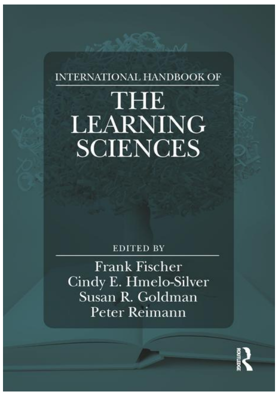

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Epistemic Cognition and Epistemic Development

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Epistemic Cognition and the Learning Sciences

Scholarship on topics such as epistemic cognition, epistemic beliefs, epistemic development, and epistemic practices has flourished in the past five decades (Chinn, Buckland, & Samarapungavan, 2011; Greene, Sandoval, & Bråten, 2016; Hofer & Pintrich, 1997; Kuhn, Cheney, & Weinstock, 2000; Sandoval, Greene, & Bråten, 2016). Much of this research has defined its scope as people's beliefs, stances, or theories related to knowledge and knowing.

In this chapter, we begin by discussing distinctive features of learning sciences (LS) approaches to epistemic cognition (EC). Second, we illustrate these approaches to epistemic cognition in the domain of science. Third, to illustrate the LS emphasis on the situativity of cognition within disciplines, we contrast EC in science with EC in history. Finally, we point to what we see as productive areas for new research.

Distinctive Features of Learning Sciences Approaches to Epistemic Cognition

In this section, we discuss distinctive features of learning scientists' approaches to epistemic cognition. Where appropriate, we contrast these features with the features of psychological work on EC, given that much EC research has been conducted by psychologists. We will not review psychological work in detail; current reviews can be found in Greene, Sandoval, and Bråten (2016). Taken collectively, the distinctive features of LS research on EC include: (1) emphasizing multidisciplinary research, (2) broadening the range of questions, (3) challenging normative assumptions, (4) a focus on practices, (5) the thoroughly social nature of EC, and (6) its situativity.

Multidisciplinary and Interdisciplinary Research

It is a definitional feature of the learning sciences to embrace multiple disciplinary approaches to investigating learning and thinking, including anthropology, psychology, sociology, computer science, epistemology, and the history and philosophy of specific disciplines (e.g., the sciences, mathematics, history). EC work may accordingly involve interdisciplinary teams (e.g., Goldman et al., 2016) or otherwise draw on scholarship from multiple disciplines. A number of the features discussed below derive in part from the multi- and interdisciplinarity of LS.

Broader Range of Questions

Psychological work has often analyzed epistemic cognition as people's beliefs related to the nature of knowledge and the processes of knowing (Hofer & Pintrich, 1997); the latter has typically been operationalized in terms of whether people believe that knowledge is sourced or justified by authority, experience, or some other source. Drawing on ideas from a broader range of disciplines, including philosophy, learning scientists have expanded the scope of epistemic cognition beyond this to focus on the many different practices (e.g., observation, scientific methods, community processes such as peer review) used by individuals and communities to create knowledge and a variety of other epistemic products (e.g., models, arguments, evidence) (Chinn et al., 2011).

Challenging Normative Assumptions

Learning scientists have challenged the explicit and implicit normative assumptions made in some mainstream psychological work on EC. For example, Chinn et al. (2011) and Bromme, Kienhues, and Porsch (2009) have questioned the frequent assumption that relying on "authorities" is a poor epistemic approach. Both point out that most human knowledge is derived from testimony from others; further, one cannot be an expert in all areas and so must rely on the expertise of others in their domains of expertise. Chinn and Rinehart (2016) noted that the common developmental assumption that realism (the view that one's theories or ideas correspond to what is really in the world) is unsophisticated is contradicted by the fact that many scientists and most philosophers adopt realist stances. Barzilai & Chinn (in press) have developed a normative analysis of the goals of epistemic education.

A Focus on Practices

Psychological work has often measured people's epistemic beliefs or stances using Likert-scale questionnaires or interviews with short vignettes (e.g., asking why experts differ on the safety of food additives; King & Kitchener, 1994). Some learning scientists (Samarapungavan, Westby, & Bodner, 2006; Sandoval, 2005) have argued that such general beliefs are too general and abstract to have much impact on people's practical thinking. Accordingly, much learning sciences research emphasizes epistemic practices as the appropriate focus of investigation. If one wants to understand, for example, why people make a jury decision, one must know how they evaluate, discuss, and integrate particular kinds of evidence that arise in the particular situation of a given trial.

