THE INQUIRY PARADOX: WHY DOING SCIENCE DOESN'T NECESSARILY CHANGE IDEAS ABOUT SCIENCE

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ABSTRACT
A long standing goal of science education in the United States has been that students develop an understanding of the nature of science, of what scientific knowledge is like and how it is constructed. Despite this interest, students continue to leave secondary schools with naïve views of the nature of science. Current science education reforms advocate inquiry as a way for students to learn about the nature of science as well as scientific concepts. Inquiry engages students in their own efforts to construct scientific knowledge, and several efforts to use technology to support inquiry have been effective at helping students understand important scientific concepts and develop certain skills of scientific reasoning. Still, there is no evidence that doing inquiry in school develops students' understanding of the nature of science. The reason for this is twofold. First, assessments of students' ideas of the nature of science universally target professional science, rather than students' own efforts to do science. Students' views on the nature of their own inquiry may be "scientific," but not be related to their views of professional science. Second, helping students to draw such relationships may depend upon an explicitly epistemic discourse in the classroom, centered on what students know and how they know it, and that connects their work to professional science. Technology can support such a discourse by helping students to generate artifacts from their inquiry structured to highlight epistemic issues. These epistemic tools should represent important epistemic forms of scientific knowledge that link to practices for making them. Most importantly, research on epistemological development must link students' practices of inquiry to their expressed beliefs about professional science.

KEYWORDS
Science inquiry, nature of science, epistemology

INTRODUCTION

For the last half century, several waves of inquiry-based reform have washed over science education in the United States. A recurring goal of these reforms is to develop students' ideas about the nature of science, their scientific epistemologies. This interest in developing students' ideas *about* science, about what scientific knowledge is, how it is generated and ratified, and how science generally gets done, stems from two concerns. One is the notion that scientific understanding extends beyond knowing a collection of concepts to include a view of science as a way of knowing. A second concern is that in order to participate effectively in a democracy, citizens must understand the nature of scientific claims that increasingly influence or even become matters of public debate. Science education is currently in the midst of a reform wave in which inquiry is urged as a "central strategy" of instruction (NRC, 1996, pg. 31), as a better way of learning science and about science. Yet, engaging students in scientific inquiry raises a paradox: doing inquiry may be the best way to develop students' ideas about science, but students' ideas about science often interfere with their inquiry. It seems that students who do not already hold constructivist epistemological beliefs do not learn as much from inquiry (Linn & Songer, 1993), and even resist it (Tobin, Tippins, & Hook, 1995).While inquiry remains the centerpiece of efforts to reform science education, too little work has been done to understand whether and how doing inquiry in science classrooms changes students' underlying ideas about the nature of science.

The inquiry paradox has two aspects that science education has yet to untangle. On the one hand, evidence suggests that students' beliefs about science are at odds with the epistemological assumptions of scientific inquiry. On the other hand, students' practices of inquiry often seem to have much in common with professional scientific practice. There is a gap between these two areas of research that centers around two issues. The first issue is that little is known about *how* students' beliefs about science influence their own efforts to conduct inquiry in school. The second issue is that assessments of students' beliefs about professional science may not elicit their personal beliefs about knowledge creation, and so potentially fail to capture any epistemological change through inquiry. This paper describes this research gap by summarizing current evidence on students' epistemological beliefs about science, and comparing these to findings about inquiry practices. This comparison suggests that inquiry could provide the basis for epistemological development, but not without an explicit epistemological discourse that connects students' work to science in society. At the same time, research on epistemological development needs to explicitly investigate the links between epistemological beliefs and inquiry practices, joining two areas of research that have so far been separate. This analysis suggests that *epistemic tools*, software that help students articulate scientific knowledge, can support meaningful epistemological discourse, and research on students' epistemological understanding.

STUDENTS' BELIEFS ABOUT SCIENCE

A sophisticated Western epistemology of science

Before looking at students' epistemologies of science, it will be helpful to consider what the target is. What sort of epistemology of science should students develop? Key to the present argument is the connection of scientific epistemology to scientific practice. Speaking broadly, and mindful of arguments against any overt scientific method, scientists engage in a set of practices intended to produce certain kinds of knowledge. This is especially important with regard to how most people encounter professional science in their everyday lives – as consumers who need to make judgments about various scientific claims in relation to decisions they make about their own lives. These include personal decisions, such as what foods to eat, as well as public decisions, such as whether or not drill in the Arctic Wildlife Refuge or allow stem cell research, to name two current controversies. Such decisions include many non-scientific factors, but thoughtful judgments demand an understanding of the role that science plays in them.

