Chapter 42
Inquiry Teaching and Learning: Philosophical Considerations

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Indeed, the very word 'cognition' acquires meaning only in connection with a thought collective.

Ludwik Fleck 1935

42.1 Inquiry in Science Education Reform

Debates regarding science education go through various stages of reform, perceived change, and more reform (DeBoer 1991). These changes have centered on the extent to which students' interests, autonomy, and knowledge are balanced against the cultural knowledge of the legitimizing institutions. Dewey (1938a), Schwab (1960), Rutherford (1964), and more recently the (USA) National Research Council [NRC] (1996, 2011) have, in various ways, called for engaging students in the scientific practices of professional scientists. These calls for reform conceptualize inquiry differently, and each can be viewed as making a set of assumptions about knowledge, science, students, and learning – thus suggesting the need for examining epistemological issues in science teaching and learning. In this chapter I consider some of the opportunities afforded by an inquiry-oriented science education but also the constraints to successful implementation of inquiry in schooling.

Inquiry in science entails conducting an investigation into the natural or designed world, or even into the applications of scientific knowledge to societal issues. Such investigations typically concern a domain for which at least some of the participating inquirers do not know the results prior to the investigation. Dewey (1929, 1938a) characterized inquiry as dialectical processes emerging from problematic situations

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aimed at reaching some resolution.[1] Inquiry has been characterized as engaging learners in scientifically oriented questions, formulating and evaluating evidence and explanations, and communicating results (National Research Council 1996). As such, inquiry is derived from views of knowledge, is underwritten by interpretations of knowledge, and instantiates perspectives on knowledge. Furthermore, the referent for what counts as inquiry activity need not be limited to the work of professional scientists, as other members of society can be viewed as engaging in scientific practices. Thus, inquiry science poses epistemological questions, and with a focus on science education, these questions can be addressed from a philosophy of science point of view.

Interesting questions arise as to whether inquiry science teaching is directed at learning knowledge and practices of science or at aspects of the nature of science or both. We can speak of learning science through inquiry, where inquiry is the means to learn knowledge and practice. Or we can view the pedagogy as inquiry about science where the intent is to communicate lessons about the nature of science. Often these perspectives on inquiry purposefully brought together, so that learning knowledge and practices through inquiry serves to inform students about science by engaging in the practices constituting scientific activity. I will refer to the dual purpose approach as teaching science as inquiry. As each of these views of inquiry presupposes views of scientific knowledge and thus manifests an epistemological orientation, we would expect to find implications of the philosophy of science for teaching science in this manner. Nevertheless, the relationship of inquiry teaching and philosophy of science is not straightforward.

42.2 Educational Challenges of Teaching Science as Inquiry

There are a number of important challenges to teaching science as inquiry. First, through many years of research and across different learning theories, it is clear that students need concepts to learn concepts. Students learn concepts in bunches, and these cannot be typically investigated one at time through (even careful) classroom-based practice activities or empirical investigations. Educators should not assume that students are able to induce sophisticated scientific concepts from empirical phenomena. While few educational programs explicitly assert that students construct knowledge in the absence of more knowing others, a number of perspectives suffer from this assumption, often under various banners such as hands-on learning, discovery, or radical constructivism (Kelly 1997). As some knowledge is required to learn, then inquiry approaches that situate the student at the center of investigation need to recognize that only with sufficient, relevant background knowledge can answerable questions be posed by students. Thus, inquiry approaches to science

[1] Dewey's (1938a) definition is as follows: "Inquiry is the controlled or directed transformation of an indeterminate situation into one that is so determinate in its constituent distinctions and relations as to convert the elements of the original situation into a unified whole" (pp. 104–105).

learning need to consider the importance of learning through engaging in activities and discourse of science with more knowing others.

A second challenge for inquiry instruction is that learning science entails more than learning the final-form knowledge of scientific communities (Schwab 1960; Duschl 1990). While propositional knowledge (*knowing that*) is important, knowing how to engage in scientific practices and how to make epistemic judgments ought not be neglected. Therefore, science learning should include conceptual, epistemic, and social goals (Duschl 2008; Kelly 2008). While much of inquiry has focused on students' engagement in practical or laboratory activities, pedagogies focused on socioscientific issues and science in social contexts pose important opportunities to learn through investigations in unknown domains (Sadler and Fowler 2006). Inquiry can arguably include evaluation of expertise, certainty, and reliability of scientific claims of others.

