Handbook of Epistemic Cognition

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METHODOLOGICAL CONSIDERATIONS FOR THE STUDY OF EPISTEMIC COGNITION IN PRACTICE

Gregory J. Kelly

Theoretical developments in epistemic cognition have called for greater and more effective use of philosophical perspectives (Greene, Azevedo, & Torney-Purta, 2008; Murphy, 2003). Recent research has examined the multiple ways that research in philosophy can inform epistemic cognition. For example, Chinn et al. (2011) developed a five-component, philosophically grounded framework to inform research on epistemic cognition. In this chapter, I provide methodological procedures emanating from a sociocultural perspective on knowing and learning. I consider ways that philosophy and the empirical study of epistemological issues, such as studies of epistemic cultures producing knowledge (e.g. Knorr-Cetina, 1999), can help conceptualize epistemic cognition as practice and contribute to robust views about how epistemology relates to learning. I draw primarily from social epistemology with a focus on scientific knowledge (Longino, 2002) for examples of how to develop methodological implications of disciplinary and situated perspectives on epistemic cognition. This social view of knowing and learning coalesces well with sociocultural psychology. In particular, the focus of this chapter will be on how to research epistemic cognition situated in social practices. I draw from sociohistorical psychology and situated cognition to illustrate the ways that meaning is learned through participation in activity (Hutchins, 1995; Kozulin, 2003; Vygotsky, 1978). The prominent role of discourse and practice as mediators for learning is illustrated with examples from professional practice and science education settings (Kelly, 2014a). The methodology I propose offers a potential contribution to the study of epistemic cognition by considering the ways that epistemic practices are constructed through interaction (Kelly, 2008, 2011; Ostman & Wickman, 2014). Illustrative examples from engineering education are provided. I propose a reflexive turn posing questions about what counts as knowledge for the study of epistemic and ontological cognition. The chapter concludes by considering ways that different, complementary views of epistemic cognition can contribute to fruitful research directions.

By providing an alternative to the typical methodological approaches to the study of epistemic cognition, I hope to expand the conversation about how substantive issues in learning can be researched from different perspectives. A practice view of epistemic cognition examines ways that knowledge is used in activity and serves to inform ways of creating pedagogies that support the development of knowledge and justification for knowledge claims (Kelly, 2011; Kelly & Sezen, 2010; Ryu & Sandoval, 2012). Building from anthropological and sociological studies of science and education and sociocultural psychology, the perspective developed here examines ways that epistemic practices are constructed in interaction through concerted activity. A key component of the interactional accomplishment of epistemic practice is discourse (Kelly, 2011). Discourse is often defined as language-in-use that includes verbal exchanges, written texts, signs and symbols, and other semiotic resources (Jaworski & Coupland, 1999). These semiotic resources include contextualization cues, such as gesture, eye gaze, prosody, and proxemics (Bloome, Carter, Christian, Otto, & Shuart-Faris, 2005; Gumperz, 2001; Green & Castanheira, 2012; Strauss & Feiz, 2014). Language use shapes social order and is shaped by social order (Fairclough, 2010; Jaworski & Coupland, 1999), as social groups use language to create particular ways of talking, thinking, acting, and being (Gee & Green, 1998). These actions, when coordinated through concerted activity, may become patterned, thus developing cultural practices of members of a group (Kelly & Green, 1998; Smith, 1996). Thus, through language use and other actions, social groups create meaning. These meanings are supported by at least three functions of language: communication of propositional information, establishment of social relationships, and expression of identity (Cazden, 2001). Patterned uses of language, the development of cultural norms, and the building of identity change over time. As these functions of language are constructed in moment-to-moment interactions, and are influenced by cultural norms, they can be examined across time scales from the micromoments through sociohistorical timescales (Kelly, 2008; Lemke, 2000; Wortham, 2003). Under certain circumstances, these social meanings and identity are related to epistemic cognition.