There is no single, consensus scientific epistemology that scientists, philosophers, and historians agree on. There are, however, several aspects regarding the nature of scientific knowledge and scientific work for which there is general agreement and that students arguably should understand. There is general agreement that scientific knowledge, such as theories and laws, are constructed by people to describe and explain the world, rather than being facts discovered in the world. As such, scientific knowledge is tentative, and the development of scientific knowledge demands creativity and imagination. At the same time, scientific claims must be "evaluated against the recalcitrance of the material world"(Driver, Newton, & Osborne, 2000). Science is therefore empirical, ideas are often generated by observations of the world and systematically revised through empirical tests. There is broad agreement, however, that empirical work is not purely objective. Instead theory guides both the design of empirical investigation and the interpretation of results. Since science is a human construction, scientific practice is embedded within historical social and cultural values. Indeed, science is socially constructed to the extent that new, revolutionary claims are not accepted until members of the scientific community have been persuaded of their value. Much of scientific practice can therefore be seen as the development of practices of inscription and argumentation. Science education therefore must be concerned with the relation between students' beliefs about scientific knowledge and their understanding of the practices used to generate and evaluate such knowledge. Fundamental to learning science should be the development of competence in making and reading inscriptions, criteria for their evaluation, and abilities to use inscriptions to communicate scientific ideas. For a summary of the philosophical and sociological work from which these ideas derive, see (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002).

Students' beliefs about professional science

Research on students' beliefs about the nature of science has gone on for several decades, and has been too thoroughly reviewed to do so here (see Abd-El-Khalick & Lederman, 2000; Driver, Leach, Millar, & Scott, 1996). Despite important differences, there are broadly consistent findings from this long-running work. Most students seem to believe that science is an accumulation of facts about the world, rather than explanations about the world created by people. They seem to think that the ideas that scientists generate and test are descriptions of the actual world. They tend to see experimentation as a process of straightforwardly proving ideas right or wrong, or even that experiments yield answers to questions directly. Most students have a hierarchical view of the relations between hypotheses, theories, and laws based upon their degree of certainty rather than their scope and purpose. That is, most students see hypotheses as guesses, theories as well-tested hypotheses, and laws as irrefutably proven theories. Students rarely see science or scientists as creative, except in a narrow sense of needing to be clever to devise experiments. They do not recognize that scientists use their imaginations to generate theoretical constructs, such as Bohr's analogy of the solar system to describe the structure of atoms, or Darwin's and Wallace's independent formulation of the process of natural selection as an explanation for species variation. Students tend to view historical ideas as uniformly wrong and current ideas as right, rather than viewing scientific knowledge developmentally.

Still, there has long been concern that the methods used to assess students' views of the nature of science are problematic. A historical reliance on survey instruments has forced subjects to express their ideas solely in terms of the researchers' framework (Lederman, Wade, & Bell, 1998). Such forced choices may not enable students to adequately express their own beliefs. Open-ended questionnaires or interviews elicit students' ideas, but are not without methodological concerns. One problem is that interpreting students' responses to questions like "What's a theory?" or "What is an experiment?" can be rather difficult, and the probing that such questions require potentially leads students towards particular responses. Another issue is that such instruments often assume that students have stable, coherent epistemological frameworks (even while characterizing the nature of science as multidimensional). Several recent studies suggest that this unitary assumption is unwarranted – that students' epistemological beliefs seem fragmented and sometimes contradictory depending upon the context (Hammer, 1994; Roth & Roychoudhury, 1994; Sandoval & Morrison, 2003).

Students' beliefs about science learning

One of the issues that plagues research on epistemological development generally is the conflation of beliefs about knowledge with beliefs about learning (Hofer & Pintrich, 1997). Clearly, they are related, but queries about students' strategies for learning do not necessarily allow inferences about their beliefs about knowledge. Instead, such views on learning may simply reflect students' beliefs about the best or easiest way to get through school, or reflect other social motives. There appears to be some relation between students' views of scientific knowledge and their ideas about how to best learn science. Students who see science as a dynamic construction of knowledge tend to have more constructivist orientations to learning. Students who have an objectivist view of knowledge, tend to favor rote learning strategies. Still, it turns out that most students resist clean classification as having either constructivist or objectivist beliefs, either about knowledge or learning (see Linn & Songer, 1993; Roth & Roychoudhury, 1994).