A third challenge to learning science as inquiry concerns the nature of the intended propositional or procedural knowledge (*knowing how*) in the curriculum. Science topics and community practices may be more or less appropriate for an inquiry approach. Some knowledge and practices may be attainable through student-centered approaches, while others require the direction of more knowing others. Clearly, at least some scientific practices can be learned only through intensive effort, which may require extensive participation in a community of learners. Other topics might be suited for other forms of instruction. Furthermore, methods of assessment, either formative or summative, need to be carefully chosen to match the learning goals appropriate to the knowledge sought.

Fourth, learning the conceptual knowledge, epistemic criteria, and social practices over time in science domains may require coordination of scope vertically (across grades over time) and horizontally (across subject matter areas at a given grade) across the curriculum. While academics find ways to separate disciplines, and there may be interesting epistemological distinctions, students experience schooling as a whole. Science may not be separate from views and knowledge of history, mathematics, reading, writing, and so forth. Thus, the challenge for teaching science as inquiry includes understanding how such approaches can be supported or undermined by other curricular decisions and pedagogies, both from within and from outside science programs.

Despite these challenges, inquiry teaching and learning have been advocated in different forms many times across generations (most recently, see NRC 2011). The potential for learning knowledge and practices of disciplines through engagement in purposeful activity has been recognized both as a means to learn science and as a way to develop student interest. The linguistic turn in philosophy and the continual rediscovery of the importance of learning through participation in discourse practices of epistemic communities have led educators to examine ways that inquiry can be enacted in various settings. This potential of engaging in discourse practices as inquiry has not always been realized, and there is still considerable debate about the nature of inquiry and its overall merits (Blanchard et al. 2010; Kirschner et al. 2006; Kuhn 2007; Minner et al. 2010). Much of the debate fails to recognize the relationship and disagreement among the learning goals, limited measures of assessment, and the purposes of education – that is, rhetorically, the interlocutors argue past each other. Much of this debate regarding differences in traditional and experiential education was identified in Dewey's (1938b) *Education and Experience*. Has the field advanced since? How can philosophy of science help? To address these issues, I consider some challenges for using philosophy of science in science education.

42.3 Challenges for Using Philosophy of Science to Inform Inquiry Science Teaching

Just as inquiry poses challenges because of the realities of teaching and learning science, drawing from the philosophy of science to inform science education poses challenges because of the nature of philosophy. Educators have called for developing philosophically informed science curricula (Hodson 2009). While this is a welcome perspective, in this section I examine the assumptions of the application of philosophy of science to science education and note that some of the difficulty lies not with educators' misunderstandings about philosophy but rather with the nature of philosophy as a discipline. I identify four dimensions of this difficulty.

First, the philosophy of science treats a number of technical issues that may not directly inform educational practices. Throughout the history of the philosophy of science, issues such as inference, perception, and abductive reasoning form the basis for a number of technical arguments conducted by specialists. These arguments are important for the development of the field of philosophy of science and may advance understanding about the nature of science, but do not necessarily lend themselves readily to educational applications. For example, one debate concerns arguments for an instrumental versus realist view of scientific theories (van Fraassen 1980; Boyd 1991): Do theories serve as predicting devices or rather do they refer to real objects in the natural world independent of our theory-dependent views of such objects? While there is something at stake in philosophy, and indeed plausibly for education, regarding instrumentalism and realism, the technical arguments do not necessarily lead to specific implications for education. For example, scientific realism and constructive empiricism recognize the strong theory dependence of scientific methods. Procedures and inferences about actions in the course of an investigation are dependent on the extant theoretical knowledge of the inquirers. This level of consensus may be enough to develop science curricula that propose reasonably informed experiences for students, without a final answer to the instrumentalist-realist debates. While the particulars of the debate may not have easy answers for education, there are useful tools and ways of thinking in philosophy of science that have merit for education.

Second, philosophy of science includes different perspectives and knowledge that change over time. As philosophy of science changes, educators need to work to understand those changes and update their own of philosophies of science. Furthermore, this effort will be complicated by the number of philosophical positions. For example, Laudan (1990) broadly identifies four major research traditions: positivist, realist, relativist, and pragmatist. Within any one of these perspectives, there is considerable variation. For example, Dewey's (1938a) pragmatism refers to science as an approach to reasoning; Toulmin's (1972) pragmatic point of view provides historical evidence from the history of science to examine conceptual change over time; Rorty's (1991) pragmatism seeks to change the nature of the conversation from technical philosophical debate to thinking about the usefulness of knowledge, be it science or other. Thus, the nature of philosophy of science is itself variable and like science fields experiences changes through research.

