Promoting Sociologically Authentic Inquiry in School Science Communities

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The sociological view of science utilized by the Environmental Inquiry (EI) project contrasts sharply with the view implicit in many school programs. From a sociology of science perspective, claims do not become facts when an omniscient authority passes judgment on them, but when peers recognize and use those claims to do useful work of their own. Scientists employ technologies and empirical tactics, reference other studies, generate inscriptions, anticipate skeptical reception, and utilize other strategies in order to achieve peer acceptance and to retain it in the face of inevitable challenges. School science, on the other hand, often represents facts as unproblematically proven by unambiguous evidence, and frames students as receivers of these clear facts.

This paper, the first paper in this set, provides an overview of the multifaceted, multi-year design of the EI project, which has involved four connected endeavors: summer inservice programs, curriculum writing by inservice and preservice teachers, university-hosted student research symposia, and most recently, doctoral fellowships for young scientists to support scientific outreach to schools. Through overlapping staffs, funding, and activities, we have built up a community of practice that promotes a more authentic experience in environmental science for secondary school students.

This paper also articulates the project's conceptual framework; we draw upon literatures from the sociology of scientific knowledge (SSK), social construction of technology (SCOT), educational implication of nature of science studies, communities of practice (COP), and situated learning. We take these perspectives not only as a guide to school science, but also to inform the design of our curriculum and professional development efforts, and our research.

Theoretical Perspectives

Sociology of Scientific Knowledge

Sociology of science (and of scientific knowledge) describes the practices of science, the construction of scientific fact, and the interactions between science and society. Central to many sociological studies of science has been the role that the community of scientists plays in the creation of scientific knowledge. Unlike the image often propagated by school science, scientific knowledge cannot be created by an individual in isolation; to become accepted as scientific "fact" a claim (and the research supporting it) must be reviewed and critiqued by one's scientific colleagues. Data does not speak for itself—a scientific community must pass judgment, accept the findings, and then build upon them in subsequent studies.

In the 1970s, sociologists of science, seeking to describe the culture of science, began to study the practice of science at the laboratory bench. In particular, they investigated the interrelationship between the scientific method (or, more accurately, the actual practice of science) and scientific knowledge—they wanted to understand how scientific statements evolve from scientific practice (Knorr-Cetina, 1983; Latour & Woolgar, 1986; Sapp, 1990; Traweek, 1988).

Sociological "laboratory studies" have helped redefine the fundamental purposes and activities of empirical work, and the relationship between scientific writing and research. Most lay people believe that scientists do research and then report their results. They notice or observe facts, test them, and then disseminate their findings through writing; an image often promoted by scientists themselves (Latour & Woolgar, 1986; Sapp, 1990). Writing, dissemination, and acceptance of results are seen as separate from, and secondary to, research activities (Gough, 1992). But laboratory studies, particularly Latour and Woolgar's (1986), demonstrate the interdependence of writing, research, and the production of knowledge. In reality, the scientific laboratory does not function as a link between a problem and a solution (Cozzens, 1990), but rather as an instrument of persuasion (Latour & Woolgar, 1986) or a "fact factory" (Knorr-Cetina, 1995). Researchers focus their energies on persuading themselves and others that what they have perceived is important and that their interpretations are valid.

Ethnographers, struck by the "seething confusion" that characterizes scientific laboratories, describe the construction of scientific facts as a long, gradual process of working to create order from the disorder (Latour & Woolgar, 1986; Sapp, 1990). To make assertions, scientists must try to distill messy data from background noise. Their initial tentative written claims serve to initiate a conversation with other scientists (Hull, 1988). Decontextualization and successive removal of uncertainty accompany the rise in status of a claim; "weasel words" (Hull, 1988), modalities (qualifiers suggesting uncertainty or contingency), and any references to social, historical, or personal contexts (Latour & Woolgar, 1986) slowly disappear.

Initially scientists concern themselves with convincing others in their lab group and "friendly," collaborating researchers of their findings. After securing internal consensus, a scientist then must expose her ideas to the larger scientific community. Review by the larger community is important in both advancing the status of the claim towards accepted knowledge and in maintaining the objectivity of science.

