The Sociological Context of Environmental Science and its Use in Rethinking Scientific Inquiry

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A perennial and understandable concern of environmental education is defining itself in relation to science education. Environmental educators argue that their responsibilities transcend the traditional focus of science education, with its emphasis on schools and schooling and its reluctance to look beyond the laboratory to concerns that are ethical, economic, emotional, political,… in a word, social. Environmental educators do not want their efforts co-opted by mainstream science education and bristle at the suggestion that their work would be "improved" by closer attention to rational, objective scientific research and a general purging of discussions about advocacy, power, and values. The epistemological stance of science–that it is objective, rule-governed, predictable, definitive–is inconsistent with what many environmental educators find most compelling about their work and how children understand the environment.

It is easy to understand why environmental education might adopt a siege mentality with respect to science and its educational proponents. EE has been slammed for distorting the nature of science, for picking and choosing the scientific facts it uses, and for getting those facts wrong (Independent Commission on Environmental Education, 1997; Sanera & Shaw, 1999). Although there is an argument to be made for striving to improve the science in environmental education, my concern in this paper is very different. I would like to argue that there is much that <u>science educators</u> can learn from <u>environmental education</u> about science, the nature of science, and scientific inquiry.

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Of course, environmental education comes in many flavors, and my focus here will be on approaches that are explicitly science-oriented. I will draw most heavily on experiences with our NSF-funded project, *Environmental Inquiry: Learning Science as Science is Practiced*. The model of inquiry used in that project is based on a conception of “authentic” scientific practice derived from contemporary sociology of science (Collins, 1985; Cunningham, 1998; Cunningham & Helms, 1998; Kelly, Carlsen, & Cunningham, 1993; Latour & Woolgar, 1986; Longino, 1990). Additional examples and insights are taken from work by Greenall Gough (1992, April; Greenall Gough & Robottom, 1993), and Helms (1998).

Inquiry and Epistemology

The role of prior knowledge in science learning. The environmental sciences provide rich terrain for student engagement in scientific inquiry. Although a key postulate of conceptual change teaching is to begin with students’ prior understandings (Kelly, 1997; Posner, Strike, Hewson, & Gertzog, 1982), nominally inquiry-oriented science teaching often focuses on subject matter that is conceptually alien to students. Without even inchoate conceptual frameworks about cellular or molecular processes, for example, biology students' “original” investigations are too infrequently productive or fruitful from a conceptual change perspective.

Investigations of local environments bridge the familiar with the novel. Even if the specific phenomena being investigated are unfamiliar–say, the “health” of a stream adjacent to a campus–students have knowledge about the local context that they can draw upon: knowledge about nearby businesses and industry, climate patterns, whether mosquitoes are a problem in the spring, whether the stream dries up in the summer. Knowledge about these phenomena is a resource that can be used in learning relevant scientific concepts, such as species diversity and its relationship to habitat; more importantly, by focusing on a local problem and by considering its formulation in a social context, students' prior understandings (some of which are narrowly scientific, many of which are not) are acknowledged and legitimated as conceptual resources. Teaching with such an orientation involves more than a willingness to probe students' beliefs about conventional curricular concepts–electrical circuits, photosynthesis, cells, the gas laws–it involves organizing the curriculum around subjects that matter to society. The benefits of doing so include cognitive opportunities for students to use prior knowledge in learning new scientific content.