Third, philosophy of science has historically been normative and relatively apolitical (with a few exceptions, see Matthews 2009; Rouse 1996). Some of the central goals of philosophy of science concern questions about how science should be practiced, rather than the actual practices occurring in real settings. While some motivation for the study of scientific reasoning emerged from the realization of scientific knowledge as remarkably (and perhaps uniquely) reliable, the focus of philosophy of science has historically been on studying structure and change of scientific theories (Suppe 1977). Machamer (1998) characterized philosophy of science as concerned with the nature and character of scientific theories, the history and nature of inquiry, the value systems of scientists, and the effects and influences of science in society. While such a view expands beyond a focus on theory, the focus of the discipline has traditionally been normative – thinking about ways that reasoning should occur to lead to reliable results. This poses challenges to educators. Developing an inquiry orientation around socioscientific issues requires some consideration of the messy, ill-formed reasoning and ambiguity that surrounds science in society. Additionally, even in highly controlled settings, the reasoning patterns of students are likely to vary from the logical rigor demonstrated in philosophy. Therefore, models of conceptual change from science disciplines can at best be viewed as analogies for promoting thinking about student learning.

Fourth, the complexity of philosophy of science, and science studies more generally, particularly the empirical study of scientific practices (such as that found in the sociology and anthropology of science), poses challenges about how to characterize the nature of scientific knowledge and practices for students (Kelly et al. 1993). The rich debates within philosophy of science require specialized knowledge and an understanding of the history of ideas in this domain. Furthermore, the nature of science within philosophy changes. The complexities of science suggest that there is no one nature of science, but rather natures of the sciences (Kelly 2008), and that learning about the knowledge and practices of scientific disciplines requires engaging with such practices in particular domains (Rudolph 2000; Schwab 1960). Philosophy of science offers insight into knowledge in the various disciplines, but is not readily applicable to inquiry science teaching.

42.4 Philosophy of Science and Inquiry

I have argued that teaching science as inquiry poses a number of serious challenges. I have subsequently argued that drawing implications from the philosophy of science similarly for inquiry is problematic. But surely a field dedicated to understanding the bases of scientific knowledge should have something important to say to those seeking to teach science. Issues such as observation, experimentation, inference, and explanation seem relevant to learning about the workings of science. Yet, such practices pose challenges for novice learners who may not have the conceptual and epistemic bases to engage in such scientific practices in inquiry settings.

What can the philosophy of science offer? I argue that despite potential problems of implementation, philosophy of science contributes much, including methods for posing questions about science, models for serious thinking about science, understandings about aspects of scientific inquiry, and a skeptical orientation regarding ways that science is characterized in curriculum materials and instruction.

42.4.1 An Inquiry Stance Toward the Nature of Inquiry

Philosophy of science provides methods for posing questions about science, scientific activity, and values entailed in such inquiry. Philosophy of science steps back from the details of specific scientific investigations, debates, and controversies and seeks to examine the rational basis for theory choice. Over time, the characterization of theory change as depicted in philosophy of science has changed, and the debates continue. For example, certain versions of early understandings of logical empiricism sought to understand the logic of theory choice. This perspective attempted to view theories as predicting devices and focused on the cognitive content (often viewed as the empirical consequences) of particular theories. Alternatives of various sorts to this depiction emerged after Kuhn's (1962/1996) influential view of theories as connected to overarching paradigms that influence the nature of observation. Recognizing the importance of theories, beyond their empirical consequences, led to a number of developments in empiricism and scientific realism, along with various social constructionist views of science. Across the perspectives, philosophy of science continues to engage in inquiry into the inquiry processes of science.

Modeling inquiry into inquiry has two implications for science teaching and learning. First, question posing serves as a model for school science pedagogy and research into learning science as inquiry. For pedagogy, inquiry requires finding ways to pose questions and problems. Indeed, recognizing what is a good question to ask is often a key feature of inquiry. For research into inquiry, posing questions about the inquiry process and examining ways that inquiry changes over time can advance educational thinking about science education. Second, inquiry into inquiry in philosophy of science demonstrates the importance of thinking about epistemic practices within a community and the value of shared repertoires for investigations and argumentation.