The Strong Programme within sociology of scientific knowledge has explored the importance of social negotiation in the production of facts. It has posited that both true and false beliefs should require sociological explanation. Central to the justification for this approach is the stance that empirical evidence alone underdetermines scientific knowledge. Social construction is necessary to move empirical data to established fact. One misunderstanding of this approach is to view it as an overly relativistic attack on scientific integrity. Rather, it is an endeavor to examine the role the social plays in that integrity. "The feeling that there is some truth to which a calculation corresponds is not rejected…[that truth is relocated] in utility and the enduring character of social practice." (Bloor, 1973, p. 188)

Thus the solution to underdetermination lies not with Nature or with the individual, but with others. This is the essence of Latour's *First Principle*:

> The fate of facts and machines is in later users' hands; their qualities are thus a consequence, not a cause of a collective action. (Latour, 1987, p.259)

Latour uses the two headed Janus to illustrate many instances where this social constructionist view has the effect of reversing conventional wisdom.

> 'Of course,' says the left side of Janus, 'everyone is convinced because Jim and Francis stumbled on the right structure. The DNA shape itself is enough to rally everyone.' 'No, says the right side, every time someone else is convinced it progressively becomes a more right structure.' (Latour, 1987, p. 13)

Another consequence of this principle is that meaning comes from use. The meaning of the helical structure of DNA comes not from its definition, but from the utility others have found in it.

Collins and colleagues have developed the Empirical Programme of Relativism (EPOR) as a means to operationalize the study of the social construction of science. The first stage of EPOR involves illustrating the *interpretive flexibility* of observations. Interpretive flexibility refers the possibility of multiple explanations for empirical data. In essence, this is a requirement to produce the sociological empirical evidence to the underdetermination of scientific fact.

> All the papers [in this set] confirm the potential local interpretive flexibility of science which prevents experimentation, by itself, from being decisive. In particular, the socially-negotiated character of experimental replication is further documented. (Collins, 1981)

This multiplicity of possibility generally does not last, however. As has already been discussed, social negotiation generally provides closure on the issue. The second stage of EPOR is to describe and explain the mechanisms that provided this closure. EPOR has a third stage, which is yet to be carried out for contemporary science. This is to connect the findings of the first two stages to the greater societal structure.

A second function of the peer review process, according to many scientists and scholars of science studies, is uphold the objective nature of science. In general, sociologists have appealed to the processes of consensus-making within the scientific community to explain the "objectivity" or, perhaps more accurately, "consensual intersubjectivity" (Ziman, 1984, p. 36). Recognizing that "the objectivity that matters so much in science is not primarily a characteristic of individual scientists but of scientists' communities" (Hull, 1988, p. 3), and that "the 'truth' and 'objectivity' of scientific knowledge derive from its collective characteristics, and are not inherent in the experiences or notions of any single person" (Ziman, 1984, p. 179), sociologists claim that "the best that scientific methodology can do is to try to neutralize subjective factors by playing off one human observer against another, and then only report what they all agreed on" (Ziman, 1984, p. 36).

For Longino, "objectivity of scientific inquiry is a consequence of this inquiry's being a social {emphasis added} and not an individual enterprise" (Longino, 1990, p. 67). She claims,

> It is important to distinguish between objectivity as characteristic of scientific method and objectivity as characteristic of individual scientific practitioners or of their attitudes and practices. The standard accounts of scientific method tend to conflate the two, resulting in highly individualistic accounts of knowledge. (Longino, 1990, p. 66)

Longino takes issue with "individualistic accounts of knowledge;" although an individual can surface plausible claims in the context of discovery, she cannot produce knowledge (Longino, 1989). Sociologists have described how the production of scientific knowledge requires judgment and acceptance by the larger scientific community. Longino retains the focus on community, not individuals, as the agents of knowledge: “Because community values and assumptions determine whether a given bit of reasoning will pass or survive criticism and thus be acceptable, individual values as such will only rarely be at issue in these analyses” (Longino, 1990, p. 82). Clearly her concern lies not with the descriptive context of discovery which focuses on how hypotheses are generated, but rather with the prescriptive context of justification which searches for “appropriate criteria for the acceptance of hypotheses” (Longino, 1993, p. 102). Longino raises the context of justification as of primary importance in science. Forming the core of her belief is her awareness that science is situated in a social and political context and that to affect scientific change one must move beyond changing a personal philosophy to convincing the larger community. For Longino, the communal, social nature of scientific knowledge and inquiry explain science’s objectivity.

Thus sociologists of science have also emphasized the role of the community in “neutralizing subjective factors” in negotiations that legitimize scientific knowledge.

Social Construction of Technology

The social construction of technology (SCOT), a more recent offspring of the sociology of science, explores the genesis and ongoing evolution of technology’s design and function as it responds to the demands of its users. Scholars in this field have described how users of the technology shape its structure both in the initial development process and after it has been produced. They have debunked a linear model for the creation of technology, instead describing how the interactions of different social groups with the technology can result in a reconfiguration of that very technology (Pinch & Bijker, 1987).