EPISTEMIC AND ONTOLOGICAL COGNITION IN PRACTICE

Greene et al. (2010) define epistemic cognition as referring to thinking about knowing, while beliefs about knowledge refer to ontological cognition. This characterization has the advantage of not labeling a set of personal beliefs a folk epistemology, as personal views about knowledge should not be confounded with disciplinary inquiry into knowledge found in philosophical studies (Kelly, 1997, 2014b). Thus, this view of epistemic cognition focuses on thinking about knowledge without assuming a coherent theory of knowledge, or epistemology, on the part of the knowing subject. Greene et al. (2010) use epistemic and ontological cognition (EOC) to refer to "both developmental and systems of beliefs models of personal epistemology" (p. 237). Rather than focusing on beliefs, I propose some research approaches to examine epistemic practices—ways of going about defining what counts as knowledge—that include interactionally accomplished understandings of knowing and uses of knowledge category systems (ontology) in learning environments. This perspective takes a view that meanings of knowing and categories of concepts "are created in the public domain in the context of collective situations and activities" (Toulmin, 1999, p. 58). Since such meanings are created in a public domain, one way to examine how thinking about knowing is accomplished is to focus on the discourse processes used in settings where issues of knowing are at stake and in play. Such a perspective views objects as acquiring properties by virtue of human activity (Bakhurst, 1997, p. 159) and through social significance where meaning is constructed and interactively acknowledged (Bloome et al., 2005). Such activity may include research settings where learners are asked about their beliefs about knowing and learning, as has often been the case for studies of epistemic cognition. An alternative to these settings would be learning contexts where meanings are defined, evoked, and socially negotiated around purposeful activity aimed at learning goals.

In a recent review of epistemology and learning, Kelly et al. (2012) identified three ways that epistemology has informed learning in science education—although these categories are specific to science in their study, the perspective is relevant to other forms of disciplinary knowledge. One group of studies considers the personal epistemology, or epistemic cognition of learners, and how learners' views of knowing influence the learning process. Another set of studies draws from philosophy, most often philosophy of science, to provide models for rational theory choice and justification of knowledge claims. A third group of studies, based in sociocultural theories of learning and the situated nature of knowing, focuses on the everyday practices of proposing, communicating, assessing, and legitimizing knowledge claims. These ways of engaging in epistemic practices occur across contexts and social groups, and draw from empirical research of professional practice (e.g. Knorr-Cetina, 1995) or the ways that teachers and students construct knowledge in educational settings (e.g. Kelly & Crawford, 1997).

To date, much of the work on epistemic cognition has focused on researching the individual's view of knowing and the influence of such views on learning. This focus has the advantage of identifying and diagnosing learners' perceptions of knowing and potentially designing learning experiences derived from such understandings. From this perspective, methodological approaches have examined students' beliefs and incorporated students' ontological cognition. Over time, such focused study has increased the rigor of such assessments. A common feature of these studies is a centering of the locus of cognition on the individual learner, even when set in a social context. I develop some alternatives to this individualistic view by thinking about ways students engage in disciplinary practices and considering how issues of knowing emerge through discourse processes. Through this process, I hope to propose complementary methods based on different ways of conceptualizing the phenomena (Kelly, 2006).

A sociocultural view of learning includes the importance of social practices and participation. Learning disciplinary knowledge includes developing abilities to engage in epistemic practices of relevant groups (Toulmin, 1972; Kelly, 2014b). Epistemic practices are the socially organized and interactionally accomplished ways that members of a group propose, communicate, assess, and legitimize knowledge claims (Kelly, 2008; Manz, 2012). These groups most often include more-knowing others in educational or professional settings. Such participation raises questions about the types of knowledge at stake in such interactions. Scheffler (1965) makes the distinction between propositional (knowledge that) versus procedural knowledge (knowledge how). Epistemic cognition often concerns complex knowledge, such as that in play for learning disciplinary knowledge. Under such conditions students need to engage in social practices where issues of knowledge are being proposed, discussed, evaluated, and assessed. Thus, in this case, epistemic cognition refers to both propositional and procedural knowledge: procedural knowledge of how to engage in conversation around substantive topics that are part of the learning process of propositional knowledge. Furthermore, learning disciplinary knowledge entails learning the processes for knowing about topics and the justification underlying such knowledge (Sandoval & Çam, 2011). Learning disciplinary knowledge requires understanding the procedures used to define and create relevant concepts. For this to occur, learners need to use language, argumentation, and embodied procedural techniques (such as that of experimentation to make sense of the scientific knowledge, or that of field testing to evaluate properties of an engineering design). Before turning to some specific methodological approaches, I propose the following premises that inform the perspective.