By epistemic *practices*, we refer to socially normed activities that people carry out to accomplish epistemic aims such as developing evidence, arguments, theories, and so on. Practices are social, in the sense that the norms used to evaluate the practices and the products they produce are socially developed, shared, and applied by communities. Practices are also tightly intertwined with the material (e.g., the laboratories, equipment, chemicals, carefully bred laboratory animals, etc., in science) (Kelly, 2016).

Although some have interpreted epistemic practices in ways that minimize the role of metacognitive reflection (e.g., Berland et al., 2016), others have pointed to a role for metacognition, especially metacognition at the practical level of epistemic activity (e.g., Barzilai & Chinn, in press; Barzilai & Zohar, 2014). For example, people's specific metacognitive beliefs about whether and how biases and error can enter into scientific observations can affect critical choices about how to conduct observations (e.g., double blind studies, etc.).

Thoroughly Social Nature of Epistemic Cognition

Processes of creating and evaluating knowledge are thoroughly social (A. Goldman, 1999). This is obviously so in the case of scientists creating and publishing knowledge in teams, and evaluating each other's work in communities of critique. But it is also true of seemingly individual reasoning; for example, the individual evaluating information about medical treatments is relying on information provided by others.

Greene et al. (2016) distinguished three relevant levels of research in epistemic cognition: the individual, the individual in interaction, and the community/system level. At the individual level, researchers studying history classes might investigate how individual students draw conclusions about historical events using primary and secondary sources. At the individual-in-interaction level, researchers could study how students argue with each other, how their arguments influence later arguments and positions, how particular forms of argumentation spread in classes, and how collective norms for argumentation emerge and take shape. Some analyses would treat groups as the unit of analysis. At the level of community/system, investigators might examine the emergence of community norms that govern what is counted as a strong argument or a good mathematical solution and look at how these community norms are sustained or revised over time (Cobb, Stephan, & McClain, 2001).

Situativity

Learning scientists emphasize the situativity of EC, by which we mean that EC can vary (within the same person or group of people) from one situation to another. There are many dimensions of situations along which EC is situated; we note two exemplars. First, EC is not only discipline but even topic specific (Chinn et al., 2011). Engaging in epistemic practices on a topic requires deep, specific knowledge of that topic—not just theoretical knowledge (e.g., knowing cell processes and structures) but also methodological knowledge without which evidence cannot be evaluated or produced (such as accepted processes for preparing slides for electronic microscopy). Accordingly, people's epistemic judgments can be expected to differ from topic to topic (Elby & Hammer, 2001). Gottlieb and Wineburg (2012) demonstrated that religious historians use sharply different ways of thinking about historical texts on the biblical Exodus versus texts on the first American Thanksgiving.

Second, even within the same topic, epistemic practices of individuals and groups can vary sharply according to how the task is framed or introduced (Kienhues, Ferguson, & Stahl, 2016). Rosenberg et al. (2006) investigated eighth-grade science students working on answering the question "How are rocks formed?" They dramatically changed their epistemic approach to this task following a simple suggestion from the teacher to focus on what they know about rocks. This prompted the students to shift from making vocabulary lists to developing a causal story of how different kinds of rocks could form.

Hammer, Elby, and their colleagues have developed a resources-based model of EC to account for its situativity (e.g., Hammer & Elby, 2002). EC is composed of epistemological resources, "fine-grained pieces of epistemology that are sensitive to context in their activation" (Rosenberg et al., 2006). Examples of resources that can be activated flexibly in different situations are: "knowledge is stuff transferred from one person to another," "knowledge is fabricated stuff," "knowledge is accumulated as lists of facts," "knowledge involves causal stories," "knowledge can be created by imagining," and so on. Different clusters of resources are activated in different contexts.

Learning Sciences Methodologies

The focus on practices in LS means that EC is typically investigated not through questions about beliefs about knowledge in general or even beliefs about knowledge in disciplines but instead through providing people with practical reasoning tasks and analyzing their reasoning as they engage with these tasks—often in collaboration with peers. Methods involve detailed analyses of discourse and interactions, such as analyzing categories of epistemic discourse (Herrenkohl & Cornelius, 2013), examining the emergence of mathematical norms (Cobb et al., 2001), or using network analysis to understand how students share epistemic responsibility (Zhang, Scardamalia, Reeve, & Messina, 2009). Students require some inferencing to move from observed talk to conclusions about epistemic commitments and practices, but the tasks involve what learning scientists would regard as authentic epistemic activity.

Learning scientists do not completely eschew methodological approaches of other fields, such as interviews, but are likely to use rich tasks with multiple pieces of evidence or multiple documentary sources to afford the opportunity to engage in thinking that connects more deeply with disciplinary knowledge and that affords opportunities to look at variation in reasoning across different situations (e.g., Gottlieb & Wineburg, 2012).