Avery (2001)has proposed that curricula can be viewed as technologies and that their development, modification, and implementation can be productively understood using insights from SCOT literature. As with more traditional technologies, prevailing curricular solutions utilized by teachers often result from the interplay of social groups and respective needs.

Situated Learning and Communities of Practice

These perspectives from science studies also resonate with recent work in situated learning. Lave and Wenger (Lave & Wenger, 1991; Wenger, 1998) have outlined a view of learning that rests on shared participation in a community of practice. This framework can be useful in understanding scientific communities as well thinking about how science courses could be structured to foster sociologically authentic science education. Lave and Wenger describe participation—legitimate peripheral participation (LPP)—as the beginning of the community membership process:

> It crucially involves *participation* as a way of learning—of both absorbing and being absorbed in—the "culture of practice." An extended period of legitimate peripherality provides learners with opportunities to make the culture of practice theirs (p. 95).

Wenger describes a community of practice as being a composite three primary components: (a) a shared repertoire that includes artifacts, routines, actions, and concepts developed or adopted and then used by the community (b) a shared enterprise that community members engage in and (c) the mutual engagement of participants.

Environmental Inquiry Perspective and School Science

The view of science described above is in strong contrast to the science often found in public high schools. Students are often presented with science as clear-cut information to be absorbed. Learning is viewed as an individual process of data acquisition. Student work involves regurgitation of that data, and is done on an individual basis. While students might be presented with specific scientists and/or experiments, they are often not made aware of the context in which that work occurred.

It is also important to note how laboratory work, when it occurs, is still often contrary to contemporary views of science. Lab work often occurs after a single set of scientific content has been introduced. The laboratory investigation functions simple as a check on the established view. At least the teacher knows the outcome ahead of time, and the students at least assume the teacher knows “the answer”. Results are unambiguous. When contrary or ambiguous results do occur, it is presumed that the lab “didn’t work”. While students may share in the physical labor of the lab, they often do not share in the results of the lab. In particular, for lab reports often the teacher is the only audience, student assessment is the only purpose, and the skill in carrying out the provided procedure the only criteria. The idea of scientific knowledge emerging from social collaboration is absent.

The views of practice cited above also contrast with common approaches to curriculum and professional development. This is particularly true of recent endeavors stemming from state imposed curricular content documents. In such settings, curriculum development is framed as a linear, intentional process of working from broad statements to specific classroom actions (with goals, standards, intended learning outcomes, benchmarks, performance indicators, and the like developed along the way). Similarly, professional development is conceptualized as a hierarchical process through which clear, well-formed curricular structures are disseminated to teachers.

In EI, we have intended to both promote a more sociologically authentic view of science and use those perspectives on science to build our own practice. We have aimed to develop curricular activities that put students in the position of being science makers. This involves dealing with real (often local) problems, allowing students to grapple with issues of experimental design, and creating opportunities for students to interact with peers over experimental results. We have built up a community of practice amongst a variety of professionals: inservice teachers, preservice teachers, university science educators, and university scientists. Curriculum development has involved adapting scientific procedures, pilot testing, and reconfiguring materials.

Overview of EI Endeavors

The Environmental Inquiry project has worked to create a community that promotes sociologically authentic science education. Over the past decade it has become a multifaceted endeavor involving preservice teachers, inservice teachers, science and science education graduate students, and education and science faculty. Overlapping staff members and a common perspective have allowed different projects to symbiotically benefit from one another. The four major projects that currently reside under the EI umbrella are the following.

<u>Institute on Science and the Environment for Teachers</u> (ISET) – This inservice education program brought teams of multidisciplinary science teachers to Cornell for three weeks during the summer to investigate issues related to water quality and watershed dynamics. The team approach served three purposes. First, one goal of ISET was to encourage science teachers to make connections between the sciences. To this end all teachers, regardless of their "home" discipline, explored concepts related to water chemistry, hydrology, and macroinvetebrate identification, land use, and remote sensing. Second, oftentimes the teachers most likely to attend summer workshops are the "superstar" teachers who least require professional development to improve their teaching. Because they needed to apply as a team, these teachers often needed to convince other less-well-prepared teachers to participate and thus our inservice efforts also

reached teachers who most needed them. Finally, by attending as a team, teachers belonged to a small cohort of teachers at their school who agreed to implement a new curricular element thereby distributing, or at least creating a network to support, the risk that can often accompany innovation.

While on campus, each team developed a school-specific curriculum project that focused on a local water resource problem, integrated the school sciences, explored science in its social context, and attended to the resources and constraints of that particular school. During the school year participants implemented their project. Teachers' efforts were supported by the ISET staff through the availability of the lending library of equipment and materials and the opportunity to request that ISET staff provide assistance during fieldwork. Participants maintained contact with each other and the project staff through follow-up workshops, school site visits, and computer networks.