Disciplinary knowledge is social knowledge. This is particularly true in well-developed, compact fields such as science and engineering, where knowledge is the product of multiple social situations and institutions, and succeeds through building on previous knowledge and peer review (Fleck, 1935/79; Longino, 1990; Toulmin, 1972, Zuckerman, 1988). Individuals may have personal knowledge of specific aspects of their social or material worlds, but such knowledge does not count as science until interactionally legitimized by a relevant community of knowers (Kelly & Chen, 1999; Kelly & Green, 1998).

Cognition is distributed across people, technologies, texts, and signs and symbols (Cole & Engestrom, 1993; Hutchins, 1995; Pea, 1993). Learning about knowing involves engaging in discourse and other social practices—this includes using knowledge and talk about knowledge (Kelly, 2011; Kelly & Sezen, 2010).

Learning occurs through participating in common ways of being and forms of life (Goodwin, 2013; Green & Dixon, 1993; Wittgenstein, 1958). Learners appropriate ways of speaking, interacting, communicating, and engaging in social groups (Kelly, 2014a), and to the extent that knowledge is involved, epistemic and ontological cognition is situated in such forms of life and distributed. Learning involves acculturation of learners into ways of being (Goodwin, 2013; Kelly & Crawford, 1997).

Epistemic cognition includes a set of practices—patterned actions involved in knowing (Kelly, 2011; Ostman & Wickman, 2014). Thus, reasoning is a social endeavor that includes using evidence and engaging in genre-specific forms of argumentation (Ford & Wargo, 2012; Kelly & Bazerman, 2003; Ryu & Sandoval, 2012). This perspective considers epistemic cognition as learned ways of reasoning about knowledge.

Ontologies are constructed through appropriation of common meanings (Lewis, 1929). There are social origins of ontological categories that are formed and reformed through acculturation, language socialization, and learning through participation (Strike, 1982). Such categories may be challenged and reconstructed through critique, reassessment, and revision (Kelly, Crawford, & Green, 2001).

METHODOLOGICAL CONSIDERATIONS FOR RESEARCHING EPISTEMIC PRACTICES

The methodological approaches I propose offer an alternative to both the developmental stage and systems of beliefs models described by Greene et al. (2010). These models have advanced methodologically and offer unique and valuable insights into individual's EOC. An alternative is to consider the interactionally accomplished nature of knowledge and student thinking about this *in situ.* The view suggested here is based on the value and need for consideration of epistemic practices used to construct knowledge in social settings. Indeed, as Toulmin (1979) has argued, aspects of mental life (such as views about knowing) are acquired features of our experience and cultural history. Based on the sociocultural view of learning, knowing, and social practices, a number of methodological approaches can be employed to consider ways of investigating epistemic and ontological cognition (EOC) *in situ.* Such approaches draw from multiple research methods, each offering unique insights into how social practices define knowledge for participants (e.g. Manz, 2012; Ryu & Sandoval, 2012; Wickman, 2004).

In this section, I provide a view of how epistemic practices and socially derived ontological categories imply certain methodological orientations and ways of investigating. Epistemic practices, and EOC more generally, are interactional, contextual, intertextual, and consequential. Each of these characteristics suggests methodological commitments.

Epistemic practices are interactional. Actions taken by members of a group become patterned ways of being through social interaction. Engaging in social practices defines what counts as knowing and knowledge, such as proposing ideas, testing hypotheses, representing concepts, evaluating merits of candidate solutions, recognizing alternatives, justifying knowledge claims, and legitimizing conclusions. Such epistemic practices are interactionally accomplished, among people, texts, and technologies, and constructed in the moment. These events are situated and contextualized, draw from common knowledge, and make reference to previous knowledge and ways of participating. A central component of these practices is the use of language, including signs and symbols, characteristic of epistemic cultures (Kelly, 2014a, b). Such discourse requires communicative knowledge about how to participate in a cultural group and includes not only the functional aspects of relevant semantics but also extensive knowledge required to fill in background assumptions that make conversation possible. Thus, there is an interactional accomplishment of social cognition around knowing.