Learning Sciences Approaches to Studying Epistemic Practice

Learning scientists recognize that epistemic practices and their development function across the levels of the community or system, the level of the individual in interaction, and the level of the individual as a cognitive agent (cf. Rogoff, 1995), as well as between microgenetic, sociogenetic, and ontogenetic scales of activity (Saxe, 2004). Levels vary in both the number of people who might constitute the unit of analysis and the temporal scale over which activity might be analyzed. As an example, we consider practices of explanation and argumentation in science.

Community/System Level

Scientific communities share and enforce criteria that govern acceptance of proffered explanations, and methods are expected to follow reliable processes established by the community. A wide range of processes and criteria operate at the level of the community, such as peer review and standards of critique and uptake of ideas. While there is broad consensus on some of these processes across the sciences, they are also differentially specified within fields (Knorr-Cetina, 1999). For example, while there is a broad view that controlled experiments are ideal for establishing causal relationships, there are many fields in which this form of experimentation is unavailable, leading those fields to develop alternative standards for justifying causal claims.

Promoting communities within school classrooms that pursue similar aims and develop versions of these reliable processes requires aims focused on both construction and critique of explanations (Ford & Forman, 2006). This includes opening up all aspects of practice, from the questions investigated to the means for investigating them, to the same contestation and stabilization seen in professional science (Manz, 2015). Manz pointed out that, in classrooms where aspects of practice naturally become contested, argumentation emerges as a functional practice for stabilizing resolutions.

Learning sciences research is rich with examples of the development of such classroom communities. The Cheche Konnen project explicitly drew connections between children's everyday life and home language (Haitian creole) and more formally scientific ways of talking and thinking (Rosebery, Warren, & Conant, 1992). Another example is Lehrer and Schauble's long-running work in which students encounter problems of measurement and modeling they must work to resolve, and in doing so develop shared classroom practices and standards for building and evaluating models (Lehrer & Schauble, 2000, 2004).

A key feature of such projects in the learning sciences is the emergence of accountability to collective norms of practice. In professional science communities, arguments function to resolve real disagreements. In classrooms, for authentic forms of argument to emerge, disagreements must be legitimate. Such legitimacy is a consequence of students being supported to become active authors of the epistemic aims and practices pursued in the classroom.

Interactional Level

A great deal of LS work on scientific argumentation and explanation focuses on individuals in interaction, at least in part because this level of analysis is where practice is most easily seen. Community norms and aims are manifested through particular interactions, and versions of collective practice are understood through analysis of how they play out in specific interactions among community members. A key indicator, in fact, of how students learn practices of argumentation is to analyze how interactions change over time, as participants appropriate versions of practice (Lehrer & Schauble, 2004; Rosebery et al., 1992; Ryu & Sandoval, 2012).

An analysis of scientists in interaction reveals the broad array of social, technical, and semiotic resources with which they interact, and through which scientific knowledge is constructed, typically with difficulty and uncertainty (Pickering, 1995). Argumentative interactions in classrooms similarly rely on the social, material, and semiotic resources available. These resources are used in relation to community level norms and practices. Learning sciences analyses of interaction show both how children are often attuned to the affordances of material and symbolic resources in making arguments, and the importance of support for making meaning from them (e.g., Engle & Conant, 2002). Interaction analyses show that students' practices are sensitive to how teachers frame the purpose and nature of instructional activity (Rosenberg et al., 2006). Efforts to build tools specifically to support argumentation also show how those tools structure both the practice and the products of argumentation (Bell & Linn, 2000; Clark & Sampson, 2007; Iordanou & Constantinou, 2014; Sandoval & Reiser, 2004). More broadly, structured opportunities for students to engage in science practices that problematize activities such as measurement promote a "grasp of practice" (Ford, 2005).

Individual Level

The cognitive practices taken up by individual scientists are situated in those practices used within particular groups and communities of scientists. Individuals learn argumentative practices through apprenticeship into the work of their specific field, rather than through some direct instruction in the nature of disciplinary arguments (Goodwin, 1994; Longino, 1990). Learning sciences research similarly shows that the cognitive practices learned by students are tied to the instructional activities in which they take part. First graders learn to identify sources of error and uncertainty through designing their own experiments (Metz, 2011). Students who develop models over the course of a school year develop epistemic conceptions of tentativeness and measurement uncertainty directly traceable to their own efforts (Lehrer et al., 2008). Middle school students identify a range of criteria for evaluating explanatory models that seem tied to their schooling experiences (Pluta, Chinn, & Duncan, 2011). Elementary children's improvement in justification practices is directly tied to persistent focus on justification in science lessons (Ryu & Sandoval, 2012).