42.4.2 Development of Understandings About Aspects of Scientific Inquiry

Philosophy of science may identify educational perspectives on science that are not readily available through causal observation, or even participation. Careful analysis of theory change, induction, and explanation in the field of philosophy of science can lead to understandings about the nature of science. Furthermore, increasingly philosophy of science is being influenced by the empirical study of scientific practice (Fuller 1988). These studies are informing philosophy of science in ways that bring further relevance to the consideration of inquiry approach in education. Four examples illustrate this case.

First, across perspectives in the philosophy of science, there is wide agreement about the theory dependence of scientific methods. Hypotheses are not tested one by one, but rather a set of auxiliary hypotheses are held constant for a given domain of knowledge for each investigation. Disagreements about results, say for a tested hypothesis, include evaluations of plausibility of the auxiliary hypotheses, as much as the meaning of empirical results for the tested hypothesis. Part of what is at stake in advancing knowledge is understanding how theory, methods, and specific results map onto the plausibility of background theoretical knowledge. Furthermore, such investigations are the product of persuasive arguments and knowledge emerging out of (often) strenuous debates. Thus, theory dependence advances in knowledge situated within a relevant epistemic community.

Second, scientists engage in social practices for years before learning to recognize phenomena from the point of view of the discipline (that is to "see as") (Goodwin 1994; Kuhn 1962//1996; Wittgenstein 1953/1958). Such socialization provides stability in the field and provides the basis for inquiry. Becoming a relevant observer or speaker or member generally requires a significant apprenticeship, as a new member of a community learns the practices and applied knowledge of the research area in question. This view builds on the work of Wittgenstein (1958) and has been shown from historical (Hanson 1958; Kuhn 1962/1996) and sociological (Collins 1985) perspectives. Importantly, engaging in social practices entails learning the discourse processes and nuanced meanings of a field. This has led to careful examination of the ways that discourse processes make visible events for observers (Lynch 1993).

Third, the use of models has become recognized as important for scientific inquiry (Giere 1999). Models in science are viewed as holding an internal structure that represent aspects of some phenomenon or mechanism (Machamer 1998). These models come in different sorts (e.g., analogous physical conditions, mathematical representations, idealized cognitive models) and serve different roles at various stages of knowledge construction (Schwarz et al. 2009). Modeling in science education draws from philosophy of science and cognitive theory. For example, Windschitl et al. (2008) proposed a view of science that focuses student discourse on learning scientific concepts. They identified several epistemic characteristics of scientific knowledge represented in models. Such models are "testable, revisable, explanatory, conjectural, and generative" (p. 943). Windschitl and colleagues propose a model-based inquiry approach that uses a set of conversations to organize knowledge, generate testable research questions, seek evidence, and construct an argument. This model-based approach to inquiry offers the possibility of moving students beyond learning only theoretical knowledge by situating them in a community that considers the epistemic criteria for scientific models (Pluta et al. 2011). Such a view is consistent with the dialogical perspectives in social epistemology.

Finally, the complexities and variety of activities that might count as science have made characterizing these activities as a whole increasingly problematic. While at one time physics may have served as a model of science, emerging views of science recognize important disciplinary differences. Furthermore, the disunity of science and the range of the many fields that can properly be called science require that understandings, such as the nature of science, and disciplinary inquiry, such as the philosophy of science, look at specific ways the actual work of science is accomplished. This issue has been brought to science education in reviews of the nature of science (Kelly et al. 1998) and in specific applications to disciplinary knowledge within fields of inquiry such as biology education (Rudolph and Stewart 1998), chemistry education (Erduran 2001), and geology education (Ault 1998).