In addition to Cornell faculty and full-time staff, two other populations assisted with the summer inservice program. Each summer we hired a handful of preservice teachers to work with ISET. These students developed new activities to model for teachers, worked with teacher teams to learn new computer programs, and served as additional resources people. After the first ISET program, we also invited back 2-3 teachers who had implemented their curricular project in their classrooms to serve as Teaching Assistants. These teachers both helped to modify and create instructional materials and workshops and provided testimony and advice rooted in their own experiences about how to best innovative in the classroom.

Finally, to reach a larger number of teachers including some who could not attend a three-week, residential program a one-week, non-residential ISET Satellite program was developed and offered by a team of ISET alumni at their local high school.

Environmental Inquiry: Learning Science as Science is Practiced (EI)[1] is a secondary school curriculum development project that aims to create instructional materials that actively promote a sociological view of scientific practice, including the process of peer review and networking with fellow student scientists. The project is creating four environmental science modules whose topics were chosen because they interfaced with research that was occurring at Cornell and because they encompassed topics that students could investigate in their local setting. They include: bioremediation and waste management, population ecology, environmental toxicology, and watershed dynamics. The text, video, and web-based materials promote a two-stage model of inquiry to engage students, including those who are underachievers in traditional science classes, in original investigations of their local environments.

Practicing teachers have been intimately involved in the development of the EI curriculum. For three year, six middle and high school teachers were selected to partner with Cornell University scientists and educators for three weeks during the summer. The EI teachers' tasks were to modify a protocol or research methodology used by researchers in cutting edge science so that it could be used in a school and to help write activities and teacher guides, pilot test the materials in their classrooms, and provide feedback. A second group of teachers (generally ISET teachers) who were not involved in the development of the units were also recruited to pilot test the materials. The modules will be published by the National Science Teachers Association Press.

Urban Ecosystems Modeling (UEM)- In this project, preservice science, mathematics, and agriculture teachers work with their peers, practicing teachers, and K-12 students at one or two

[1] Environmental Inquiry is the name of the umbrella program that houses all of the individual projects described here as well as one specific curriculum development project. With the exception of this section, EI refers to the conglomeration of all project activites.

high-needs urban schools to produce environmental science materials that resonate with those urban students' experiences. Most environmental science curriculum materials and many activities focus on topics that are not immediately observable to or accessible by urban dwellers. UEM was designed to tailor environmental science materials specifically for urban students. For example, one year the project focused on creating physical and computer models of urban water delivery systems.

Preservice teachers enrolled in a curriculum design course gather information about the students' knowledge, the resources and challenges of the school, and the local setting. Then, throughout the semester they develop a curriculum for that school. Preservice students have the opportunity to pilot test their lessons in the classrooms and gather feedback from each other, the high school students, and the participating teachers to guide their curricular revisions.

Fostering collaboration between preservice teachers and inservice teachers led to some inspiring teacher education for both parties; classroom teachers have been exposed to new computer technologies and the scientific knowledge that the preservice students possess and preservice teachers in turn benefit from the pedagogical and practical expertise of the practicing teachers.

Student Research Congresses and Online Peer Review – To promote understandings about the role of peer review, assessment, and feedback in science and engineering in middle and high school classes, we have organized two types of events for middle and high school students. The Technology Design Challenge poses an engineering design problem with a few specifications and constraints. For example, one year students were instructed to develop a device that would collect a water sample from a site that was 6 feet from the shore and 10 feet deep. The scoring rubric included questions about the cost of the device, whether it met the specifications, aesthetic appeal, and whether or not the water remained uncontaminated during its ascent to the surface. Students working in teams create their devices at their schools and often present them to their classmates there before they gather at Cornell on a Saturday to present their products. After a short oral presentation and demonstration, the other students participating in the Congress complete the scoring rubric.

The Research Congresses also encourage students to work in teams. For this event, students are presented with a research topic, such as bioassays, around which they generate a research question. By focusing on a common topic all students can obtain a basic knowledge of the concepts and methodologies that underlie all projects which permits them to draw their understandings to evaluate others' work.

Students conduct and analyze their research in teams at their schools. They may then participate in peer review in one or two manners. The EI project has created an online peer review system. Students can log into the system, describe their bioassay research question and results, and have it virtually reviewed by peers at other schools. They also have the option of creating a poster that describes their study and its findings to bring to the Congress at Cornell. During the Research Congress some members of the team remain near the poster to answer questions while other circulate to peer review each other's work. In the current model (which evolves each year) each participant is randomly assigned three posters to review using a scoring rubric that we have created. This ensures that all posters are assessed.