Methodological invention in school science. The role of "discovery" in science, although still popular in media accounts, is not central to contemporary philosophical accounts of science (Kuhn, 1970), sociological accounts of science (Brannigan, 1981; Woolgar, 1976), or conceptual change accounts of science learning (Posner et al., 1982; Strike & Posner, 1992). Epistemologically, science is probably more appropriately viewed as a process of evidence-based argumentation and persuasion rather than discovery (Kuhn, 1993). Nevertheless, the model of scientific inquiry experienced by students in school science all too often resembles what Chalmers (1982) and Millar (1989) call naïve inductivism: observations precede theory and theory precedes experimentation. For example, in one common school science investigation, students design experiments to "discover" that plants grow toward light. Usually they also learn that the teacher knew this beforehand and had an explanation that didn't require the experiment at all.[2]

An alternative approach is to assume that science novices (be they children beginning their studies or experienced scientists working in a new problem area) generally begin with well-established *protocols* for conducting their initial work in a particular domain. These protocols are the products of existing scientific communities, and mastering them is a prerequisite for having one's claims taken seriously (Collins, 1985). In our own work, examples of protocols appropriate for secondary

[2] I don't mean to suggest that students shouldn't do activities like this, just that we should be hesitant about characterizing them as experiments and their results as discoveries. If the purpose is to demonstrate a well-known phenomenon, why not simply call the activity a demonstration?

environmental science investigations include lettuce seed bioassays for assessing the toxicity of chemicals in the environment (Trautmann, Carlsen, Cunningham, & Krasny, in press) and methods for assessing the integrity of riparian habitats using remote sensing (Carlsen, Trautmann, Cunningham, & Krasny, in preparation). These protocols are methodologically invariant, but the results of their application to local environmental phenomena are intentionally unknown to students and their teachers beforehand. In that respect, they are similar to many other protocols used by environmental science educators around the world, such as FeederWatch, GREEN, Globe, and others (see, e.g., TERC, 1997).

From a sociological perspective, environmental research protocols are useful because they provide science classrooms with novel data without the fiction that scientists invent experimental methods out of thin air. The students' job is not to demonstrate that they have "discovered" already-established knowledge, certified by the teacher and the textbook; it is to construct a persuasive argument about what original data mean to them, and should mean to others. If they are successful, they will achieve, within their community, recognition that they are proficient and that their scientific work can be trusted. However, this is accomplished through persuasion, not by comparing their results to a right answer. In this respect, the often-ambiguous results of children's environmental studies are much more authentic representations of scientific work than the 10,000th replication of Boyle's law.

What is a persuasive argument? The use of protocols is only a first step in a view of science-as-argument: the collection of data on novel problems using established methods. If the results of environmental research are not known to teachers *a priori*, how can the results of student research be evaluated?

From a straightforward epistemological perspective, one standard might be to evaluate arguments with respect to their rationality; that is, are conclusions based in some philosophically coherent and explicit fashion on appeals to data, using discipline-specific rules? In science education, Russell (1983) has proposed a methodology for undertaking such evaluations, using prior work by Toulmin (1958) and

Peters (1966; 1967). Recent sociolinguistic studies by Kelly and others (Carlsen, 1997; Kelly, Druker, & Chen, 1998) have demonstrated that this standard can be applied in science education research. However, the analysis of the rationality of claims using sociolinguistic methods requires careful study of the verbatim transcripts of videotaped lessons--hardly a practical tool for use in the give-and-take of ordinary classroom life. Furthermore, there is little reason to believe that students and teachers in science classrooms rely on formal philosophical analysis to evaluate truth claims.

Accounts from sociology of science suggest that the process of fact-making in science—traditionally an epistemological concern—is a considerably more nuanced and socially situated process than philosophical accounts might suggest. Scientists “make” facts in part by removing the contingencies from their claims and by making challenges prohibitively expensive for their competitors (Latour & Woolgar, 1986). If it suits their purposes, they are not above using their positions (Schaffer, 1989) or the media (Gieryn & Figert, 1990) to bolster their claims.

The gold standard in science for the evaluation of scientific arguments is peer review, a practice that has been almost unused in science education. We have found that peer review among secondary students can be reliable and useful (Carlsen, Cunningham, & Trautmann, 2000, April), as part of environmental science research projects and technology design challenges.[3] Peer review can be undertaken within an individual classroom (perhaps beginning with one-on-one face-to-face “pair review”), at an invitational research congress, or online using a computer-administered system that is anonymous in both directions. In the absence of known “right answers”–a common issue in environmental research by students–peer review offers a pragmatic and sociologically authentic strategy for the evaluation of data-based arguments.