42.4.3 Values of Scientific Communities

Philosophy of science identifies values undergirding scientific inquiry. Such values are relevant to inquiry in science education. As an illustrative example, I consider the identification of values in science and the importance of establishing discourse ethics for fair debate in science fields. Longino's (1990, 2002) social epistemology articulates ways that productive discourse can be accomplished in scientific communities. In her work Longino (1990) examined both constitutive values internal to scientific communities and contextual values that influence assumptions in science. Her work considered how values for discourse could be established to promote reason and objectivity given the deeply value-laden work of science. Her solution was to propose a set of four social norms for social knowledge (Longino 1990, 2002): The *venue* refers to the need for publicly recognized forums for the criticism of evidence, methods, assumptions, and reasoning. Everyday venues may include research meetings, conference presentations, and publications. *Uptake* refers to the extent to which a community tolerates dissent and subjects its beliefs and theories to modification over time in response to critical discourse. This value is somewhat contested, as in some areas dissent can be interpreted as not adhering to the best available explanation. *Publicly recognized standards* are needed as a basis for criticism of the prevailing theories, hypotheses, and observational practices. These standards contribute to framing debates regarding how criticism is made relevant to the goals of the inquiring community. One would expect public standards to evolve over time as research groups, communities, and disciplines develop new knowledge and practices. Finally, Longino (2002) argued for communities characterized by *equality of intellectual authority*. This equality needs to be tempered, so differing levels of expertise and knowledge are appropriately considered. While these are values identified as prescriptive for public discourse in science, such values may be applicable to inquiry in science education (Kelly 2008).

42.4.4 Developing Skepticism Toward Portrayals of Science in Curriculum Materials and Instruction

Philosophy of science can help educators promote a healthy skepticism regarding how science is characterized in curriculum materials and instruction. Inquiry in science education is often seen as a means to realizing understandings about the nature of science – importantly this often entails opportunities to raise issues about science (Crawford et al. 2000). Machamer (1998) characterizes the philosophy of science as "the discipline that studies the history and structure of inquiry" (p. 2). The study of inquiry, thus, should evince aspects of the ways that disciplinary knowledge is constructed, assessed, used, and communicated. These issues have been taken up in science education, relying on the philosophy of science and science studies more generally. A fundamental question is whether there can be a consensus view characterizing the nature of science as a set of declarative statements, or if inquiry can serve as a means for engaging in aspects of disciplinary practice where epistemological issues arise. For example, Rudolph (2000) cautions about assuming a generalized view of science or a standard set of assumptions about the nature of science, given the disciplinary differences and the heterogeneous practices across the workings of science in its many forms and disciplines. Irzik and Nola (2011) make similar arguments against a consensus view of the nature of science. Their perspective takes a family resemblance view to account for the many ways science differs across disciplinary perspectives. Importantly, these authors note that while actual inquiry practices vary, engaging in "data collecting, classifying, analyzing, experimenting, and making inferences" (p. 593) is central to developing understandings of science. Considerations of the criteria for which such practices are relevant to a given situation, and under what conditions, can lead to productive conversations about how to characterize science for the various educational purposes of different science education programs. For example, Van Dijk (2011) proposed that a family resemblance view of the nature of science offers the flexibility for the fields of science communication where promoting scientific literacy is a key goal. This perspective recognizes the disunity of science and argues against viewing science as a set of declarative statements, suggesting that such a perspective offers ways of communicating the nuances in the variation across images of science.

Allchin (2011) suggests that achieving a robust view of science requires abilities to make sense and assess the validity of scientific claims. As suggested in the preceding section on inquiry into inquiry, philosophy of science can model the reasoning needed to understand the complexities of science while supporting skepticism toward generalized statements about science. Allchin proposes methods for evaluating students' understanding through engaging students in case studies of assessment of scientific claims, thus showing how the substantive knowledge and explanatory ideals of a given discipline is related to the inquiry methods (Ault and Dodick 2010; Kelly et al. 2000). This view of inquiry entails engagement with knowledge of the natural, designed, or socioscientific worlds, for a given task, and thus takes the expanded view of inquiry (beyond just hands-on science) described in the introduction of this chapter.

42.5 Toward a Sociocultural Philosophy of Science for Education

42.5.1 Shift in Epistemic Subject from the Individual to a Collective

Philosophy of science has shifted the epistemic subject from the individual learner to the relevant social group (Fuller 1988; Longino 2002). Such a shift provides the basis for a thoroughly social view of knowledge and practice in science (Lynch 1993) and science education (Kelly and Chen 1999). There are clear curricular implications for a social epistemology. These include creating practical experiences that take into account the extant knowledge of the students, designing investigations that acknowledge the interpretative flexibility of empirical evidence, and situating decisions about experimental results and socioscientific issues in a dialogical process (Kelly 2008). The social basis of scientific knowledge has a long history. From Fleck's (1935/1979) thought collective, Wittgenstein's (1958) language games, Kuhn's (1962/1996) paradigms, to Toulmin's (1972) constellation of explanatory procedures, to Longino's (1990) shared values, a continuous thread runs through twentieth-century philosophy of science: the sociocultural basis for scientific progress.

