate programs, differing academic backgrounds, and most notably, disparate cultures, has brought about a dramatic expansion in research on epistemic cognition. Multiple challenges persist, however, and although researchers have been addressing many of the concerns quite systematically, others have also arisen. This chapter provides a brief overview of the field by delineating three waves of development, describes the challenges that have been addressed to date, and identifies broader issues for the research community to address collaboratively in the years ahead.

Epistemic Cognition: Defining the Field

Epistemic cognition, broadly conceived, is a term used to describe a set of mental processes that involve the development and employment of one's conceptions of knowledge and knowing. The construct has been studied under varied nomenclature over time, such as epistemological beliefs (Schommer, 1990; Schommer-Aikins, 2004) , epistemological theories (Hofer & Pintrich, 1997), folk epistemology (R. F. Kitchener, 2002), reflective judgment (King & Kitchener, 1994, 2004), epistemological reflection (Baxter Magolda, 2001), women's ways of knowing (Belenky, Clinchy, Goldberger, & Tarule, 1986; Clinchy, 2002), epistemological resources (Elby & Hammer, 2010; Hammer & Elby, 2002), and epistemic cognition (Chinn, Buckland, & Samarapungavan, 2011; Greene, Torney-Purta, & Azevedo, 2010; K. S. Kitchener, 1983). Research has also been conducted on beliefs about epistemology at a disciplinary level, such as beliefs about math (De Corte, Op 't Eynde, Depaepe, & Verschaffel, 2010; Muis, 2004a, 2004b; Schoenfeld, 1992; Weber, Inglis, & Mejia-Ramon, 2014), history (Maggioni, VanSledright, & Alexander, 2009; VanSledright, 2004; Wineburg, 1991), and science (Deng, Chen, & Tsai, 2011; Lederman, 2007; Samarapungavan, Westby, & Bodner, 2006; Sandoval, 2014).

In the first usage of the term "epistemic cognition," Kitchener (1983) described it as a higher order process in a three-level model of cognitive processing, with basic cognition at the first level (e.g., perceiving, reading, memorizing) and metacognition at the second, involving a monitoring of one's cognitive processes. Epistemic cognition, resting on the foundation of the first two levels, was postulated as occurring when individuals considered the *limits*, *certainty*, and *criteria* for knowing (K. S. Kitchener, 1983). This process was later

described as the foundation of critical thinking, evoked when solving ill-structured problems (King & Kitchener, 2002). The connection among cognition, metacognition, and epistemic cognition has been theorized in several different ways (Barzilai & Zohar, 2014; Hofer, 2004a; Kuhn, 1999), but several aspects remain central. One is that prior accounts of cognition and metacognition alone do not account for the type of mental processes involved in epistemic cognition. Secondly, the psychological construct that involves beliefs about knowledge and knowing needs to be understood as a *process*, a set of mental activities that involve the activation and application of epistemological understanding. Thirdly, epistemic cognition is an essential element of critical thinking and a meaningful topic worthy of educational attention. All of these properties are at the core of an evolving understanding of epistemic cognition.

Although Kitchener and King continued to use epistemic cognition to describe their work on reflective judgment (King & Kitchener, 2002), the term began to be used by other researchers primarily within the last decade, with several attempts to bring a philosophical perspective to an understanding of the term. In arguing for epistemic cognition as the most precise descriptor for the field, Greene, Azevedo, and Torney-Purta (2008) described it as a term that "emphasizes knowledge and the processes involved in its definition, acquisition, and use" (p. 143). Heeding Murphy's call for better integration of philosophy into educational psychology broadly and into personal epistemology research especially (Murphy, 2003), the authors also separated ontological and epistemic cognition, and expanded the notion of justification of knowledge. Epistemic cognition was also the overarching term chosen to define a more highly elaborated integration of philosophy and

psychology in a new model that offers an expansion of relevant dimensions (Chinn et al., 2011; Chinn, Rinehart, & Buckland, 2014).

As noted, the range of terms used to describe this construct have varied by researchers and by discipline, and within this chapter the terms that are historically accurate are generally used to describe those research traditions, as it seems anachronistic to suggest otherwise. In addition, it may be fruitful for the field to view epistemic cognition as a broad set of cognitive processes that encompass these other constructs, as subsets of the larger field. For example, the use of the term epistemic cognition does not necessarily imply that constructs such as epistemic beliefs or epistemological resources or epistemic aims are invalid or have been supplanted, but might suggest that we need to better understand how each cognitively operates and how they work together within this overarching construct. The problem with using the term epistemic cognition to stand for all prior work in the field is to risk ignoring the nuanced distinctions among them as well as to dismiss the differing cognitive properties of each of these constructs, how they are instantiated in practice, and how they can best be studied.

Furthermore, in regard to terminology, although there have been numerous calls to adhere to philosopher R. Kitchener's differentiations of when to use "epistemic" and when to use "epistemological" (R. F. Kitchener, 2002), this practice has not been widely followed. As he notes, the term "episteme" refers to knowledge, and "epistemology" to a theory of knowledge. Thus epistemic beliefs would refer to beliefs about knowledge and knowing, and epistemological beliefs would refer to beliefs about epistemology, making the former a more accurate representation of what researchers have addressed. He also notes that philosophers view cognitions as considerably weaker than a state of knowledge, and that

"epistemic cognition is cognition (representation) about the epistemic, but it need not be knowledge about the epistemic" (Kitchener, 2002, p. 93). My hope is that as the field moves toward the use of epistemic cognition to describe a broad body of research, leaders in this field will err on the side of inclusiveness, drawing on a history of diverse research paradigms and models and using that richness to create a more sharply honed theoretical synthesis. Such a synthesis would clarify the components of epistemic cognition and how they operate as well as how they develop over time, and identify how these processes are related to other aspects of cognitive development and are influenced by education, culture, and other environmental influences.

Research on Epistemic Cognition: Three Waves of Scholarship

In the progression of research on epistemic cognition, three waves of scholarship are notable. The first of these is the primarily qualitative, interview-based research that led to the creation of several parallel developmental models (Baxter Magolda, 1992; Belenky et al., 1986; King & Kitchener, 1994; King, Kitchener, Davison, Parker, & Wood, 1983; Kuhn, 1991; Perry, 1970). The second wave involved a reconceptualization of the construct as a set of beliefs (Schommer, 1990), assessed by questionnaires with Likert-scale items. Research proliferated as a result, particularly in regard to linking epistemic beliefs to other constructs.

The third wave involves the flourishing of research in the past decade or so that has been characterized by several key themes. These include theoretical development and new paradigmatic models, greater attention to philosophical underpinnings of the field, research on domain generality and specificity, the expansion of methods and measures, the inclusion of broader populations other than college students, the cultural proliferation of

research, a rethinking of grain size and situating epistemic cognition, more work on the relation to other constructs, and the application to new contexts and issues, such as digital literacy and the public understanding of science.

The First Wave: Developmental Models of Epistemic Cognition

As described in depth elsewhere (Hofer & Pintrich, 1997), interest in college students' beliefs about knowledge and knowing originated with Perry's qualitative, phenomenological, longitudinal study of Harvard undergraduates (Perry, 1970, 1981). Consistent with psychological paradigms of the period in which he began his research (pilot studies began in 1953), Perry expected to find that personality differences were likely to explain the different ways in which students made sense of their educational experiences. Perry designed his first measure, the Checklist of Educational Values (CLEV), by drawing on research on authoritarian personality, allowing him to select for further interviews those students who scored at the extremes or the mean of what he described as dualistic or contingent thinking, or who had shown significant change during an academic year. Years later, in the analysis of the resulting open-ended interviews conducted over four years of college, Perry (1970) and his research staff concluded that the differences they observed were not evidence of personal style, as they had expected, but instead offered evidence for a scheme of intellectual developmental during college. More in tune with the invariantly sequenced, hierarchically integrated stage theories prominent in psychology at the time this work was published (Erikson, 1959; Kohlberg, 1969; Piaget, 1972), the "Perry scheme", as it has come to be called, delineated nine positions of intellectual and ethical development. These cluster into four categories: dualism, multiplism, contextual relativism, and commitment within relativism.