Epistemic practices are contextual. These practices are situated in time, space, social practices, and cultural norms. Knowledge is constructed through specific processes with variations across disciplines and ways of knowing (Knorr-Cetina, 1999; Longino, 1990). Knowledge construction occurs over time through a series of interactions from interactions around data collection, to conversations about interpretation, to forms of representation, and to processes of communication, evaluation, and legitimation (Bazerman, 1988; Lynch, 1992). Engaging in epistemic practices thus occurs in various venues and settings and these practices need to be examined as they occur in the making (Kelly, Chen, & Crawford, 1998). Thus, the study of epistemic practices needs to be situated in specific contexts. This suggests methodologies that examine knowledge construction over time and levels of analysis (Lemke, 2000; Wortham, 2003)—for example, at the interactional micro, meso, ontogenetic, and sociohistorial time frames. This emphasis on situating discourse events in a broader context of use shows how discourse processes both shape social practices and are embedded in such practices (Gee, 1999; Gee & Green, 1998). Time scales are interrelated, as specific events are situated in ongoing activity influenced by cultural practices. For example, interactional events are constructed through discourse processes and actions, creating and being shaped by sequences of mesolevel social practices (e.g. Kelly et al., 2001). The mesolevel time scales refer to weeks and months of collective activity (Wortham, 2003). These events draw from contexts, practices, texts, and artifacts created at longer time scales (Goodwin, 2000). For example, the genre of an experimental article in science (Bazerman, 1988) becomes a cultural model that can be taken up and used to create new texts within this patterned use of language (Kelly & Bazerman, 2003; Takao & Kelly, 2003). Through moment-to-moment interactions, meanings are negotiated while drawing from the patterned activities of a relevant social group (Goodwin, 2000) and those cultural artifacts relevant to the task at hand.

Epistemic practices are intertextual. Discourse processes make use of and reference to previous discourse, both spoken and written texts, including the various signs and symbols characteristic of disciplinary knowledge, and are thus intertextual

(Bazerman, 2004; Green & Castanheira, 2012). Reference to previous texts codifies an ontology of a social group (e.g. members of a discipline or subdiscipline) through use and shared assumptions of meaning (Wittgenstein, 1958). The concepts in a given ontology "are not simply dictated by the findings of the laboratory, or by any sort of sense-experience. Their origin is social and historical and represents some enduring human interest" (Lewis, 1929, p. 6). The ontology is populated by a set of concepts, emerging from human interests, and constructed by social groups with histories and common cultural experiences (Vygotsky, 1978). Examining ways that texts (verbal and spoken discourse, signs and symbols) are referenced, taken up, appropriated, and reinterpreted identifies how concepts populate an ontology. Thus, intertextuality serves a method to identify socially salient concepts comprising such an ontology.

Epistemic practices are consequential. Ways of creating, representing, evaluating, and legitimizing knowledge have consequences for what and whose knowledge counts. Members entering into a knowledge generating culture bring ways of knowing with them that may or may not count or be recognized (e.g. Traweek, 1988). Therefore, as different epistemic cultures engage in sets of different practices (Watson-Verran & Turnbull, 1995) an understanding of EOC can be examined through the empirical study of knowing *in situ.* The empirical study of ways that knowledge is legitimized offers paths for understanding how power, culture, and social processes are tied to what gets taken for knowledge in certain contexts.

ILLUSTRATIVE EXAMPLE: EPISTEMIC PRACTICES IN ENGINEERING DESIGN

The illustrative example of epistemic practices occurs in a fourth grade elementary classroom learning aerospace engineering (Cunningham & Kelly, 2015). The curriculum is a unit in the *Engineering is Elementary* curriculum (*Engineering is Elementary*, 2011). Engineering represents a unique form of disciplinary knowledge. Engineering education is rarely studied, particularly in elementary schools, and almost never examined as interactionally accomplished in educational contexts (Cunningham & Carlsen, 2014). While engineering education may share some common epistemic practices with other fields, such as science, literacy, and mathematics, it also includes practices unique to engineering. Such unique practices include addressing and designing solutions to real-world problems, comparing multiple alternative solutions, using investigations to test parameters across a range of conditions, optimizing designs given specific constraints, and communicating results to a client (Cunningham & Carlsen, 2014). In addition to these unique features of engineering practice, two other related topics warrant mention. First, engineering involves ethics, as designs and analyses of systems are not value neutral—designs influence values and human relationships (Johnson & Wetmore, 2008). Second, in addition to propositional and procedural knowledge, engineering draws from knowledge that is concretized in instrumentation (cf. science and instrumentation, Latour, 1987) or through templates and embodied knowledge from previous experiences (cf. gothic cathedral designs, Watson-Verran & Turnbull, 1995). Thus, engineering education represents an area of interest for the study of epistemic practices.