So, after more than four decades, we are certain only that students' beliefs about the nature of science are not as sophisticated as we would hope. It seems as though they hold specific beliefs about the absolute nature of scientific knowledge and the ability of experiments to provide definitive answers, but we remain unsure of whether or not students really hold such views or if these positions are artifacts of our own assessments. We know little of how students' epistemological beliefs develop, and how science education contributes to this. Crucially for inquiry-based reforms, we know very little about how students' beliefs about science influence their own inquiry.

STUDENTS' PRACTICES OF INQUIRY

Most students have a difficult time conducting their own inquiry without some kind of guidance. Most of the research into students' efforts to conduct inquiry has focused on their strategies of experimentation and their attempts to coordinate claims with evidence, and more recently researchers have begun to examine practices of argumentation. In contrast to studies of expressed epistemological beliefs, students' inquiry practices appear to have much in common with scientific practice.

Investigation strategies

Cognitive scientists have been studying experimentation and hypothesis-testing strategies for several decades and have documented a variety of difficulties for students and non-scientists (Zimmerman, 2000). When viewed against normative standards for experimentation, students do not seem to be very scientific. They are often unsystematic in their experimentation, failing to control variables across tests and often ignoring patterns of results and attending only to the most recent one. Many of these studies, especially early ones, can be criticized on the grounds that the tasks involved are only tangentially related to science, and that subjects may not approach them with the same goals researchers have defined. This issue of goals is particularly important in trying to infer whether or not people are acting "scientifically." Studies that have manipulated the goal orientation that subjects are likely to take have found that when subjects see the purpose of experimentation as generating causal explanations, they design better experiments and are more systematic. When students have more causal knowledge about a domain, they experiment within that domain more effectively. All of these findings suggest that differences between students' and scientists' experimentation strategies are partially related to epistemology, in terms of the goals that experimenters pursue, but may stem mostly from differences in knowledge about the domain of investigation.

Coordinating claims with evidence

Children and adult non-scientists often fail to attend to important patterns in data, and are biased to ignore or distort data that threaten strongly held ideas. For educators, this is obviously a problem because it can interfere with students' learning scientifically accepted ideas that challenge intuitive conceptions. Is the failure to accurately coordinate theory with evidence necessarily unscientific, as it has been characterized? Students' approaches to anomalous data seem to have much in common with professional scientific practice, as the historical record suggests scientists are highly unlikely to abandon theories in the face of conflicting data except as a last resort (Chinn & Brewer, 1993).

Examinations of the ways in which students try to make sense of data reveal several strategies that can be considered scientific and useful. Students prefer plausible causal mechanisms over implausible correlations to explain events (Koslowski, 1996). They also generate causal mechanisms to explain incomplete or missing data (Brem & Rips, 2000). This disposition toward causal mechanism aligns well with the theory-laden nature of science. Related to this, students appear sensitive to the criterion for causal coherence in scientific explanations, although their ability to meet that criterion depends upon their conceptual understanding of specific problems (Sandoval, 2003). Students' difficulties in coordinating claims with evidence may have mostly to do with knowledge about specific domains, about possible causes and the evidence that bears on them, rather than epistemological naïveté.

Practices of argumentation

Modern epistemological perspectives on science view argumentation as a central scientific practice, and some have argued that argumentation should be central to science instruction (Driver et al., 2000). Argumentation has recently become an object of study, through both conversation and written artifacts. Most of these analyses have focused on the structure of students' arguments. Students practices of argumentation are not, on the whole, structurally different from scientists. That is, students make claims about data, provide warrants for claims, and so forth. In conversation, students will challenge unwarranted claims, at least some of the time. Students mainly seem to differ from scientists, not surprisingly, in the choices they make about when claims need to be warranted. Many claims that require warrant, from a normative perspective, are often unwarranted and go unchallenged. In written artifacts, students often fail to explicitly cite the data that warrant claims, even when they have used that data to generate their claims (Sandoval, 2003). Such aspects of students' argumentative practices are partially explained by their depth of knowledge in particular domains. It takes domain knowledge to recognize claims as unwarranted, for example. At the same time, students' epistemic criteria for what makes a good argument or a good explanation lack the precision common to professional scientific argumentation. Again, this should not be surprising. Analyses of students' argumentation provides one way to understand students' epistemic criteria in relation to desired instructional outcomes.