Although Perry did not use the term epistemological development, researchers who followed recognized in his stages an evolving understanding of what it means to know and, accordingly, how one goes about the processes of learning and understanding. Some researchers then followed similar processes as Perry, creating interview questions designed to elicit how college students made meaning of their own experiences over time (Baxter Magolda, 1992; Baxter Magolda & Porterfield, 1985) or how women, in particular, viewed knowledge and knowing (Belenky et al., 1986). Although Perry's questions had been unusually open-ended ("Would you like to say what has stood out for you during the year?"), others designed ill-structured problems around topics such as the safety of chemical additives in foods (King & Kitchener, 1994), with interview questions that probed epistemic thinking, such as whether experts could disagree and whether more than one point of view might be possible (Kuhn, 1991).

These early models of epistemic cognition portrayed the construct as a highly integrated, multi-dimensional conception, one that evolved in response to educational and environmental conditions. An analysis of the extant models showed similar dimensions and progression of development (Hofer & Pintrich, 1997), regardless of the number of stages in the model or the methods employed. The underlying assumption was that as students progressed in their development, these facets worked together. Individuals were generally described as moving from an objectivist, absolutist stance toward knowledge and knowing toward a more subjectivist, relativist position, before learning to effectively coordinate the two, thus operating with an evaluativistic perspective (Kuhn, Cheney, & Weinstock, 2000).

The central contributions of this first wave of research are foundational in some lines of current work, by several of these same researchers who have continued to contribute immeasurably to the field, and by those who have followed. This group of researchers identified a construct that had not yet been addressed by psychologists, and one that seemed to play a significant role in higher education and to be connected to the process of critical thinking (Kurfiss, 1988) and argumentation (Kuhn, 1991). They identified open-ended methods that allowed for a phenomenological take on students' meaning making and pioneered questions designed to elicit epistemic cognition in response to ill-structured problems. They used their findings to create developmental models that became useful heuristics for understanding development during the college years, assisted by other researchers and those who helped translate research into practice (Knefelkamp, 1998; Knefelkamp & Slepitza, 1978; Moore, 2002) which helped post-secondary educators understand the value of higher order epistemic stances and how education might foster that process. These developmental models are the basis of a strand of research that informs student development work in higher education (Baxter Magolda, Creamer, & Meszaros, 2010; King & Baxter Magolda, 2005). As noted earlier, this was also the period when the term epistemic cognition was coined (K. S. Kitchener, 1983), even though it was not in wide use by others.

The Second Wave of Research: Paradigmatic Shifts, Dimensionality, and Connections to Other Constructs

Schommer's proposal for a model of *epistemological beliefs*, with dimensions that were believed to be more or less independent (Schommer, 1990), challenged the assumptions of developmental models, launching a second wave of research that has

continued alongside the developmental research paradigm. This conceptualization of the construct described a set of beliefs that could be tapped through self-report measures, by responses to items rated through Likert-type scales. Drawing from such sources as Perry's CLEV, beliefs about mathematics (Schoenfeld, 1985, 1992), and items written to assess beliefs about intelligence (Dweck & Leggett, 1988), Schommer created a 63-item measure that for the first time made it possible not only to assess larger groups of students than could be assessed using interview methods, but also to link epistemology to other constructs. In this model, sophistication proceeds in a linear direction that can be captured through degree of agreement with a set of items initially written to tap five dimensions: fixed ability, quick learning, simple knowledge, certain knowledge, and source of knowledge. As noted in an earlier review (Hofer & Pintrich, 1997), the developmental models were also multi-dimensional, but the progression was expected to advance across dimensions at each stage, in a more integrated fashion. Those models also included more attention to the nature of justification in knowing, and did not include fixed ability or quick learning.

A flurry of research followed Schommer's work, and over the next decade other models and measures were offered, with various dimensional configurations and names (Hofer, 2000; Kardash & Howell, 2000; Schraw, Bendixen, & Dunkle, 2002). Schommer had also pioneered the investigation of linkages between epistemological beliefs and other constructs of interest to educational psychologists, showing that beliefs were related to comprehension (Schommer, 1990), performance, and strategy use (Schommer, Crouse, & Rhodes, 1992). Others explored how epistemic beliefs connected to such constructs as need

for cognition (Kardash & Scholes, 1996) and conceptual change (Windschitl & Andre, 1998), among others.

Parallel to these developments taking place in educational psychology, science educators were growing increasingly interested in how student beliefs about the nature of science (the values and assumptions of science as a way of knowing) influenced the ability to learn and understand science (Lederman, 1992), a body of work that has also continued to expand. In addition, researchers began to assess epistemological interventions (Elan & Clarebout, 2001), an area of inquiry that has continued to grow, and to challenge the domain specificity of the field (Buehl, Alexander, & Murphy, 2002; Hofer, 2000), demonstrating how individuals could hold differing epistemic beliefs about specific disciplines. The most significant contribution of this second wave of research was that it offered a paradigmatic shift that changed the field and made the work known to educational psychologists, who were eager to assess relations with other constructs and now had a method to do so.

The Third Wave of Epistemic Cognition Research: Theoretical, Cultural and Methodological Expansion

In the past dozen years, research on the topic of personal epistemology and epistemic cognition, broadly defined, has grown exponentially, and research on epistemic cognition has become a prominent topic in educational psychology journals and a growing area of research in the learning sciences. Although the nomenclature varies, related research continues to appear within the fields of higher education, developmental psychology, science education, and teacher education, as well as in other areas. A healthy tension began to permeate the field as researchers debated issues of dimensionality, grain

size, domain and topic specificity, the role of context, and offered new paradigmatic models, measures, and methods of analysis. Advancements have been prominent in several areas, as described below.

Theoretical development and new paradigmatic models. Although use of the terms epistemic and epistemological beliefs continue to appear in a large number of articles, researchers have also challenged whether epistemic understanding exists at that level, or might be organized as theories (Hofer & Pintrich, 1997), or operate as more fine-grained epistemological resources (Hammer & Elby, 2002; Hammer & Elby, 2003) or be more situated and contextual (Sandoval, 2005, 2014). Paradigmatic approaches to epistemology have grown, particularly in the rethinking of the relation to metacognition (Barzilai & Zohar, 2014). In particular, theoretical models have also been elaborated by drawing more on the philosophical origins of the field, as elaborated below.

Greater connection to philosophy. Several epistemic cognition researchers have done notable work in reading philosophy more deeply, working with philosophers directly, and developing new models that take philosophical epistemology seriously (Chinn et al., 2011; Greene, Azevedo, & Torney-Purta, 2008; Murphy, 2003). Central to any philosophical account of epistemology is the nature of justification (R. F. Kitchener, 2011), and expanding the dimensions of epistemic cognition to encompass the various means by which knowledge is justified (Greene et al., 2008) has been a critical contribution to the field.

Further alignment with philosophical accounts of epistemology can help further the field of epistemic cognition. In a paper linking personal epistemology and philosophical epistemology, philosopher R. F. Kitchener (2011) listed ten major questions of epistemology that he expects "any adequate epistemology would addresses….and hence

that PE (personal epistemology) should include" (p. 89). These include areas addressed to some degree in various programs of epistemic cognition research, such as the nature of truth, the sources of knowledge and whether they are external to the individual or internal, as well as the role of justification. Kitchener also listed others that are less often explored by personal epistemology or epistemic cognition researchers, such as the respective roles of reason and sense experience, definitions of propositional knowledge, and the nature of a priori versus posteriori knowledge. His comments provide potential fruitful insights for further research in this regard. Psychologists have also begun to take traditional philosophical problems and address them experimentally (Starmans & Friedman, 2012).