The following examples are a sample of the kind of interactions that identify how what counts as knowledge can be investigated by studying sociocultural practices. In this particular unit, the students experience four lessons designed to engage them in engineering design related to aerospace engineering and a set of associated science concepts. The first lesson introduces the children to aerospace engineering through a storybook. The story is set in Brazil where two young boys face a challenge that prompts them to develop a parachute that can bring an object to the ground safely. The storybook introduces an engineering design process (ask, imagine, plan, create, improve) that the students later will use in the design of their own group projects. In Lesson Two the students work as aerospace engineers to design spacecraft destined for a planet in our solar system (*Engineering is Elementary*, 2011). As they work, students must consider the characteristics of their planet (e.g. distance from Earth, temperature, composition of the surface, and atmosphere), as well as the mission their craft must accomplish. The third lesson invites the students to begin to think about the variables that influence parachute design—children conduct investigations to understand how properties of parachutes (such as size and material composition) affect their drop speed. Both of these goals are accomplished through student group investigations. Lesson Four entails students using the engineering design process to design a parachute. They imagine individual designs, based on the results of the variables studied in Lesson Three, and then come to a consensus within their group of four students to create a design. These designs are tested, and the class shares and compares their results and characteristic features across the eight student groups. These data then are used by each group to redesign their parachute before continued testing and evaluation.

For illustrative purposes I present three short episodes from Lesson Four—the building and testing of the student teams' initial designs, redesigning based on results of initial testing, and testing and interpretation of the "improved" designs. Identifying relevant epistemic practices was accomplished through a series of analytic steps.

First, the sociolinguistic analysis begins with an ethnographic description of the educational context (Green & Castanheira, 2012; Gumperz, 2001; Kelly & Crawford, 1997). In this case, the classroom events were video recorded with two cameras. The four lessons occurred across six days totaling over six hours of classroom instruction and videotape data. Initial analysis entailed reviewing the curricular materials, teacher guidebooks, videotapes of the classroom activities, and class and student artifacts.

Second, after this initial stage of ethnographic description, more detailed analyses focus on the ways the classroom practices were constructed by the participants. For this study of engineering education, transcripts of talk and action were created totaling over 2400 turns of talk. Each turn was coded for the type of discourse move. The events were segmented by the participants through sociolinguistic cues, including shifts in ideas often redundantly marked with variations in proxemics (spatial separation and body movement) and prosody (rhythmic and intonational organization; Green & Castanheira, 2012; Gumperz, 2001). These formed the basis for the creation of larger units of analysis (phase and sequence units). A set of cohesive turns of thematically tied interactions were identified as sequences of activity (Kelly & Chen, 1999). These sequences build phase units representing concerted and coordinated action among participants reflecting a common content focus of the group. This form of analysis allows for developing an understanding of the unfolding of the talk-in-interaction, as it occurs over time in a particular sequence of activity (Goodwin, 2000).

Third, these turns of talk are contextualized in the sequences of ongoing activity. Examining the instructional conversation at different levels of analysis (turn, sequence, phase) situates a given instance of interaction in an overall sequence of actions taken, allowing for over time analysis of practices (this would be at the interactional and mesolevel analysis). During this phase of the analysis, emergent themes start to be developed, including ways that knowledge is constructed, evoked, and evaluated. Instructional conversations provide a basis to examine how epistemic practices are enacted through concerted activity. Based on the theoretical assumptions described previously, this analysis can take the form of looking across units of analysis. For example, event maps provide a timeline of major actions and serve to situate particular instances of knowledge use in the ongoing activity of the classroom. The use of event maps, tied to more specific representations of the video data (Erickson, 1992), allow for different ways of representing social practices by "zooming in" to understand instances of action, and "zooming out" to view patterns of activity (Kelly et al., 2001). Any one instance of talk and action does not constitute a social practice; rather chains of coordinated activity can be identified by analysts as patterns, suggesting practices in use by the members of the classroom. For this study, event maps were created and examined to look across units of analysis. Table 24.1 represents a sample of phase units and the sequence units for one selected phase—the location in the conversation where students made observations and interpretations of the teams' data (shown at phase beginning labeled "Presentation and comparison of data from first design across groups" at 0:11:35.9). The transcripts for episode 1 (shown in Table 24.1 as the sequence unit beginning at 0:13:41.7) and episode 2 (shown in Table 24.1 embedded in the sequence labeled "observing and comparing data set" beginning at 0:15:29.6) were part of this phase of activity and presented below. Episode 1 centered on the identification of an apparent anomaly and episode 2 considered the functionality of components of the student teams' parachute designs.