LS research on practices of explanation and argumentation in science shows that children from a very early age display cognitive capabilities consonant with professional science practices, and that such early competencies can be extended and refined through appropriately structured instruction. A good deal is now known of the features of such instruction for a range of science practices. A number of questions remain open concerning how understanding of practices generalize, how generalization is tied to contexts of learning, and how students perceive relations between the science they do in school, professional science, and science as encountered in everyday activity.

Comparisons with Other Disciplines: History in Contrast to Science

LS approaches are of course applicable to EC within any discipline. As discussed earlier, learning scientists generally view EC as varying across disciplines and topics. For example, Goldman et al. (2016) presented a detailed analysis of reading practices across literary reading, science, and history, including differences along epistemic dimensions. In the following sections, we analyze some specific differences in epistemic practices between science and history.

To illustrate an additional LS approach to EC, we use a model developed by Chinn et al. (2014), the AIR model, as a lens for this analysis. This model specifies three principal components of EC: (1) aims and values—the goals that people set in particular situations (e.g., to know, understand, develop a model, etc.) and what they value (e.g., valuing knowledge that solves societal problems); (2) ideals—the criteria or standards applied to evaluate epistemic products such as models and evidence; and (3) reliable epistemic processes—the processes that are used to create knowledge and other epistemic products (e.g., processes of testimony, observation, statistical analysis, argumentation, peer review, etc.). We discuss differences in aims, ideals, and reliable processes across science and history.

Epistemic Aims

A diversity of epistemic aims prevails in both disciplines. LS approaches to EC assume a diversity of aims. Scientists aim to create general models, establish laws, test the reliability of methods, or estimate parameters such as Planck's constant. Historians seek to establish the authenticity of a particular document, develop a historical narrative, understand the perspective of historical actors, or provide a broad explanation of events (Tucker, 2011).

Some aims appear to be unique to one discipline. Developing models is central to the practice of science, but models do not figure in discussions of historiography (see Tucker, 2011). Conversely, some movements in historiography uniquely emphasize the aim of constructing historical narratives with plots, settings, characters, and literary devices (Green & Troup, 1999).

When aims look similar at a first glance, deeper differences may appear. Scientists aim to develop general explanations (the general causes of a disease) as well as particular ones (how a particular person developed a disease). Although some historians have sought general explanations in history (e.g., how economic systems change), others have objected to such explanations, given the particularity of historical events, so that explanations of historical events must always be particular (Tucker, 2011).

Epistemic Ideals

Some epistemic ideals (or criteria) for evaluating epistemic products seem relatively specific to one field or another. In science, philosophers have argued that scientists evaluate explanations using ideals such as fit with evidence, simplicity, and making new predictions of future events (see Pluta et al., 2011). Historians would likely agree that fit with evidence is an ideal in their field (although the nature of evidence across fields differs vastly), but the complex, rich, contextual descriptions prized by many historians are not simple, and most contemporary historians do not hold their histories accountable to predicting future events (Tucker, 2011). Similarly, contextualization (weaving the rich chronological, social, and personal contexts surrounding events) is an ideal that appears to be distinctive to history (Wineburg, 2001).

Other ideals that appear to be the same on the surface may differ very substantively, such as corroboration. In science, marks of corroboration might include statistical meta-analyses, which would not figure in evaluation of whether historical accounts are well corroborated. In contrast, historical corroboration would involve careful textual comparison of primary source documents (Goldman et al., 2016).

Reliable Processes for Achieving Epistemic Aims

Scientists and historians use a variety of processes to reliably achieve their epistemic aims. Some processes are shared: some scientists and some historians use statistical analyses, though the problems faced by historians with missing data mean that historians need to use approaches not needed by scientists with more complete data (Howell & Prevenier, 2001). Other processes differ sharply. Scientists conduct controlled experiments, make live observations of ongoing behaviors and activities (such as animal behavior or chemical reactions), and use techniques for combining evidence such as meta-analysis; all of these appear to be absent in historical inquiry. In contrast, historians engage in processes such as taking historical actors' perspectives through empathy (Breisach, 2007) and developing extensive counterfactual scenarios to support claims (Weinryb, 2011).