Furthermore, epistemology has been regarded by many philosophers as social in nature (Goldman, 2011), and this has merited recent attention of epistemic cognition researchers (Bromme, 2003; Greene et al., 2008). This inclusion of the social dimensions of knowledge is likely to have significant applicability in more culturally inclusive models of epistemology (Hofer, 2008). Social epistemology, while acknowledging individual epistemic decision-making, takes into account the role of evidence provided by others, such as arguments and opinions (interpersonal social epistemology), as well as group judgments, such as those made by juries (collective social epistemology), and community and societal level influences on the knowledge state of a society (e.g., institutional social epistemology) (Goldman & Blanchard, 2012). As Goldman and Blanchard (2012) noted, this latter perspective is particularly relevant to the public understanding of science, a growing topic of attention in epistemic cognition (Sinatra et al., 2014). This particular aspect of epistemology seems to show promise for future development of psychological models of epistemic cognition as well as the potential to direct researchers' attention to constraints

and affordances of knowledge building that influence individuals, such as classrooms (e.g., epistemic climate, Bendixen & Rule, 2004, and Feucht, 2010), schools, communities, the media, and the political climate.

Simultaneous with this third wave of epistemic cognition in psychology is the rise of interest among philosophers in how people think about the issues that philosophers have long pondered and theorized, including epistemology (Beebe, 2014). Grasswick (2014), for example, has explored issues of epistemic trust in regard to how laypersons perceive climate change experts, and examined the role of positionality in knowledge production. The field of experimental philosophy is growing as well (Alexander, 2012; Machery & O'Neill, 2014), with philosophers making use of psychological methods to explore traditional philosophical issues, and this is a fruitful time for collaboration on shared research. Not only do psychologists need to learn from and connect with philosophers on matters of shared interest, but philosophers are also learning from psychologists as they begin to undertake experimental studies of laypersons' employment of epistemology.

Domain generality and domain specificity. Although arguments were made for moderate domain generality in the second wave of research (Schommer & Walker, 1995), this issue now seems well-resolved in support of the existence of domain specificity (Hofer, 2006a; Muis, Bendixen, & Haerle, 2006). Epistemic cognition appears to operate at three levels: general beliefs about knowledge, disciplinary perspectives on beliefs (e.g., that knowledge might be more certain in one field than another), and beliefs that are specifically about disciplines (the nature of science, for example) (Hofer, 2005). Researchers are also actively pursuing the idea of topic-specific beliefs. What we know far less about is how domain-specific and domain-general beliefs operate together, although

one recent study suggests that this may vary by level of background in the field (Schommer-Aikins & Duell, 2013). One persistent issue is that researchers differ in what they mean by domain (Hofer, 2006b) with educational psychologists presuming it to be synonymous with discipline (Muis et al., 2006) and developmental psychologists referring to matters of taste, aesthetics, and values, for example (Chandler & Proulx, 2010; Kuhn et al., 2000; Mason, Boldrin, & Zurlo, 2006; Wainryb, Shaw, Langley, Cottam, & Lewis, 2004). More precision and clarity are needed in this area.

Methodological critiques and expansion. The study of epistemological development began with interview studies and then an attempt to codify assessments of stages into written measures, followed by a period in which epistemological beliefs were studied through Likert scales. Although these methods all continue, use of the Likert scale has become particularly problematic, for several reasons (Hofer, 2005). One issue is that the scale suggests a linear progression, which runs counter to the developmental view that meaning is restructured at each level, from absolutism to multiplism to evaluativism. Likert scales may capture the low end of the spectrum well, in identifying agreement with certainty of knowledge (e.g., "truth is unchanging in this field"). Complete disagreement with such a measure of certainty, however, is more likely to indicate multiplism rather than a fully sophisticated epistemic understanding, and it is unclear how evaluativism can be inferred at all from such measures, when used to capture a construct by summing responses. Secondly, similar problems exist in the applicability and relevance of what counts as sophisticated or availing beliefs in Likert scale measures in many contexts, particularly in discipline-specific and topic-specific studies of epistemic beliefs (Braten, Stromso, & Samuelstuen, 2008). The problem is the presumption, inherent in the

measurement, that sophistication always proceeds away from certainty and a reliance on experts. This means that those who question the certainty of what is known about gravity or doubt the authority of experts on the topic of evolution would be seen as exhibiting advanced epistemic beliefs. Researchers need to rethink what counts as sophistication or what beliefs are actually availing in regard to diverse topics, contexts, and educational settings, and then design measures that better capture this complexity. Moreover, little evidence of reliability and validity exists for the survey instruments most often in use (Clarebout, Elen, Luyten, & Bamps, 2001; DeBacker, Crowson, Beaslery, Thom, & Hestevold, 2008), and this is further complicated when they are used in other cultures, with little consistency in findings (Buehl, 2008).

New measures and methods have been developed and refined and added to the repertoire of techniques used to assess epistemic cognition, as reviewed in the related chapters in this volume (Kelly, in press; Mason, in press). These have included a semantic differential instrument (Stahl & Bromme, 2007), use of think-aloud protocols (Ferguson, Braten, & Stromso, 2011; Hofer, 2004a; Mason, Boldrin, & Ariasi, 2010) , as well as classroom observational methodologies (Elby & Hammer, 2010; Hofer, 2004e), the use of card sorts and network analysis (Peters-Burton & Baynard, 2013), and mixed methods studies (Bromme, Pieschl, & Stahl, 2010).

Inclusion of broader populations. Interest in college student learning has continued since the original line of work on epistemological development, and is the population that serves as the basis for many studies of epistemic beliefs, whether by interest or convenience. In this third wave of research, however, many researchers have expanded the age range of those studied, including pre-schoolers (Barth, Bhandari, Garcia,

MacDonald, & Chase, 2014; Burr & Hofer, 2002; Wildenger, Hofer, & Burr, 2010), elementary school children (Conley, Pintrich, Vekiri, & Harrison, 2004; Elder, 2002), and a growing number of studies of adolescents (Cano, 2005; Murphy et al., 2010). What seems to be a pressing need is to organize the findings into a more coherent and nuanced developmental account than the rough three-level heuristic that seems to have survived the decades, as well as to further involve adult participants in order to better understand the function of epistemic cognition in society (Kuhn, 1991), and to conduct studies that include both children and adults (Greene & Yu, 2014), and students and experts (Samarapungavan et al., 2006). The field would benefit from further analyses of real-world epistemic judgments, such as the studies of juror reasoning (Weinstock, in press; Weinstock & Cronin, 2003) .

One of the most significant developments in the expansion of populations studied during this third wave has been research on teachers' epistemic beliefs and the role they play in students' beliefs and learning (Brownlee, Schraw, & Berthelsen, 2013), as reviewed in a later chapter (Buehl & Fives, in press). Another line of current research examines how epistemological beliefs may be related to pre-service teachers' motivation for choosing science teaching, an important line of inquiry (Kilinc & Seymen, 2014).

Cultural proliferation. Perhaps one of the most exciting and important aspects of the recent exponential growth of epistemology research has been the entry of scholars from across the globe (Hofer, 2008; Khine, 2008) and now spanning the continents. For the most part, these researchers have used existing western measures and translated them, with mixed success (see Buehl, 2008, for a comprehensive review), although new measures have also been designed (Stahl & Bromme, 2007), surprisingly little has been done to

create measures that might more effectively tap what could be culturally distinctive about epistemic understanding in other environments. Issues of the role of authority (Hofer, 2010), the social nature of knowledge, and how the purpose of knowledge is viewed may all differ, for example, between North America and many Asian countries, yet existing measures likely would be insensitive to these distinctions. The next wave of research may challenge existing models further, perhaps with more research that expands dimensionality and challenges the universality of the continuum of sophistication implied in existing models. Further comparative cross-cultural work is also needed, but is also hampered by instrumentation; as Buehl (2008) noted, current measures that lack a cultural conceptualization of dimensionality are not likely to be appropriate for assessing group differences.

Rethinking grain size and situating epistemic cognition. A significant subject of attention in the field during the last decade has been a consideration of the grain size and context of epistemic cognition. In addition to an expansion of studies addressing epistemic cognition within various disciplines (Mason, 2003; Muis, 2004b; Sandoval, 2014; Tsai, 2005; VanSledright, 2004), researchers have turned their attention to topic-level beliefs, such as epistemic beliefs about climate change (Stromso, Braten, & Samuelstuen, 2008) and the internet (Chiu, Liang, & Tsai, 2013; Stromso & Braten, 2010). What is needed is a model of how different levels of beliefs operate together, and in what types of contexts particular levels take precedence in guiding understanding.