Table 24.1 Sample of event map showing only phase units and sequence units for only one selected phase ("Presentation and comparison of data from first design across groups") occurring at 0:11:35.9 on day 2 of lesson 4

Time stamp	Phase unit		Sequences for selected phase
(0:00:32.3)	Review of average drop speed concept		
(0:05:49.0)	Frame for comparing data across groups		
(0:08:00.5)	Recording group data: drop speed, suspension line length, canopy diameter		
(0:11:35.9)	**Presentation and comparison of data from first design across groups**	(0:11:35.9)	looking for patterns in data
		(0:13:41.7)	noticing anomaly in data set
		(0:14:54.6)	observing and comparing across data set
		(0:16:22.6)	discussing value and limits to suspension line length
(0:17:41.3)	Work on improved design in student groups		
(0:42:01.1)	Transition to drop and test phase of improved design		
(0:47:28.8)	Data recording of improved design		
(0:10:03.0)	Transition back to classroom		

Fourth, once conversations are contextualized by the researchers (they are already contextualized by participants through their actions and understandings), specific codes for types of epistemic practices can be identified in the transcripts by examining the talk and action in detail. Looking closely at the level of turn, and sequences of interactions, specific practices can be identified in the talk and actions of participants. This allows the researchers to examine whether and in what ways instances of actions are tied together as patterns. In the examples provided below, a number of codes were used to identify epistemic practices such as "communicating features of designed objects," "representing data," "recognizing patterns in data," and "pointing out anomalies."

Episode 1: Observing and Finding Patterns in Data

In this episode the student teams have each communicated the canopy size, suspension line lengths, and average drop speeds of their parachutes to the class after performing tests of their respective parachute designs. The teacher recorded the results on a flip chart table in the front of the class for all to see (reproduced in Table 24.2). She began this sequence ("looking for patterns in data," at 11:35.9) by asking the students if there was "anything you noticed?" (line 774).

Table 24.2 Data across eight student teams for first parachute design presented to class on flip chart

Team	Average drop speed	Canopy diameters	Suspension line length
1	2.7	14"	21"
2	3.3	12"	16"
3	3.9	12"	24"
4	3.7	14"	21"
5	2.6	16"	18"
6	3.1	14"	14"
7	2.6	18"	13"
8	5	12"	23"

Line #	Speaker	Talk and action
774	Teacher:	Alright, teams, anything you noticed? Anything you noticed at all? Valerie, what about you guys?
775	Valerie:	I noticed [groups] 8 and 3 were exactly the same suspension line length.
776	Teacher:	8 and 3. Tyson noticed the same thing. Tyson, can you just say what you just said to me?
777	Tyson:	I don't get why if we got the same canopy size and they only had one inch more than us for the suspension lines and it's such a difference for the average drop speed.
778	Teacher:	Let's talk about this. Do you remember when you built your canopy?

Valerie[1] (775), and previously Tyson, noticed that two of the groups (group 3 and group 8) had very close suspension line lengths (24" vs. 23"). The teacher prompted Tyson (776) to repeat something he had mentioned to her earlier. Tyson poses his confusion (777) about why a seemingly small difference in two parachute designs (that is, same canopy material and size, and only a one inch difference in suspension line length) led to a big difference in average drop speed (3.9 ft/sec vs. 5 ft/sec). Tyson participated in one of the groups in question, and thus his own identity as a student and emergent engineer may play into his keen interest in this pattern in the data. This interchange led the teacher to have the students reflect on the nature of the construction of the parachutes and their canopies. This short episode shows the beginnings of some epistemic practices. As Tyson tries to make sense of the data, he is comparing designs, evaluating results, and questioning how small differences in parachute specifications led to significant variations in performance.

Episode 2: Using Observations and Interpreting Functionality of Components of Design

This sequence began with a student's observation about a pattern she noticed in the data collected and shared by the class: designs with "shorter suspension lines and bigger canopies had lower average drop speed" (791). Much like the first episode, after getting the class' attention, the teacher asked one student to share out a potentially insightful observation (792).