There are many examples that illustrate the importance of the sociocultural basis of scientific progress. Three examples highlight some of the relationships with inquiry: the *sociohistorical contexts of scientific discovery*, the *acculturation of new members to a community*, and the *relevance of epistemic criteria and evaluation of knowledge claims*. Before reviewing their implications, it is important to recognize the distinction between the aims of scientific groups, which are orientated toward producing new knowledge, and the aims of education, which include acculturating novices into ways of understanding the natural world. Scientific and educational institutions have different purposes, and failing to recognize the differences confounds aspects of inquiry with discovery, learning, and so forth. Inquiry in science activity may lead to new knowledge. Inquiry in education serves to instruct members how to engage in relevant specific processes of investigation, use concepts in context, and develop means for understanding community practices. Under some circumstances, inquiry in educational settings generates new knowledge within the local community, thus showing some similarity with scientific communities.

Advances in science emerge from *sociohistorical contexts* where relevant groups of inquirers draw from extant knowledge, design and execute ways of collecting evidence, and propose solutions and evaluate solutions to outstanding, communally recognized problems. Fleck's (1935/1979) analysis of the science of syphilology provides a telling case. A variety of notions of the origins and causes of syphilis emerged from various social constituents. Religious, astrological, and medical communities proposed ways of understanding the origins and nature of the disease. The eventual development of the idea of syphilis as an infectious disease occurred through agonistic debates in which both the nature of the causal entity and the relevance of certain preconditions were simultaneously examined. For any experimental result to be taken as evidence, a whole set of preconditions and assumptions of the thought collective need to be taken into consideration. The eventual success of the identification of the infectious agent was the result of the collective effort of a community of health officials, whose contributions and work "cannot easily be dissected for individual attribution" (p. 41). The debate had to be won around the epistemic criteria for evidence – not just around the nature of the evidence from the different perspectives.

A second example of the epistemic shift relevant to inquiry for education is the manner that newcomers are acculturated into particular ways of seeing, communicating, and being. This realization about the substantive and important socialization into the ways of being in science counters forms of positivism (Ayer 1952) that based scientific progress on logic and objective experimental facts (although see Carnap 1950). These ways of being are dependent on the social practices of a relevant community (Mody and Kaiser 2008). Much of the work of apprenticeship for the ways of seeing, communicating, and being entails active participation in the practices of a relevant community. Learning to participate and become a member involves collective action. Understanding the ways that the language of a group operates, the nuances in meaning, and the path to modification in such meaning involves use of discourse in contexts. Furthermore, the completion of such an apprenticeship may be critical to being taken seriously by peers (Collins 1985).

A third example of social processes involved in scientific progress concerns the epistemic criteria for the evaluation of knowledge claims. Rather than viewing reasoning in science as a logical process of hypothesis testing, contemporary philosophy of science recognizes the dialectical processes of persuasion, debate, and critique. Indeed, scientific knowledge is social knowledge to the extent that knowledge claims are judged in relevant disciplinary communities. Longino (2002) and Habermas (1990) each have proposed norms for productive conversations in communities that respect alternatives but focus clearly on the strength of marshalling evidence. This leads to implications for inquiry centered on the social basis for decisions and the importance of using evidence in science. A dialectic approach to the construction of knowledge claims has plausible relevance to education. Nevertheless, such an approach needs to consider the local context and participants. Interesting questions about inquiry can be raised about students' developmental ages and abilities and variations regarding the science topic at hand.

42.5.2 Philosophy of Science and Learning

The relationship of philosophy of science and learning has been a central part of numerous developments in science education. One intersection occurred during a focus on constructivist learning in science education. Constructivism entered science education through a focus on students' ideas and understandings, building initially on Piaget (for review, see Kelly 1997). These learning theories and their close cousins, such as conceptual change theory, brought a welcomed focus on students' conceptions. Through careful attention to how students made sense of science phenomena, researchers were able to examine learning from the learners' point of view. This had a significant impact on science education and brought in philosophy of science. For example, the development of the alternative conceptions movement and conceptual change theory both used the work of Kuhn (1962/1996) and others to consider how students' constellation of conceptions served as framework for sensemaking. These foci led to pedagogy attending to students' sensemaking and provided opportunities for students to be actively involved in knowledge construction.