The situated nature of epistemic cognition has become a fertile area for understanding how these processes operate, and this issue also relates to debates about scale. Are these fine-grained resources (Elby & Hammer, 2010; Hammer & Elby, 2003)

dependent on context for activation, or are they beliefs that are accessible to the individual through self-report (Schommer-Aikins, 2002)? How labile are they? How malleable? Sandoval (2014) has argued for a contextual, situated view of epistemic cognition, tied to activities and their structure. From this perspective, a developmental account of epistemic cognition for science educators would eschew the invariant stages of earlier psychological models and focus more on students' experiences with science, both in and out of school, how individuals come to understand science, and how this cognition is situated in the settings in which it occurs (Sandoval, 2014). These varying views of epistemic cognition that have become increasingly well articulated during the past decade are helping to shape a new generation of researchers, and point the way to new methods and questions.

Relation to other constructs. Other than the cultural explosion, work on connecting epistemic cognition to other constructs has probably been one of the most pronounced developments in the field. Researchers have worked to delineate the connections to metacognition (Barzilai & Zohar, 2014; Bromme et al., 2010; Hofer, 2004a; Hofer & Sinatra, 2010; Kuhn, 1999; Mason & Bromme, 2010) and self-regulation (Pieschl, Stahl, & Bromme, 2013). We also are learning more about the role of epistemic climate (how the nature of knowledge and knowing is represented in classrooms) (Feucht, 2010; Muis & Duffy, 2013) and how it fosters epistemic cognition. The relation to other constructs includes need for cognition and need for closure (DeBacker & Crowson, 2006), conceptual change (Mason, 2010; Mason & Boscolo, 2004; Murphy, Alexander, Greene, & Edwards, 2007), motivation (Buehl & Alexander, 2005), volition (Rule & Bendixen, 2010), and argumentation (Kuhn, Zillmer, Crowell, & Zavala, 2013; Mason & Scirica, 2006; Yang & Tsai, 2010). (See Hofer & Bendixen, 2012 for a more comprehensive review.) More work is

merited to address not only how epistemic cognition relates to other cognitive constructs, but also what teachers can do to foster more meaningful connections, for example, between epistemic cognition and self-regulation.

Exploring epistemic cognition in new contexts. At a time when technology has exponentially enhanced our access to information, epistemic cognition researchers have recognized that information and digital literacy are fundamentally epistemological issues. In their online searches, individuals make judgments about the veracity and certainty of what they read (Hofer, 2004a), are challenged to construct knowledge from multiple viewpoints (Barzilai & Eshet-Alkalai, 2015), and need both effective skills of self-regulated learning and productive epistemic cognition (Greene, Yu, & Copeland, 2014). The ease of digital access to information, the hidden and vested interests of online providers of information, and the shaping of content to specific consumers, all suggest the importance of teaching epistemic strategies as part of digital literacy, as well as the need for further research in these areas. A growing body of work has addressed this topic (Ferguson et al., 2011; Mason et al., 2010; Stromso & Braten, 2010).

Intervention studies. Researchers have long been curious about the role that education plays in the development of epistemic cognition, particularly from a developmental perspective during the college years (King & Kitchener, 1994; Widick, Knefelkamp, & Parker, 1975). Similarly, following the logic that more availing epistemic cognition is beneficial to the learning process, researchers have begun to examine interventions with both teachers (Gill, Ashton, & Algina, 2004) and students (Mason & Scrivani, 2004; Muis & Duffy, 2013), including short-term interventions (Kienhues, Bromme, & Stahl, 2008). This work is still in its initial phases and merits further attention

from researchers, with the need to explore how best to intervene, the structure and timing of interventions, and the duration of effects. One recent line of work posits the idea of "epistemic conceptual change" as a means of promoting reasoning and thinking in science, with suggestions for teachers (Sinatra & Chinn, 2012), a model that might help guide additional interventions.

Advancements in Epistemic Cognition and Challenges for Researchers

Roughly at the start of the third wave of research on epistemic cognition, Pintrich (2002) identified a key set of issues for the field, commenting that "the research on personal epistemologies is moving from an area of…interest to a fairly small group of dedicated researchers to a position of salience in the general research effort on development and learning" (p. 413). Most of these issues have been addressed extensively since that time, such as domain generality and specificity; the relation to cognition, motivation, and learning; components of epistemic cognition; and measures and methods, although work remains, of course.

Concerns about the nature of the construct, one of the issues Pintrich listed, have become far more sophisticated and nuanced in the last decade, involving a deeper reading of the philosophical literature, as noted earlier (Chinn, Buckland, & Samarapungavan, 2010; Greene et al., 2008). There is a pressing need for reconciliation among approaches and the development of congruent models that can guide the fourth wave of research, as well as tests of proposed models (Bendixen & Rule, 2004). What remains to be seen is whether the use of the term epistemic cognition as defined by Greene et al. (2008), as broadly encompassing the processes involved in the definition, acquisition, and use of knowledge, will open the door to a broader research agenda. How knowledge is acquired and used, for

example, involves the entire learning process, and this creates a larger category of potential concepts than those relating to the origins, justification, and limits of knowledge and knowing. In addition, Chinn and colleagues, for example, have suggested that epistemic cognition consists of aims and values, epistemic ideals, and reliable processes for achieving epistemic ends (Chinn et al., 2014). Others have elaborated on expanding the nature of justification (Greene et al., 2008), and some initial assessments support the utility of this contribution (Braten, Ferguson, Stromso, & Anmarkurud, 2013; Greene & Yu, 2014). In addition, the field also needs further cultural examination and possibly expansion of the dimensions, as existing models originated in the west.

Another area that has received little recent attention is the mechanism of change and the process of development. Most early models converged on a general progression of development toward greater sophistication over time, but new issues emerged with situated models (Hammer & Elby, 2002), as well as the idea of recursion (Chandler, Hallett, & Sokol, 2002). Both are continuing to get attention, but it remains unclear whether contextualist models can be reconciled with developmental accounts. Issues of recursion, with individuals looping back through developmental progressions, particularly at various transitions in education, may speak to the contextual nature of development.

Broader Challenges for Epistemic Cognition Researchers

In addition to the concerns raised above that are continuing to be addressed, broader challenges have arisen. The list of further research prospects will no doubt be expanded at length in this volume, chapter by chapter. In addition, however, there are several larger concerns for this growing body of researchers to address together, as a community of

scholars invested in a topic we believe to be of meaning and importance to a wider audience.

Consensus on naming the field. As noted earlier, we would benefit as a research community from agreeing on a term that broadly contains the array of scholarship being conducted by those interested in the cognitive processes that involve epistemic reasoning, thinking, and understanding. This volume may help establish epistemic cognition as that term, allowing us to find one another's work at conferences and in journals, regardless of our disciplinary training and divisional affiliations.

One problem with terms in this field, whichever they may be – epistemological beliefs, personal epistemology, epistemic cognition – is that they seem inaccessible to those outside of academia. In honoring the construct's philosophical origins in our naming conventions, we may risk losing a broad audience of teachers, journalist, scientists, and others who could make use of the very ideas we champion. Epistemology is not a term in ordinary discourse, and no matter what form of it is used to create a psychological construct, the terms may appear to have an air of academic pretension, although that is not intended. What makes it possible for us to discuss our findings with each other may be keeping others from making use of them.

Refinement of models and theoretical synthesis. Sometimes we still seem to be describing parts of the same elephant, without certainty that we are aware of the whole being. We need a better integration of approaches, and models that combine a developmental perspective with the conceptions of resources, beliefs, frameworks, and theories, with a deeper understanding of the processes by which these elements work together, and in various contexts. The higher education community sees advanced

epistemological development as a desirable outcome of a college education; educational psychologists see epistemic beliefs as predictors of learning; some science educators and learning scientists view epistemic resources as a contextual variable. Epistemic cognition is all these things: multi-directional in its influence, situated, contextual. We are in need of better models that explain these inter-relationships so we can better interpret and utilize the research being generated.