Sourcing is central to both history and science. There is a difference, however. Both historians and scientists evaluate the trustworthiness of their peers as "secondary sources"—i.e., historians evaluate other historians, and scientists evaluate other scientists (Collins, 2014). Historians also evaluate the trustworthiness of primary sources who produce the diaries and other documents that are the primary data for their research. However, scientists do not typically evaluate the trustworthiness of their "primary sources"—the lab assistants who report results of research—except in rare cases of suspected fraud. Thus, the processes used by historians to evaluate primary sources (e.g., evaluating human motivations, biases, contextual positioning, and so on) are typically not salient when scientists evaluate their primary sources (lab assistants, etc.), who are assumed to use procedures that render these personal factors irrelevant.

Disciplinary Differences in Inquiry by Learners

To this point, we have noted differences between inquiry by *experts* in science versus history. These differences also appear in research with *learners* engaged in the practices of scientists and historians. As noted earlier, Goldman et al. (2016) developed a detailed analysis of goals for instruction based on analyses of disciplinary differences in epistemic practices and have developed efficacious curricula based on their analysis. Herrenkohl and Cornelius (2013) described class interactions in curricula developed for history and science that indicated that fifth and sixth graders can learn to develop distinct aims, justificatory practices, and processes for constructing knowledge across the two disciplines.

Conclusion and Implications

The distinctive features of LS research on EC suggest directions for productive new research to advance the field (see also Sandoval et al., 2016; Barzilai & Chinn, in press). In accord with the value LS places on interdisciplinary and multidisciplinary research, EC research would benefit by more extensive collaborations, e.g., by philosophers working with psychologists and educators. (2) LS researchers should fully explore the broader range of questions that have been opened up by recent LS scholarship, such as a broader range of epistemic aims, deeper explorations of practices used productively by experts and laypeople, and so on. (3) The LS work on normative assumptions should be expanded into detailed normative accounts that can be used to establish productive goals of epistemic education. (4) Although LS researchers are leaders in investigating practical and social aspects of EC, more research is needed particularly at the individual-in-interaction level and the community/systems level, both to understand effective modes of knowledge production by expert communities and to understand how to promote learning in schools and other settings. LS researchers could also investigate further the proper roles of metacognition in sophisticated EC. (5) Finally, research on EC would benefit from more systematic analyses of the ways in which context affects EC, as well as how people can learn to be effective thinkers across multiple contexts.

Learning scientists should also be leaders in designing effective learning environments to promote epistemic growth. Such work would systematically examine implications of theories of EC for setting goals for education and then for achieving these goals, using the field's understanding of effective scaffolding, methods of collaborative learning, and other features of design to promote achievement of these goals.

Further Readings

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

A model of EC grounded in a broad review of philosophical work. It is the precursor to the AIR model (Chinn et al., 2014) discussed in this chapter, and the article provides readers with a broad range of philosophical references that can be consulted. It also argues for a strong contextual-sensitivity of EC and for social components of EC.

Goldman, S. R., Britt, M. A., Brown, W., Cribb, G., George, M., Greenleaf, C., et al. (2016). Disciplinary literacies and learning to read for understanding: A conceptual framework for disciplinary literacy. *Educational Psychologist, 51*, 219–246.

An explanatory account of differences in the critical literacy practices across three disciplines—literary reading, science, and history—along dimensions including epistemic dimensions of epistemology; inquiry practices and strategies of reasoning; and forms of information. The article exemplifies interdisciplinary scholarship and points to important aspects of disciplinary situativity in EC.

Manz, E. (2015). Representing student argumentation as functionally emergent from scientific activity. *Review of Educational Research, 85*(4), 553–590.

A review of research on the epistemic practice of argumentation, emphasizing the embedding of argumentation in the activity systems of communities and the central role of community norms for argumentation practice. Emphasizing the material and representational aspects of science, Manz shows that it is necessary for students to find critical features of investigations to be genuinely problematic to engage in argumentation to stabilize their scientific work.

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

A detailed account of how the resources theory of Hammer and Elby (2002) can be applied to explain the epistemic practices of eighth graders discussing the rock cycle. This paper illustrates both contrastive analyses of cases and analyses of discourse, and it provides a helpful elaboration of what resources are and how they figure in two kinds of epistemic practices.

Sandoval, W. A., Greene, J. A., & Bråten, I. (2016). Understanding and promoting thinking about knowledge: Origins, issues, and future directions of research on epistemic cognition. *Review of Research in Education, 40*, 457–496.

A comprehensive review of the origins of research on epistemic cognition and the conflicts and convergences among different traditions of scholarship. They point to the need to comparatively test competing models of epistemic cognition, pursue methodological nuance, and connect analyses of EC across settings and time.

NAPLeS Resources

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