DEVELOPING EPISTEMOLOGICAL BELIEFS THROUGH INQUIRY

While students' arguments and interpretations of data can be read as scientific in the ways just discussed, it is possible that their strategies are driven by goals to get absolutely right answers and to weed out wrong answers. That is, the same broad set of strategies could possibly serve different epistemological goals. Besides, it is unclear from studies of students' practice whether they are pursuing scientific goals or school goals, and the latter is much more likely. What is known is that engaging students in the practice of inquiry is insufficient to change their epistemological beliefs about science (Lederman et al., 1998).

Explicit epistemological discourse

Simply engaging in inquiry activities in which epistemological issues are implicitly embedded does not appear to change students' views of professional science (Meichtry, 1992; Sandoval & Morrison, 2003). Changing epistemological ideas seems to require a sustained discourse on epistemological issues. Even so, epistemological change seems to take time. Smith et al. (2000) report that the teacher in their study did not explicitly label epistemological identities such as 'hypothesis', but created a setting in which students were constantly challenged to justify their ideas with evidence, consider alternative views, and so on. The discourse in this classroom explicitly centered on how students knew what they knew. These students had significantly more sophisticated epistemological perspectives on science than a comparison group. This study is remarkably singular, however, as the students in the treatment group had the same teacher for six years. Rosebery and colleagues (1992) documented shifts in the language that their students used to talk about claims and evidence over the course of a year in which discourse norms were a central focus of instruction. Yet, they did not assess students' epistemological beliefs more formally, so it remains unclear whether or not students' changes in arguing about their own ideas changed their views about science. Developing norms of argumentation consistent with scientific practice should contribute to epistemological development, more than didactic instruction is likely to. Still, more needs to be known about how to structure and sustain such a discourse, and how to assess its effects on students' beliefs about professional science.

Epistemic tools to structure artifacts and discourse

Inquiry focused on the construction of artifacts can support, in principle, an epistemological discourse because it can focus talk on the nature of the artifacts themselves and their relation to the processes by which they are made. Such artifacts need to represent valued forms of scientific knowledge, such as models or theory-based arguments for specific cases. There are a variety of recent software tools designed to support students' construction of such artifacts (Bell & Linn, 2000; Jackson, Stratford, Krajcik, & Soloway, 1994; Sandoval, 2003; Toth, Suthers, & Lesgold, 2002). These are *epistemic tools* that structure the form of the artifacts that students might construct in ways that make salient the epistemic features of those forms. As such, they can provide guidance to students about the purpose of their inquiry – to construct a good artifact – and the strategies that may help them meet their goals. Epistemic tools support an explicit discourse about knowledge construction as they are used, and this seems to help students in solving specific problems. The artifacts from such tools can support a broader epistemological discourse, however, as they are taken up in conversation in the classroom. Public comparison of epistemic artifacts should go beyond comparing their quality, but extend to public discussions about the nature of the artifact itself. For example, in comparing models, it is important for teachers and students to explicitly consider what models are (and are not), what they are for, and how they might be developed. That is, considerations of quality have to be grounded explicitly in terms of the epistemological purpose of the artifact. This is an important way in which students' work in school can be compared explicitly to scientific work, through a linkage of goals. Students can model and explain for the same reasons that scientists do, while the strategies they use to do so and the knowledge they draw upon may be different.

There has been a tremendous amount of effort to develop inquiry-based science curricula and to understand how these help students learn science. Such efforts usually ignore epistemological issues or take them for granted. When epistemology is an explicit concern, such efforts can illuminate much about students' understanding of inquiry through analyses of how they pursue it and the nature of the artifacts that they produce. Indeed, engaging students in the construction of disciplinary artifacts is an important way of understanding their epistemological ideas. In building artifacts, students have to make decisions about when they have arrived at a satisfactory solution, what counts as good, and so on.