Increasing awareness of the construct among psychologists, learning scientists, and educators more broadly. Although growth in the field has included multiple edited volumes (Bendixen & Feucht, 2010; Brownlee et al., 2013; Hofer & Pintrich, 2002c; Khine, 2008; Taylor & Ferrari, 2011) and special issues of journals such as *Educational Psychologist*, *Metacognition and Learning*, *Contemporary Educational Psychology,* and *Asian Pacific Researcher*, this focus of attention does not seem to have led to the type of wider awareness in either the psychological or educational community that might be expected. Currently research on the connection to other variables seems unidirectional, in that epistemic cognition researchers investigate the relation with other constructs such as motivation and learning strategies, but the construct is seldom used by others as an additional explanatory variable in broader studies. This may also be an artifact of measurement problems, however, and the vagaries of terminology in use.

The need for "translators" and reaching a broader audience of practitioners. In some areas of psychology and education, research has reached practitioners through authors capable of expressing ideas and findings in layperson terminology and identifying implications for practice. Examples abound, such as Willingham's "Ask the Cognitive Psychologist" columns in *American Educator,* or books on teaching for college faculty

(Svinicki & McKeachie, 2014), or books on motivation for teachers (Anderman & Anderman, 2013). Others have learned how to successfully convey their own research to lay audiences, a growing trend in psychology; Dweck's (2006) reframing of her research on incremental theories of ability into the idea of a "growth mindset" is notable in its impact on teachers, parents, and students. Do we need an even simpler way of describing our work than "epistemic cognition"? Or do we just need to get better and more comfortable at explaining what it means when we talk to teachers and students?

For a topic that is the subject of dozens of books and thousands of articles and that has been shown to play an influential role in learning and to be influenced by educational processes, there is very little visibility in teacher education or in the field of information literacy. Given what we have learned about the role of epistemic cognition in the learning process, as well as the influence of teachers' beliefs (Buehl & Fives, in press), we need to make this a construct teachers would not only think it was important to understand but would know how and why to foster in their classes. Yet research on the topic has appeared only intermittently and briefly in the top educational psychology texts and rarely in developmental textbooks. Do we need to do more to make it clear why it matters? Or are we writing in ways that make our findings less than accessible? This seems to be a primary challenge for the field in the next era. We need to go beyond writing for other researchers and academics and learn to write for those who can use this information. Foremost, this would be teachers, who address epistemic beliefs as impediments to learning on a daily basis but may not be aware of it and lack a sense of the construct in a way that would make it applicable to instruction. Imagine a textbook chapter, for example, that would provide teachers with the research on epistemic cognition, but also provide tools to foster an

examination of their own epistemic cognition and a means of examining their classroom practices in this light, as well as understanding their students' epistemic beliefs, development, and epistemic processes.

Making it clear to a larger audience why it matters to understand epistemic cognition. Epistemic cognition can offer an explanatory mechanism not only for student learning processes, but for why laypersons may have divergent beliefs about such well established scientific claims as evolution, climate change, and a variety of issue of public importance (Sinatra et al., 2014). Scientists are beginning to address issues of science denial in their journals (Rosenau, 2012), seeking psychological explanations for rejection of scientific consensus on central principles and topical issues that have been largely resolved by scientists but remain questionable for much of the public. Epistemic cognition researchers have much to offer to help with such an understanding. Those who communicate about science in the media could also benefit from our knowledge of how individuals may misinterpret the tentative nature of science.

Conclusion

The field of epistemic cognition has progressed in three waves of development and is well poised for major accomplishments in the years ahead. In 2003, Mayer noted that the field was still in its infancy and showed stunted growth, given thirty years of prior research at that time. He argued that moving the field forward required "a productive attitude towards science, a set of testable theories, a set of useful research methods, and a solid base of empirical results" (Mayer, 2003, p. 317) and argued that publishing in mainline, peer-reviewed journals would be a step toward respectability. Given the work that has been done since that time, and the vast number of peer-reviewed articles in top-tier respectable

journals, researchers are to be commended for considerable advancements in the progression of epistemic cognition research. As each of the following chapter authors are likely to outline for us, much work remains, as well. Those of us engaged in this enterprise can help make it clear to others that epistemic cognition is not only an educational concern but also involves the development and application of a critically useful set of skills that can be applied, and which continue to develop, throughout life.

References

Alexander, J. (2012). *Experimental philosophy: An introduction*. Cambridge: Polity.

Anderman, E. M., & Anderman, L. H. (2013). *Classroom motivation*. Boston: Pearson.

Barth, H., Bhandari, K., Garcia, J., MacDonald, K., & Chase, E. (2014). Preschoolers trust novel members of accurate speakers' groups and judge them favorably. *Quarterly Journal of Experimental Psychology, 67*, 872-883.

Barzilai, S., & Eshet-Alkalai, Y. (2015). The role of epistemic perspectives in comprehension of multiple author viewpoints. *Learning and Instruction*, *36*, 86-103.

Barzilai, S., & Zohar, A. (2014). Reconsidering personal epistemology as metacognition: A multifaceted approach to the analysis of epistemic thinking. *Educational Psychologist, 49*, 13-15.

Baxter Magolda, M. B. (1992). *Knowing and reasoning in college: Gender-related patterns in students' intellectual development*. San Francisco: Jossey Bass.

Baxter Magolda, M. B. (2001). *Making their own way: Narratives for transforming higher education to promote self-development*. Sterling, VA: Stylus.

Baxter Magolda, M. B., Creamer, E. G., & Meszaros, P. S. (Eds.). (2010). *Development and assessment of self-authorship: Exploring the concept across cultures*. Sterling, VA: Stylus.

Baxter Magolda, M. B., & Porterfield, W. D. (1985). *Assessing intellectual development: The link between theory and practice*. Alexandria, VA: American College Personnel Association.

Beebe, J. R. (Ed.). (2014). *Advances in experimental epistemology*. London: Bloomsbury Academic.

Belenky, M. F., Clinchy, B. M., Goldberger, N. R., & Tarule, J. M. (1986). *Women's ways of knowing: The development of self, voice, and mind*. New York: Basic Books.

Bendixen, L. D., & Feucht, F. C. (2010). *Personal epistemology in the classroom: Theory, research, and implications for practice*. Cambridge, UK: Cambridge University Press.

Bendixen, L. D., & Rule, D. C. (2004). An integrative approach to personal epistemology: A guiding model. *Educational Psychologist, 39*, 69-80.

Braten, I., Ferguson, L. E., Stromso, H. I., & Anmarkurud, O. (2013). Justification beliefs and multiple-documents comprehension. *European Journal of Psychology of Education, 28*, 879-902.

Braten, I., Stromso, H. I., & Samuelstuen, M. S. (2008). Are sophisticated students always better?The role of topic-specific personal epistemology in the understanding of multiple expository texts. *Contemporary Educational Psychology, 33*, 814-840.

Bromme, R. (2003). Thinking and knowing about knowledge: A plea for and critical remarks on psychological research programs on epistemological beliefs In M. H. G. Hoffman, J. Lenhard, & F. Seeger (Eds.), *Activity and sign: Grounding mathematics education* (pp. 1-11). Netherlands: Kluwer.

Bromme, R., & Goldman, S. R. (2014). The public's bounded understanding of science. *Educational Psychologist, 49*, 56-69.

Bromme, R., Pieschl, S., & Stahl, E. (2010). Epistemological beliefs are standards for adaptive learning: A functional theory about epistemological beliefs and metacognition. *Metacognition and Learning, 5*, 7-26.

Brownlee, J., Schraw, G., & Berthelsen, D. (Eds.). (2013). *Personal epistemology and teacher education*. New York: Routledge.

Buehl, M. M. (2008). Assessing the multidimensionality of students' epistemic beliefs across diverse cultures. In K. M. S (Ed.), *Knowing, knowledge and beliefs: Epistemological studies across diverse cultures*. Dordrecht, The Netherlands: Springer.

Buehl, M. M., & Alexander, P. A. (2005). Motivation and performance differences in students' domain-specific epistemological belief profiles. *American Educational Research Journal, 42*, 697-726.

Buehl, M. M., Alexander, P. A., & Murphy, P. K. (2002). Beliefs about schooled knowledge: Domain specific or domain general? *Contemporary Educational Psychology, 27*, 415-449.