<u>Cornell Environmental Inquiry Research Partnership</u> (CEIRP)- Our latest project aims to promote research-based projects in classrooms by engaging science graduate students in educational outreach. CEIRP pairs 6 undergraduate and 7 graduate fellows at Cornell with secondary science teachers. The fellows are pursuing majors, masters, doctoral degrees in an

environmentally related science such as geology, natural resources, horticulture, plant pathology, and biology. The fellows, who have conducted scientific research, guide teachers' and students' efforts to conduct open-ended, inquiry-based environmental science projects.

In our work, it is often difficult to identify a specific activity or workshop as belonging to a unique program—we have worked hard to integrate the projects and include elements of preservice and inservice professional development and curriculum development in all projects. Over the past decade we have created a community of people who have been interested in and committed to improving school science education by infusing understandings that are sociologically authentic. We have worked to recognize, utilize, and crossfertilize the expertise of the various groups of participants: practicing teachers, future teachers, science education faculty, scientists, science educators, and science students. Like the science projects that we encourage teachers and students to explore, our work has aimed to build community, has been rooted in a local community, has fostered open-ended projects that lack a correct answer, has modeled innovative approaches, has worked to include all students and teachers, has capitalized upon the expertise of an array of resources, and has continually solicited feedback from those involved about the merit of our ideas.

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References

Avery, L., & Carlsen, W. S. (2001). *Knowledge, identify, and teachers' multiple communities of practice.* Paper presented at the National Association for Research in Science Teaching, St. Louis MO.

Bloor, D. (1973). Wittgenstein and Mannheim on the sociology of mathematics. *Studies in History and Philosophy of Science, 4*(2), 173-191.

Collins, H. M. (1981). Stages in the empirical programme of relativism. *Social Studies of Science, 11*, 3-10.

Cozzens, S. E. (1990). Autonomy and power in science. In S. E. Cozzens & T. F. Gieryn (Eds.), *Theories of science in society* (pp. 164-184). Bloomington, IA: Indiana University Press.

Gough, N. (1992). *Laboratories in school: Material places, mythic spaces.* Paper presented at the American Educational Research Association, San Francisco, CA.

Hull, D. L. (1988). *Science as a process: An evolutionary account of the social and conceptual development of science.* Chicago, IL: University of Chicago Press.

Knorr-Cetina, K. (1983). The ethnographic study of scientific work: Toward a constructivist interpretation of science. In K. Knorr-Cetina & M. Mulkay (Eds.), *Science observed: Perspectives on the social study of science* (pp. 115-140). Beverly Hills, CA: Sage Publications.

Knorr-Cetina, K. (1995). Laboratory studies: The cultural approach to the study of science. In S. Jasanoff & G. Markle & J. Petersen & T. Pinch (Eds.), *Handbook of science and technology studies* (pp. 140-166). Thousand Oaks, CA: Sage Publications, Inc.

Latour, B. (1987). *Science in action*. Cambridge, MA: Harvard University Press.

Latour, B., & Woolgar, S. (1986). *Laboratory life: The construction of scientific facts*. Princeton, NJ: Princeton University Press.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.

Longino, H. E. (1989). Can there be a feminist science? In N. Tuana (Ed.), *Feminism & science* (pp. 45-57). Bloomington: Indiana University Press.

Longino, H. E. (1990). *Science as social knowledge: Values and objectivity in scientific inquiry*. Princeton: Princeton University Press.

Longino, H. E. (1993). Subjects, power and knowledge: Description and prescription in feminist philosophies of science. In L. Alcoff & E. Potter (Eds.), *Feminist epistemologies* (pp. 101-120). New York: Routledge.

Pinch, T., & Bijker, W. (1987). The social construction of facts and artefacts: Or how the sociogy of science and the sociology of technology might benifit each other. In W. E. Bijker & T. P. Hughes & T. J. Pinch (Eds.), *The social construction of technological systems* (pp. 17-50). Cambridge, Mass: MIT Press.

Sapp, J. (1990). *Where the truth lies: Franz Moewus and the origins of molecular biology*. Cambridge, UK: Cambridge University Press.

Traweek, S. (1988). *Beamtimes and lifetimes: The world of high energy physics*. Cambridge, MA: Harvard University Press.

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge: Cambridge University Press.

Ziman, J. (1984). *An introduction to science studies and the philosophical and social aspects of science and technology*. Cambridge: Cambridge University Press.