It is important to see that while a sustained public epistemological discourse in the classroom can exploit epistemic tools and the artifacts they help students create, the challenge of creating and sustaining this discourse is not technological. The key changes in roles are social. For teachers, the change in roles extends beyond the familiar exhortation to act as a coach. To support a sustained epistemological discourse demands that teachers give up their own position of absolute authority and instead adopt a more democratic position in developing norms and standards in the classroom. These norms include the criteria for what counts as valued knowledge and the means for making it as well as standards of discourse, i.e., how people should talk to each other. Of course, students' roles must also shift from recipients of information to constructors and evaluators of knowledge claims. Yet, in this social shift teachers have the crucial role. A full discussion of this role is beyond the present scope, but it is worth pointing out that the demands of organizing and facilitating such a discourse is not something that science teachers are currently prepared for. Consequently, it is not enough to develop good tools and give them to teachers. Science teachers themselves need opportunities to understand science. Here, as with students, the evidence on efforts to change teachers' ideas about the nature of science is somewhat discouraging, and points to the need for an explicit epistemological focus to science teacher education (Abd-El-Khalick & Lederman, 2000).

RESEARCH LINKING PRACTICES TO BELIEFS

To provide a more solid foundation for instructional practice and to assess the effects of instruction on epistemological beliefs, research on beliefs must be linked to research on practice. On one hand, students' expressed beliefs about professional science seem naïve and unscientific. On the other hand, aspects of their own efforts to engage in science seem scientific. The difficulty in squaring these contradictory images is that the research on scientific epistemology has largely taken place separately from research on scientific practice and efforts to support students' inquiry. For inquiry reforms to prosper, these areas of research need to be integrated in ways that can contribute to a grounded theory of epistemological development and instructional approaches that draw on such a theory.

A practice-based theory of epistemological development

Available assessments of epistemological beliefs assume multiple dimensions of epistemological beliefs, but seem to also assume that such beliefs comprise stable, coherent frameworks. An alternative account that may explain reported inconsistencies in students' epistemological views is that epistemological conceptions are fragmented "resources" that students bring to bear differently in different contexts (Hammer & Elby, 2002). This view can potentially explain the differences between students' reported beliefs about professional science and their own work to construct scientific knowledge. The resources view has grown out of diSessa's "knowledge in pieces" theory of conceptual change (diSessa, 1993). Hammer and Elby propose that through their efforts to learn about the world, including formal schooling experiences but not limited to those, people develop a loose collection of epistemological ideas that guide subsequent efforts to build knowledge. They propose some candidate resources regarding the form or source of knowledge, such as "knowledge is stuff." According to Hammer and Elby, such a resource has implications for learning, including that knowledge can be acquired and transferred. Teachers have knowledge, for example, that they can give to students. This resource also includes the notion that giving someone your knowledge "stuff" does not take it away from you.

Other epistemological ideas can be inferred from much of the literature discussed above. People generally seem to believe that causal mechanisms must be plausible and also that plausible causal mechanisms have more weight than implausible correlations of data. People generally seem to believe that claims need evidence, or at least are more believable when they have evidence. Ideas like "claims must be plausible" and "evidence strengthens claims" are productive resources for inquiry. A less productive idea for inquiry is that "evidence is objective" as opposed to, say, "evidence is interpreted." That students hold an "evidence is objective" resource can be inferred from responses to interviews and questionnaires (Driver et al., 1996; Lederman, 1992) and also potentially explains certain patterns of students' use of evidence in written arguments. Often data are simply presented without explication, as if their meaning were self-evident (Sandoval, 2001).

This resources theory or some grounded account is most likely to explain the apparent instability and internal contradictions of students' views of science, as well as recent findings suggesting that epistemological ideas develop differently across domains (Kuhn, Cheney, & Weinstock, 2000). This perspective raises several questions. What epistemological resources do people actually use? How do they differ across domains such as science and history? How does school contribute to their development? How do resources interact during specific episodes of reasoning, in school or out? Pursuing answers to these questions requires at least three concurrent strands of research that must be actively interconnected.

Practices of knowledge creation and evaluation

Research efforts to support inquiry commonly treat students' strategies of investigation as objects of study, but the epistemological aspects of strategy use are rarely treated explicitly. As suggested above, the analysis of the artifacts that students construct from their inquiry is a key opportunity for exploring students' investigation strategies relative to epistemic goals. The strategies and practices that students use during the construction of knowledge artifacts enables inferences about the epistemological criteria students try to meet. The strength of such analyses is that they enable comparison between students' practices of scientific knowledge construction and normative objectives (e.g., Bell & Linn, 2000; Kelly & Takao, 2002; Sandoval, 2003). The limitation of such analyses is that by themselves they cannot illuminate students' goals.