Buehl, M. M., & Fives, H. (in press). The role of epistemic cognition in teacher learning and praxis. In J. A. Greene, W. A. Sandoval, & I. Braten (Eds.), *Handbook of epistemic cognition*. New York: Routledge.

Burr, J. E., & Hofer, B. K. (2002). Personal epistemology and theory of mind: Deciphering young children's beliefs about knowledge and knowing. *New Ideas in Psychology, 20*, 199-224.

Cano, F. (2005). Epistemological beliefs and approaches to learning: Their change through secondary school and their influence on academic performance. *British Journal of Educational Psychology, 75*, 203-221.

Chandler, M. J., Hallett, D., & Sokol, B. W. (2002). Competing claims about competing knowledge claims. In B. K. Hofer & P. R. Pintrich (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 145-168). Mahwah, NJ: Erlbaum.

Chandler, M. J., & Proulx, T. (2010). Stalking young persons' changing beliefs about belief. In L. D. Bendixen & F. C. Feucht (Eds.), *Personal epistemology in the classroom: Theory, research, and implications for practice* (pp. 197-219). Cambridge, UK: Cambridge University Press.

Chinn, C. A., Buckland, L. A., & Samarapungavan, A. (2010). *Expanding the dmensions of research on epistemic cognition: Applying philosophy to psychology and education*. Paper presented at the American Educational Research Association, Denver.

Chinn, C. A., Buckland, L. A., & Samarapungavan, A. (2011). Expanding the dimensioins of epistemic cognition: Arguments from philosophy and psychology. *Educational Psychologist, 46*(3), 141-167.

Chinn, C. A., Rinehart, R. W., & Buckland, L. A. (2014). Epistemic cognition and evaluating information: Applying the AIR model of epistemic cognition. In R. N. Rapp & J. L. G. Braasch (Eds.), *Processing inaccurate information: Theoretical and applied perspectives from cognitive science and the educational sciences* (pp. 425-453). Cambridge: MIT Press.

Chiu, Y.-L., Liang, J.-C., & Tsai, C.-C. (2013). Internet-specific epistemic beliefs and self-regulated learning in online academic information searching. *Metacognition and Learning, 8*, 235-260.

Clarebout, G., Elen, J., Luyten, L., & Bamps, H. (2001). Assessing epistemological beliefs: Schommer's questionnaire revisited. *Educational research and evaluation, 7*(1), 53-77.

Clinchy, B. M. (2002). Revisiting women's ways of knowing *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 63-87).

Conley, A. M., Pintrich, P. R., Vekiri, I., & Harrison, D. (2004). Changes in epistemological beliefs in elementary science students. *Contemporary Educational Psychology, 29*, 186-204.

De Corte, E., Op 't Eynde, P., Depaepe, F., & Verschaffel, L. (2010). The reflexive relation between students' mathematicss-related beliefs and the mathematics classroom culture. In L. D. Bendixen & F. C. Feucht (Eds.), *Personal epistemology in the classrroom: Theory, research, and implications for practice* (pp. 292-327). Cambridge, UK: Cambridge University Press.

DeBacker, T. K., & Crowson, H. M. (2006). Influences on cognitive engagement: Epistemological beliefs and need for closure. *British Journal of Educational Psychology, 76*.

DeBacker, T. K., Crowson, H. M., Beaslery, A. D., Thom, S. J., & Hestevold, N. (2008). The challnge of measuring epistemological beliefs: An analysis of three self-report instruments. *Journal of Experimental Education, 76*, 281-312.

Deng, F., Chen, D.-T., & Tsai, C.-C. (2011). Students' views of the nature of science: A critical review of the research. *Science Education, 95*(6), 961-999.

Dweck, C. S., & Leggett, E. L. (1988). A social-cognitive approach to motivation and personality. *Psychological Review, 95*(2), 256-273.

Elan, J., & Clarebout, G. (2001). An invasion in the classroom: Influence of an ill-structured innovation on instructional and epistemological beliefs. *Learning Environments Research, 4*, 87-105.

Elby, A., & Hammer, D. (2010). Epistemological resources and framing: A cognitive framework for helping teachers interpret and respond to their students' epistemologies. In L. D. Bendixen & F. C. Feucht (Eds.), *Personal epistemology in the classroom: Theory, research, and implications for practice* (pp. 409-434). Cambridge, UK: Cambridge University Press.

Elder, A. D. (2002). Characterizing fifth-grade students' epistemological beliefs in science *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 321-346). Mahwah, NJ: Erlbaum.

Erikson, E. (1959). Identity and the life cycle: Selected papers. *Psychological Issues, 1*, 1-171.

Ferguson, L. E., Braten, I., & Stromso, H. (2011). Episemic cognition when students read aloud multiple documents containing conflicting scientific evidence: A think-aloud study. *Learning and Instruction, 22*, 103-120.

Feucht, F. C. (2010). Epistemic climate in elementary classrooms. In L. D. Bendixen & F. C. Feucht (Eds.), *Personal epistemology in the classroom: Implications for theory and research* (pp. 55-93). Cambridge: Cambridge University Press.

Gill, M. G., Ashton, P. T., & Algina, J. (2004). Changing preservice teachers' epistemological beliefs about teaching and learning in mathematics: An intervention study. *Contemporary Educational Psychology, 29*, 164-185.

Goldman, A. I. (2011). A guide to social epistemology. In A. I. Goldman (Ed.), *Social epistemology: Essential readings* (pp. 11-37). Oxford: Oxford University Press.

Goldman, A. I., & Blanchard, T. (2012). Social epistemology. *Oxford Bibliographies Online*. Retrieved from

Greene, J. A., Azevedo, R., & Torney-Purta, J. (2008). Modeling epistemic and ontological cognition: Philosophical perspectives and methdological directions. *Educational Psychologist, 43*, 142-160.

Greene, J. A., Torney-Purta, J., & Azevedo, R. (2010). Empirical evidence regarding relations among a model of epistemic and ontological cognition, academic performance, and educational level. *Journal of Educational Psychology, 102*, 234-255.

Greene, J. A., & Yu, S. B. (2014). Modeling and measuring epistemic cognition: A qualitative re-investigation. *Contemporary Educational Psychology, 39*, 13-28.

Greene, J. A., Yu, S. B., & Copeland, D. Z. (2014). Measuring critical components of digital literacy and their relationships with learning. *Computers and education, 76*, 55-69.

Hammer, D., & Elby, A. (2002). On the form of a personal epistemology. In B. K. Hofer & P. R. Pintrich (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 169-190). Mahwah, NJ: Erlbaum.

Hammer, D., & Elby, A. (2003). Tapping epistemological resources for learning physics. *Journal of the Learning Sciences, 12*, 53-90.

Hofer, B. K. (2000). Dimensionality and disciplinary differences in personal epistemology. *Contemporary Educational Psychology, 25*, 378-405.

Hofer, B. K. (2004a). Epistemological understanding as a metacognitive process: Thinking aloud during online searching. *Educational Psychologist, 39*, 43-55.

Hofer, B. K. (2004b). Exploring the dimensions of personal epistemology in differing classroom contexts: Student interpretations during the first year of college. *Contemporary Educational Psychology*, *29,* 129-163.

Hofer, B. K. (2005). The legacy and the challenge: Paul Pintrich's contributions to personal epistemology research. *Educational Psychologist, 40*, 95-105.

Hofer, B. K. (2006a). Beliefs about knowledge and knowing: Integrating domain specificity and domain generality. *Educational Psychology Review, 18*, 67-76.

Hofer, B. K. (2006b). Domain specificity of personal epistmology: Resolved questions, persistent issues, new models. *International journal of educational research, 45,* 85-95.

Hofer, B. K. (2008). Personal epistemology and culture. In M. S. Khine (Ed.), *Knowing, knowledge and beliefs: Epistemological studies across diverse cultures*. Dordrecht, The Netherlands: Springer.

Hofer, B. K. (2010). Epistemology, learning, and cultural context: Japan and the U.S. In B. M. B. Magolda, E. G. Creamer, & P. S. Meszaros (Eds.), *Development and assessment of self-authorship: Exploring the concepts across cultures*. Sterling, VA: Stylus.