Line #	Speaker	Talk and action
791	Naomi:	This isn't really a comparison but I noticed that the people who had shorter suspension lines and bigger canopies had lower average drop speed.
792	Teacher:	Naomi just said I noticed that . . . can I have you, Kiara, stand up? I don't know who this team is. Can you hold this? Turn this way. Naomi said, I noticed that . . . Naomi, can you say that one more time and we'll try to kinda point to it as you're talking? You have to speak loud because I can't hear you over here.
793	Naomi:	I noticed that the parachutes with shorter suspension lines and bigger canopies went slower and had lower average drop speed.
794	Teacher:	Than something with a long suspension line. Why do you think a long . . . We know that long suspension lines do help you, we know that, compared to the really, really short ones. But how long do you think it has to be? Do you think that long is really going to help you?
795	Student:	No
796	Teacher:	What's the purpose of the suspension line? What do you think the purpose is, Navarro?
797	Navarro:	To hold out the . . . to make it so it goes like this instead of just going like that. [*student manipulates a model parachute to show two different arrangements*]

Line #	Speaker	Talk and action
798	Teacher:	So it kinda keeps it like in a bowl kind of shape?
799	Navarro:	Yeah.

Naomi repeated her observation, which led the teacher to use the observation to examine the functionality of the suspension lines (794). Given the nature of the question, a student recognized the limiting value of suspension line length (each unit of length adds weight, and may have diminishing returns for their function). When prompted by the teacher about the role of the suspension lines, Navarro demonstrated the functionality of this component of the design through embodied knowledge—he physically demonstrated how the suspension lines serve to expand the canopy and maintain its shape throughout the flight (797). In this episode, the emerging epistemic practices are making observations, noticing patterns in data, examining the functionality of components of designed objects, and demonstrating the functionality of components of designed objects.

Episode 3: Recognizing a (Seeming) Anomaly

Episode 3 occurred later in the lesson (1:19:14.6) when the students were again comparing data across groups on a common table presented on a flip chart. This time the discussion centered on the second, improved design, which took into account the previous designs, the data collected and compared across the groups, and the discussions about the related variables. The teacher again collected the results from the student team groups, noting in a different color on the same data table the results of the "improved" student teams' designs. In this case, a student began the exchange with a question about how two teams had similar characteristics, but different results.

Line #	Speaker	Talk and action
1218	Navarro:	How does number 4 and number 8 have the same thing, but they have different drops [speeds]?
1219	Teacher:	4 and 8 have the same what? Same this? OK and different drops, but look at how close they are.
1220	Navarro:	Yeah but still.
1221	Teacher:	Aren't they pretty close? How far away are they? Four tenths? That's really close, that's really close. Well it should be . . .
1222	Teacher:	Navarro makes a good point. You would think it would be the same. How would we get data to be really, really close? Close to what we think?
1223	Navarro:	Do it over and over.
1224	Teacher:	Over and over and over and over. Test and test and test and test.

During the discussion, Navarro pointed out an anomaly in the data table (1218): groups 4 and 8 had the same measures for relevant variables (canopy size [18"], suspension line lengths [14"]), but differed in the dependent variable of drop speed

(2.3 vs. 2.7 feet per second). The teacher noted that the drop speeds are close, but then recognized that Navarro had a point about the variation in the data (1219, 1221). She used this anomaly to address a broader issue about data collection by posing the problem for the student about "how to get the data to be really, really close?" (1222). Navarro responded by noting the value of multiple data trials (1223). By looking closely at these interactions, a number of epistemic practices can be identified including: improving engineering design through a process; taking into account previous designs, data, and collective thought; pointing out anomalies; and noting the value of multiple data trials.

In these three episodes some hypotheses about the emerging epistemic practices can be identified. As a class, teacher and students working together with the help of the engineered objects, data representation, and common ways of speaking and writing, were able to take actions that can be argued are burgeoning practices of engineering. For example, they communicated features of designed objects, represented data, compared designs, evaluated results, recognized patterns in data, improved engineering design through a process, pointed out anomalies, and noted the value of multiple data trials.