Beliefs about personal knowledge creation

Analyses of students' practices of inquiry need to be supplemented by examinations of students' beliefs about their own scientific work. Such investigations must be able to discriminate students' views of such work as schoolwork from more clearly epistemological criteria. It is critical to determine whether or not students see inquiry in school as anything other than schoolwork. Such research can naturally supplement analyses of students' practice, by asking students to explain what they were trying to accomplish through a particular investigation or in a particular artifact, and how they thought their strategies would do that. For example, high school students explaining problems of natural selection often fail to cite crucial data for claims of differential traits and selective advantage, despite having looked at relevant data and apparently drawing their conclusions from them (Sandoval, 2003). Why? Is it because they do not feel citing data is important? Do they believe that these data are understood by everyone in the class, and thus citation is superfluous? Are they unsure of the meaning of data and thus unsure of how to use it in their explanations? Sandoval's study does not answer these questions, but such answers are needed to clarify how students' epistemological ideas influence their inquiry. Such research does not appear to have been done, but it is the critical step in linking enacted practices to espoused beliefs, and changes in beliefs to changes in practice.

Beliefs about disciplinary knowledge creation

The need to ground research on scientific epistemologies more directly in students' own work does not obviate ongoing efforts to assess students' beliefs about the nature of professional science. On the

contrary, such assessments are an important way to determine whether or not efforts to develop students' epistemological ideas have any effect. Efforts to develop open-ended assessments (e.g., Lederman et al., 2002) should continue. It is probably the case, however, that such instruments will remain inherently ambiguous because of the numerous ways that decontextualized philosophical questions might be interpreted. The very fact that so many great thinkers throughout history have attempted to characterize the nature of scientific knowledge and the methods for creating it should make researchers cautious about their interpretations of students' responses to such profound questions.
Most importantly, research on scientific epistemologies and their development will progress only as research in these three areas are combined. Work on what might be called students' practical epistemologies, epistemology as manifested in action, must be linked to their expressed beliefs about professional science. One possible strategy for making this connection is to ask students to reflect on how the work they do in school relates to scientific work, rather than simply asking abstract, decontextualized questions about the nature of theories or experimentation.

CONCLUSIONS

Given the long history of science education reform efforts, it is troubling that so little progress has been made in developing students' ideas about the epistemological nature of science. Inquiry-based instruction is now seen as the primary vehicle for the development of scientific epistemologies, but it does not seem to change students' epistemological ideas. Instead, students' ideas about science appear to drive their efforts at inquiry and frame their views of that work. This is the inquiry paradox. I have argued here that solving the inquiry paradox requires a more grounded and interconnected approach to understanding students' epistemological beliefs and their influence on students' efforts to build scientific knowledge. This grounded approach must combine assessments of students' practices of knowledge construction with queries about their epistemological views of such work and its relation to professional scientific practice. Epistemic tools, software programs that structure students' articulation of their own scientific knowledge, can support such research in two ways. First, they help to create a context in which students' inquiry can be explicitly grounded in epistemological terms, through focusing on the nature of the artifact such inquiry should produce. Second, these artifacts can be analyzed in ways that illuminate students' epistemological commitments. Both instructionally and analytically, structured artifacts can support exploration of students' epistemological commitments and how they change through instruction.

This approach will provide several benefits. First, it will provide a clearer picture of the epistemological beliefs that guide students' personal knowledge construction, including their ideas about the kind of knowledge they can construct and how to do so. This will enable a much better assessment of the commonalities and differences between students' epistemological beliefs and formal scientific epistemologies. This picture can add greatly to developmental research on personal epistemology by generating accounts of how epistemological ideas develop through experience, namely school science experiences. Second, one of the biggest questions about epistemological development is the extent to which epistemological conceptions are general or vary across domains (e.g., science, history, ethics). The grounded approach argued for here can be pursued across domains to address this question. Finally, a better picture of students' epistemological beliefs about science and their influence on inquiry will enable better models for instruction that can fulfill the promise of science education reform for a citizenry that understands the role of science in their everyday lives.

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