Hofer, B. K., & Bendixen, L. D. (2012). Personal epistemology: Theory, research, and future directions In K. Harris, S. Graham, & T. Urdan (Eds.), *APA educational psychology handbook, Vol. 1. Theories, constructs, and critical issues* (pp. 227-256). Washington, DC: American Psychological Association.

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*, 88-140.

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

Hofer, B. K., & Sinatra, G. M. (2010). Epistemology, metacognition, and self-regulation: Musings on an emerging field. *Metacognition and Learning, 5*, 113-120.

Kardash, C. M., & Howell, K. L. (2000). Effects of epistemological beliefs and topic-specific beliefs on undergraduates' cognitive and strategic processing of dual-positional text. *Journal of Educational Psychology, 92*, 524-535.

Kardash, C. M., & Scholes, R. J. (1996). Effects of preexisting beliefs, epistemological beliefs, and need for cognition on interpretation of controversial issues. *Journal of Educational Psychology, 88*, 260-271.

Kelly, G. J. (in press). Methodological considerations for interactional perspectives on epistemic cognition. In J. A. Greene, W. A. Sandoval, & I. Braten (Eds.), *Handbook of epistemic cognition*. New York: Routledge.

Khine, M. S. (2008). *Knowing, knowledge, and beliefs: Epistemological studies across diverse cultures*. Dordrect, The Netherlands: Springer.

Kienhues, D., Bromme, R., & Stahl, E. (2008). Changing epistemological beliefs: The unexpected impact of a short-term intervention. *British Journal of Educational Psychology, 78*, 545-565.

Kilinc, A., & Seymen, H. (2014). Preservice teachers' motivations for choosing science teaching as a career and their epistemological beliefs: Is there a relationship? *Journal of Turkish Science Education, 11*(1), 115-132.

King, P. M., & Baxter Magolda, M. B. (2005). A developmental model of intercultural maturity. *Journal of College Student Development, 46*, 571-592.

King, P. M., & Kitchener, K. S. (1994). *Developing reflective judgment: Understanding and promoting intellectual growth and critical thinking in adolescents and adults*. San Francisco: Jossey-Bass.

King, P. M., & Kitchener, K. S. (2002). The reflective judgment model: Twenty years of research on epistemic cognition. In B. K. Hofer & P. R. Pintrich (Eds.), *Personal epistemology:*

The psychology of beliefs about knowledge and knowing (pp. 37-61). Mahwah, NJ: Erlbaum.

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

King, P. M., Kitchener, K. S., Davison, M. L., Parker, C. A., & Wood, P. K. (1983). The justification of beliefs in young adults: A longitudinal study. *Human Development, 26*, 106-116.

Kitchener, K. S. (1983). Cognition, metacognition, and epistemic cognition. *Human Development, 26*, 222-232.

Kitchener, R. F. (2002). Folk epistemology: An introduction. *New Ideas in Psychology, 20*, 89-105.

Kitchener, R. F. (2011). Personal epistemology and philosophical epistemology: The vew of a philosopher. In J. Elen, E. Stahl, R. Bromme, & G. Clarebout (Eds.), *Links between beliefs and cognitive flexibility: Lessons learned* (pp. 79-103): Springer.

Knefelkamp, L. L. (1998). Introduction. In W. G. Perry (Ed.), *Forms of intellectual and ethical development in the college years: A scheme* (pp. xi-xxxviii). San Francisco: Jossey-Bass.

Knefelkamp, L. L., & Slepitza, R. L. (1978). A cognitive-developmental model of career development: An adaptation of the Perry scheme. In C. A. Parker (Ed.), *Encouraging development in college students* (pp. 133-150). Minneapolis: University of Minnesota Press.

Kohlberg, L. (1969). Stage and sequence: The cognitive-developmental approach to socialization. In D. Goslin (Ed.), *Handbook of socialization theory and research* (pp. 347-480). New York: Rand-McNally.

Kuhn, D. (1991). *The skills of argument*. Cambridge: Cambridge University Press.

Kuhn, D. (1999). Metacognitive development. In L. Balter & C. S. Tamis-LeMonda (Eds.), *Child psychology: A handbook of contemporary issues* (pp. 258-286). Philadelphia: Psychology Press.

Kuhn, D., Cheney, R., & Weinstock, M. (2000). The development of epistemological understanding. *Cognitive development, 15*, 309-328.

Kuhn, D., Zillmer, N., Crowell, A., & Zavala, J. (2013). Developing norms of argumentation: Metacognitive, epistemological, and social dimensions of developing argumentive competence. *Cognition and Instruction, 31*(4), 456-496.

Kurfiss, J. G. (1988). *Critical thinking: Theory, research, practice, and possibilities*. Washington, DC: Association for the Study of Higher Education.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29*, 331-359.

Lederman, N. G. (2007). Nature of science: Past, present, and future. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 831-879). Mahwah, NJ: Erlbaum.

Machery, E., & O'Neill, E. (Eds.). (2014). *Current controversies in experimental philosophy*. New York: Routledge.

Maggioni, L., VanSledright, B. A., & Alexander, P. (2009). Walking on the borders: A measure of epistemic cognition in history. *The Journal of Experimental Education*, 77, 187-214.

Mason, L. (2003). High school students' beliefs about maths, mathematical problem solving, and their achievement in maths: A cross-sectional study. *Educational Psychology, 23*, 73-85.

Mason, L. (2010). Beliefs about knowledge and revision of knowledge: On the importance of epistemic beliefs for intentional conceptual change in elementary and middle school students. In L. D. Bendixen & F. C. Feucht (Eds.), *Personal epistemology in the*

classroom: Theory, research, and practice (pp. 258-291). Cambridge, UK: Cambridge University Press.

Mason, L. (in press). Psychological perspectives on measuring epistemic cognition. In J. A. Greene, W. A. Sandoval, & I. Braten (Eds.), *Epistemic cognition*. New York: Routledge.

Mason, L., Boldrin, A., & Ariasi, N. (2010). Searching the web to learn about a controversial topic? Are students epistemically active? *Instructional Science, 38*, 607-633.

Mason, L., Boldrin, A., & Zurlo, G. (2006). Epistemological understanding in different judgment domains: Relationships with gender, grade level, and curriculum. *International journal of educational research, 45*, 43-56.

Mason, L., & Boscolo, P. (2004). Role of epistemological understanding and interest in interpreting a controversy and in topic-specific belief change. *Contemporary Educational Psychology, 29*, 103-128.

Mason, L., & Bromme, R. (2010). Situating and relating epistemological beliefs into metacognition: Studies on beliefs about knowledge and knowing. *Metacognition and Learning, 5*, 1-6.

Mason, L., & Scirica, F. (2006). Prediction of students' argumentation skills about controversial topics by epistemological understanding. *Learning and Instruction, 16*(5), 492-509.

Mason, L., & Scrivani, L. (2004). Enhancing students' mathematical beliefs: An intervention study. *Learning and Instruction, 14*, 153-176.

Moore, W. S. (2002). Understanding learning in a postmodern world: Reconsidering the Perry scheme of intellectual and ethical development. In B. K. Hofer & P. R. Pintrich (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 17-36). Mahwah, NJ: Erlbaum.

Muis, K. R. (2004a). *Epistemic styles and mathematics problem solving: Examining relations in the context of self-regulated learning.* Simon Fraser University.

Muis, K. R. (2004b). Personal epistemology and mathematics: A critical review and synthesis of research. *Review of Educational Research, 74*, 317-377.

Muis, K. R., Bendixen, L. D., & Haerle, F. C. (2006). Domain generality and domain specificity in personal epistemology research: Philosophical and empirical reflections in the development of a theoretical model. *Educational Psychology Review, 18*, 3-54.

Muis, K. R., & Duffy, M. C. (2013). Epistemic climate and epistemic change: Instruction designed to change students' beliefs and learning strategies and improve achievement. *Journal of Educational Psychology, 105*, 213-225.

Murphy, P. K. (2003). The philosophy in thee: Tracing philosophical influences in educational psychology. *Educational Psychologist, 38*, 137-145.