Despite the many positive contributions of constructivism to science education, there were two central philosophical problems. First, many forms of constructivism, particularly radical constructivism, set their epistemological commitments on the mind of the individual learner. This view conceptualized the problem of knowledge and learning as a cognizing subject making sense through exploration. This epistemological orientation ignored the important contributions from philosophy of language and other social views. Thus, by committing to a Cartesian subject, the constructivist orientation was ill equipped to integrate discourse and consider the value of social practice (Kelly 1997). Rather than viewing learning as socialization into a community, constructivists tended to view learning as changes in the cognitive structure of an individual mind. Second, some forms of constructivism confounded the construction of knowledge with ontological questions about reality and world making. Radical constructivism in particular was clear about its commitment to an idealist ontology and failed to understand the nuanced ways other ontological commitments could adhere to similarly reasonable pedagogies (see contributions in Matthews 1998).

A serious competitor to constructivist theories of learning emerged in the form of sociocultural theory. This view of learning conceptualizes the problem of learning as one of participation and appropriation of knowledge and practices of some relevant group. Central to this view is the important role of discourse processes through which everyday events are constructed (Kelly and Green 1998). By viewing learning as acculturation, the role of social processes and cultural practices are emphasized. From this point of view, as groups affiliate over time, they form particular ways of speaking, acting, and being that are defined by the group membership and evolve as the group changes (Gee and Green 1998; Kelly 2008; Kelly et al. 1998). Discourse practices established by the group become cultural tools for members to construct knowledge. These cultural tools, signs, and symbols mediate social interaction, which forms the basis for learning (Vygotsky 1978). Learning does not occur only for individuals because the cultural tools themselves serve as resources for members and evolve as members internalize the common practices and transform them through externalization (Engestrom 1999). Thus, this view of learning entails more than changes in the internalized cognitive structure of individual minds; instead, participants learn to be members of a group with common knowledge, identity, and affiliation through shared cultural practices that constitute membership in a community.

Sociocultural psychology and philosophy of science share some important central tenets and premises about science, knowledge, and inquiry. Both represent a shift in the epistemic subject from the individual learner or scientist to the relevant epistemic *community*, the relevance of agency within the potential created by a social language, and the value of dialectical processes for proposing, evaluating, and testing knowledge claims. Perspectives from Vygotsky (1978) and neo-Vygotskians (Cole and Engestrom 1993) evince the importance of considering how inter-psychological processes can be internalized by individual learners. Thus, much like the social epistemology in the philosophy of science (Fuller 1988; Longino 2002; Toulmin 1972), the individual has agency and plays a key role in the development of knowledge but does so within the social languages of a relevant community. This suggests that instructional design for inquiry should consider how social practices are established and used to communicate ways of inquiring into the natural world. Such communication occurs across events leading to the development of knowledge, including the problem-posing phase of inquiry, the sensemaking talk around investigations, deliberation around meaning of results, and evaluation of the epistemic criteria for assessing proposed ideas, models, and theories.

42.6 Conclusion: Philosophical Considerations for Inquiry Teaching and Learning

Science education has considered inquiry as a goal for reform a number of times across decades – for examples, see Dewey (1929), Schwab (1960), Rutherford (1964), and NRC (1996). Whether or not inquiry was in the foreground, we have seen proposed educational change in the form of goals, standards, and frameworks. Reforms come and go and sometimes come back (Cuban 1990), yet careful consideration of aims should always be present in the conversation about education. This chapter examined philosophical considerations of inquiry, yet science education reform in any form or name can be informed by philosophy of science. Reform in education should not be aimed to reach final resolution of the issues around curriculum, instruction, and assessment once and for all. Rather, reform is a process that can include participants as part of a vibrant democracy where agency and identity are formed through active engagement in educational decision-making (Strike 1998).

This chapter argued for a view of philosophy informed by the empirical study of everyday practice (Fuller 1988; Kelly and Chen 1999; Lynch 1993). I conclude by first considering ways that this view of philosophy can inform science education. I then offer some research directions for the field of history, philosophy, and sociology of science and science teaching.