These illustrative examples show ways that the study of interaction can be used to examine epistemic practices, and through the study of practices, an examination of epistemic cognition. In these cases, *what counts* as knowledge is intersubjective and often in play as participants converse. The students and teacher referred to previous events, aspects of the student team designs, and commonly shared data. Thus, the questions about knowledge (e.g. relationship of limited utility of suspension line length after threshold for canopy envelopment) are distributed across the participants and relevant texts. The discussion relied on multiple participants, as each built on previous comments/observations, took the conversation in a particular direction, and evoked the texts presenting the data from the trials. These events are illustrative of how a distributed epistemic cognition can be developed through experience in knowledge building practices of proposing, communicating, constructing, analyzing, and justifying. To fully examine epistemic cognition in these cases, or others derived from events of classroom life, research methods need to be extended to examine ways of identifying patterns over time and across practices through systematic inquiry (Kelly, 2014b). Furthermore, these events suggest the need to examine how individual students take up and learn from the social processes of making these decisions about engineering design and analysis. Consistent with the ethnographic orientation of the perspective presented here, a logical next step would be to examine the artifacts, such as the students' engineering notebooks, for evidence of how they learned to engage in the epistemic practices constructed in the public spaces. Additional analysis may be provided by complementary research methods that consider in detail how students reason about knowing and knowledge.

REFLEXIVITY: BUILDING COMPLEMENTARY METHODS FOR INVESTIGATING EOC

Research in epistemic and ontological cognition has advanced into new and interesting areas. The field is developing new methods and seeking ways to bring philosophical and other epistemological perspectives to the study of students' thinking about knowing and knowledge. In this chapter I proposed an alternative view of epistemic and ontological cognition to complement the current work in the field. By considering the ways that students use knowledge in social practices to learn disciplinary knowledge (in this case engineering), I proposed a methodological approach to complement the current paradigms in this field.

As a field we can turn questions about what counts as knowledge and how knowledge claims are legitimized on ourselves. Such reflexivity has the potential to advance complementary methods for research in EOC. In previous work, I proposed three types of dialectic epistemic conversations about research methods (Kelly, 2006). As analysts, we commit to certain vocabularies and ways of conceptualizing phenomena. Our research is communicated in textual, aural, and visual forms that provide a context of presentation. Each approach creates affordances and constraints to understanding social phenomena, and thus each needs to recognize the contingency of the respective research language (Rorty, 1989). By considering the contingencies of the research approaches, the field can become more reflexive and sensitive about these choices and more able to recognize the limitations of any one given framework for observation, description, and analysis (Kelly, 2014c). In considering ways that alternative research methodologies can be complementary around substantive issues of interest, Kelly (2006), building on Habermas (1990), Longino (2002) and Strike (1995), proposed three types of critical discourse to promote learning across differences.

The first is *critical discourse within-group*. These conversations center on the developmental and definitional work regarding the creation, specification, and extension of a research group's central theories, assumptions, and ontological commitments. Included in the developmental work would be the socialization of new members. In the case of EOC, a number of outstanding issues could be treated from within the various traditions of research, including, but not limited to, the developmental stage and systems of beliefs models described by Greene et al. (2010) and the sociocultural approach suggested in this chapter. Topics such as the nature of beliefs, stages, and systems of categories forming the basis of research instruments are debated and developed within the various points of view. Affordances and constraints of interactional analysis of the study of epistemic practices similarly could be examined.

A second conversation is *critical discourse regarding public reason*. These conversations focus on the development of epistemological commitments to assess value of educational research across traditions. Typically, considerations of methodological approaches and the potential contribution of any given approach rest on a set of substantive assumptions about knowledge in the field. Looking across the different approaches, and based in the understandings of what counts as social science research, criteria for effective methods can be discussed and debated. Likely issues to emerge are criteria such as internal consistency, empirical adequacy, usefulness for practitioners, potential for further research development, and so forth.

The final type of conversation concerns *hermeneutical conversations across groups*. These conversations center on what can be learned from differences across traditions and reevaluate both "critical discourse within-group" and "critical discourse regarding public reason." These sorts of conversations would consider ways that different methodological approaches address similar substantive issues and can be potentially mutually informative.

This book represents an advance in research in epistemic and ontological cognition by engaging in studies of the application, theoretical development, critique, and methodological approaches of epistemic and ontological cognition. What counts as knowledge about others' EOC depends on the sets of categories of analysis (ontology of the field) and of ways of proposing, justifying, evaluating, and legitimizing knowledge claims about EOC. This chapter examines the assumptions of the social practices of EOC for learners and researchers of learners.

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NOTE

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