Murphy, P. K., Alexander, P., Greene, J. A., & Edwards, M. N. (2007). Epistemological threads in the fabric of conceptual change research. In S. Vosniadou, A. Baltas, & X. Vamvakoussi (Eds.), *Reframing the conceptual change approach in learning and instruction*: Elsevier.

Murphy, P. K., Buehl, M. M., Zeruth, J. A., Edwards, M. N., Long, J. F., & Monoi, S. (2010). Examining the influence of epistemic beliefs and goal orientations on the academic performance of adolescent students enrolled in high-poverty, high-minority schools. In L. D. Bendixen & F. C. Feucht (Eds.), *Personal epistemology in the classroom: Theory, reearch, and implications for practice* (pp. 328-367). Cambridge, UK: Cambridge University Press.

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

Perry, W. G. (1981). Cognitive and ethical growth: The making of meaning. In A. Chickering (Ed.), *The modern American college* (pp. 76-116). San Francisco: Jossey-Bass.

Peters-Burton, E., & Baynard, L. R. (2013). Network analysis of beliefs about the scientific enterprise: A comparison of scientists, middle school science teachers and eighth grade science students. *International Journal of Science Education, 35*.

Piaget, J. (1972). Intellectual evolution from adolescence to adulthood. *Human Development, 15*, 1-12.

Pieschl, S., Stahl, E., & Bromme, R. (2013). Adaptation of context as core component of self-regulated learning: The example of complexity and epistemic beliefs. In R. Azevedo & V. Aleven (Eds.), *International handbook of metacognition and learning technologies* (pp. 53-65). New York: Springer.

Pintrich, P. R. (2002). Future challenges and direction for theory and research on personal epistemology. In B. K. Hofer & P. R. Pintrich (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 389-414). Mahwah, NJ: Erlbaum.

Rosenau, J. (2012). Science denial: A guide for scientists. *Trends in Microbiology, 20*, 567-569.

Rule, D. C., & Bendixen, L. D. (2010). The integrative model of personal epistemology development: Theoretical underpinnings and implications for education. In L. D. Bendixen & F. C. Feucht (Eds.), *Personal epistemology in the classroom: Theory, research, and implications for practice* (pp. 94-123). Cambridge, UK: Cambridge University Press.

Samarapungavan, A., Westby, E. L., & Bodner, G. M. (2006). Contextual epistemic development in science: A comparison of chemistry students and research chemists. *Science Education, 90*, 468-495.

Sandoval, W. A. (2005). Understanding students' practical epistemologies and their influence on learning through inquiry. *Science Education, 89*, 634-656.

Sandoval, W. A. (2014). Science education's need for a theory of epistemological development. *Science Education, 98*, 383-387.

Schoenfeld, A. H. (1985). *Mathematical problem solving*. San Diego, CA: Academic Press.

Schoenfeld, A. H. (1992). Learning to think mathematically: Problem solving, metacognition and sense making in mathematics. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 334-370). New York: Macmillan.

Schommer, M. (1990). Effects of beliefs about the nature of knowledge on comprehension. *Journal of Educational Psychology, 82*, 498-504.

Schommer, M., Crouse, A., & Rhodes, N. (1992). Epistemological beliefs and mathematical text comprehension: Believing it is simple does not make it so. *Journal of Educational Psychology, 82*, 435-443.

Schommer, M., & Walker, K. (1995). Are epistemological beliefs similar across domains? *Journal of Educational Psychology, 87*, 424-432.

Schommer-Aikins, M. (2002). An evolving theoretical framework for an epistemological belief system. In B. K. Hofer & P. R. Pintrich (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 103-118). Mahwah, NJ: Erlbaum.

Schommer-Aikins, M. (2004). Explaining the epistemological belief system: Introducing the embedded systemic model and coordinated research approach. *Educational Psychologist, 39*, 19-29.

Schommer-Aikins, M., & Duell, O. K. (2013). Domain specific and general epistemological beliefs and their effects on mathematics. *Revista de Investigacion Educativa, 31*, 317-330.

Schraw, G., Bendixen, L. D., & Dunkle, M. E. (2002). Development and evaluation of the Epistemic Belief Inventory (EBI). In B. K. Hofer & P. R. Pintrich (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 261-275). Mahwah, NJ: Erlbaum.

Sinatra, G. M., & Chinn, C. A. (2012). Thinking and reasoning in science: Promoting epistemic conceptual change. In K. R. Harris, S. Graham, & T. Urdan (Eds.), *APA educational psychology handbook: Vol. 3. Application to teaching and learning* (pp. 257-282). Washington, DC: American Psychological Association

Sinatra, G. M., Kienhues, D., & Hofer, B. K. (2014). Addressing challenges to public understanding of science: Epistemic cognition, motivated reasoning, and conceptual change. *Educational Psychologist, 49*, 123-138.

Stahl, E., & Bromme, R. (2007). The CAEB: An instrument for measuring connotative aspects of epistemological beliefs. *Learning and Instruction, 17*, 773-785.

Starmans, C., & Friedman, O. (2012). Folk conception of knowledge. *Cognition, 124*(3), 272-283.

Stromso, H. I., & Braten, I. (2010). The role of personal epistemology in the self-regulation of internet-based learning. *Metacognition and Learning, 5*, 91-111.

Stromso, H. I., Braten, I., & Samuelstuen, M. S. (2008). Dimensions of topic-specific epistemological beliefs as predictors of multiple text understanding. *Learning and Instruction, 18*, 513-527.

Svinicki, M. D., & McKeachie, W. J. (2014). *Teaching tips: Strategies, Research, and Theory for College and University Teachers*. Belmont, CA: Wadsworth.

Taylor, R., & Ferrari, M. (Eds.). (2011). *Epistemology and science education: Understanding the evolution vs. intelligent design controversy*. New York: Routledge.

Tsai, C.-C. (2005). Developing a multi-dimensional instrument for assessing students' epistemological views toward science. *International Journal of Science Education, 27*, 1621-1638.

VanSledright, B. A. (2004). What does it mean to think historically and how do you teach it? *Social Education, 68*, 230-233.

Wainryb, C., Shaw, L. A., Langley, M., Cottam, K., & Lewis, R. (2004). Children's thinking about diversity of belief and in the early school years: Judgments of relativism, tolerance, and disagreeing persons. *Child Development, 75*, 687-703.

Weber, K., Inglis, M., & Mejia-Ramon, J. P. (2014). How mathematicians obtain conviction: Implications for mathematics instruction and research on epistemic cognition. *Educational Psychologist, 49*, 36-58.

Weinstock, M. (in press). Epistemic cognition in legal reasoning. In J. A. Greene, W. A. Sandoval, & I. Braten (Eds.), *Handbook of epistemic cognition*. New York: Routledge.

Weinstock, M., & Cronin, M. A. (2003). The everyday production of knowledge: Individual differences in epistemological understanding and juror-reasoning skill. *Applied Cognitive Psychology, 17*, 161-181.

Widick, C., Knefelkamp, L. L., & Parker, C. A. (1975). The counselor as a developmental instructor. *Counselor Education and Supervision, 14*, 286-296.

Wildenger, L., Hofer, B. K., & Burr, J. E. (2010). Epistemological development in very young knowers. In L. D. Bendixen & F. C. Feucht (Eds.), *Personal epistemology in the classroom: Theory, research and implications for practice* (pp. 220-257). Cambridge, UK: Cambridge University Press.

Windschitl, M., & Andre, T. (1998). Using computer simulations to enhance conceptual change: The roles of constructivist instruction and student epistemological beliefs. *Journal of Research in Science Teaching, 35*, 145-160.

Wineburg, S. (1991). Historical problem solving: A study of the cognitive processes used in the evaluation of documentary and pictorial evidence. *Journal of Educational Psychology, 83*, 73-87.

Yang, F. Y., & Tsai, C.-C. (2010). An epistemic framework for scientific reasoning in informal contexts. In L. D. Bendixen & F. C. Feucht (Eds.), *Personal epistemology in the*

classroom: Theory, research, and implications for practice (pp. 124-162). Cambridge, UK: Cambridge University Press.