Philosophy has the potential to inform educational practice and ways of thinking about reform in educational policy. First, philosophy offers ways of posing questions. Posing questions and examining implications represent a contribution of such philosophical considerations. A number of central questions continue to be posed: What counts as understanding? What does it mean to learn? What is knowledge?

How can disciplinary knowledge and practice be assessed? Posing questions and examining in detail any proposed reform offer a contribution to the overall debate in educational reform. Second, philosophy can contribute through conceptual sorting. Through philosophical analysis of the conceptual content of educational texts (policy, curriculum, frameworks, standards) and of education events (research, teaching), philosophy can bring clarity or identify areas of ambiguity. Developing understandings about the nature of knowing, inquiry, and meaning is central to reform that progresses and advances thinking about education. While such meanings can be informed by empirical study, understanding the meaning of inquiry requires careful thought and analysis. The study of everyday practice in science and education settings (Kelly et al. 2012; Lynch 1993) can inform our views about the nature of science, inquiry, and meaning; nevertheless, there is considerable theoretical work needed to render empirical results informative. Thus, normative decisions about directions for science education cannot be answered by empirical study alone, or even more empirical studies – a balance must be struck between careful, descriptive studies and philosophical considerations of meaning. Third, philosophy of science can inform our field by scrutinizing the nature of education research, including the important work of understanding ways to develop productive conversations across theoretical traditions (Kelly 2006). Science and education are human endeavors that require ideas to be generated and assessed through dialectic processes. The field of educational research should consider ways to enhance discourse around educational practice.

With these philosophical considerations in mind, I now consider some plausible research directions for science education regarding inquiry. Inquiry in science education has taken many forms and served different goals (Abd-El-Khalick et al. 2004). In this chapter I identified a number of problematic aspects to thinking about learning science as inquiry. By drawing from a social epistemology in the philosophy of science, I have examined reasons why inquiry as an instructional approach has both potential and drawbacks. The efficacy of this approach depends crucially on how it is implemented, for whom, under what conditions, and for what purposes. I propose four areas for research regarding inquiry in science education.

First, we learned much as a field from the detailed, analytical work of the anthropology and sociology of science (e.g., Knorr-Cetina 1999). The study of everyday practice makes clear the social processes by which *what counts* as science is discussed, debated, and determined. Inquiry contexts, such as the model-based inquiry approach of Windschitl and colleagues (2008), provide a context to examine empirically the value of such approaches for science education. While science studies have their drawbacks, they offer insights into the inner workings of the various sciences. The methodological orientation to examine inquiry as it is interactionally accomplished in everyday life suggests that a similar approach in science education can be fruitful. Close, careful studies of the discourse events around inquiry can illustrate how inquiry is enacted. Contexts such as design challenges, investigations, and studies of socioscientific issues provide potentially inventive pedagogies that can be investigated empirically.

Second, there is a persistent lack of interest among students in pursuing science (Sjøberg and Schreiner 2010). Inquiry models for science instruction have been proposed as a means to address such concerns, beginning with Schwab (1960) and continuing thereafter. Yet, it is not clear that engaging students in inquiry, either into the natural world through investigations or into the socioscientific world through debate, will necessarily increase student interest in science. Research derived from philosophy of science may make science more real, authentic, or consistent with professional practice, but this may not take into account students' views and interests. Furthermore, studies examining the referent for science beyond that of professional science may point to directions that are better at engaging students – for example, ways that citizens use science to address everyday environmental concerns. Such studies would pose a new set of questions about what counts as science for the field.

Third, striving to meet the conceptual, epistemic, and social goals of science education (Duschl 2008) requires a critical analysis and discussions about the nature of inquiry. Such research would need to be reflexive about inquiry into inquiry. Work in science studies and the philosophy of education may be helpful for understanding how inquiry can be conceptualized in science education. I have argued both for the descriptive, empirical studies of science and science education and for the importance of the normative or moral arguments for reason, science, and education. The field of science education can be informed by both perspectives.

Fourth, inquiry most broadly construed entails learning and self-actualization. The educational goal of inquiry should not only be to meet specific standards, concepts, or procedures, but rather to develop the capacity for further learning. Through engagement in the sociocultural resources of other people and through interaction with the natural, designed, or social world, learners can develop an enhanced capacity to learn and develop new ideas. Education from inquiry should develop the ability to engage in more inquiry.

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