[3] We are presenting two other papers at NARST 2001 that provide more recent data on the use of peer review in environmental science education.

Values and Science

“Value-laden” versus “scientific?” Environmental education has been criticized for being overly issue-driven instead of information-driven; political instead of scientific; preachy; even anti-human in its portrayal of people as intruders on the earth–in short, laden with questionable values but dressed in the clothing of science.[4] Despite these criticisms, EE practitioners have steadfastly maintained a commitment to teach environmental science only within a larger framework that emphasizes human values, decision-making, and action: themes originally identified in international conferences in Belgrade and Tbilisi (UNESCO, 1978). Values and commitments–and their use in analyzing issues and taking action–are central to conceptions of environmental literacy (Hungerford, Litherland, Peyton, Ramsey, & Volk, 1996).

In their guidelines concerning “depth” in environmental education materials, the NAAEE has reiterated its view that achieving greater conceptual understanding does not merit purging environmental education of value considerations:

> EE materials should foster awareness of the natural and built environment; an understanding of environmental concepts, conditions, and issues; and an awareness of the feelings, values, attitudes, and perceptions at the heart of environmental issues. (North American Association for Environmental Education, 1996)

In this respect, environmental education sets a good example for science education. As a field, we often seem uncomfortable with the extent that societal values infiltrate scientific work. Although we acknowledge the importance of constitutive values in science (such as the desirability of reporting data truthfully), science education has relatively little to say about the ways in which contextual values from the larger society shape research programs and scientific work. Defining demarcation criteria between science and non-science remains an important part of the science curriculum, and the relationship of

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[4] See, for example, “EE Criticisms and Responses–Point/Counterpoint” in The Environmental Education Advocate (1996, Fall) or online at http://www.uwsp.edu/cnr/neeap/ neeapservices/newsletters/ 1994_1998/f96re.htm.

science to external values (e.g., attitudes about gender, race, religion) is left largely at the level of "science helps society."

This is too bad, for a couple of reasons. First, science constantly defines and redefines its own boundaries within society, reshaping itself as needed to protect its interests (Gieryn, 1999). The notion that it achieves objectivity through methods that are isolated from social norms and interests is simply not true, and the perpetuation of that myth through the science curriculum probably only undermines public confidence in science.

A second and more important reason to put values on the table in science education is that the strategy offers the prospect of better science. Helen Longino has proposed what she calls a contextual empiricist model of inquiry, in which the values influencing claims are not obscured. Instead, they are made explicit considerations in weighing competing claims:

> That theory which is the product of the most inclusive scientific community is better, other things being equal, that that which is the product of the most exclusive. It is better, not as measured against some independently accessible reality but better as measured against the cognitive needs of a genuinely democratic community. This suggests that the problem of developing a new science is the problem of creating a new social and political reality. (Longino, 1990, p. 214)

In environmental education, this reality can involve viewing scientific knowledge as historically, culturally, politically, and economically situated: what Kemmis, Cole, and Suggett (1983) and Greenall Gough and Robottom (1993) call a "socially critical orientation" to the curriculum.

<u>Communities of Practice</u>

Finally, we should note the development in recent years of educational theories that define learning as a process of shared participation in a community of practice (Wenger, 1998), rather than an individualistic process of discovery and truth-establishing. Seen through lenses like Lave and Wenger's "legitimate peripheral participation," the work of children, teachers, and other adults in collaborative stream studies, wetlands restoration, and biological control projects represents much more than an "application" of scientific knowledge to the solution of real-world problems. Such projects can be authentic communities of scientific practice that produce educational outcomes unattainable in more conventional educational settings. Studies of local environmental problems give students a sense of "purposeful doing" (Helms, 1998), of participating, of science in a social context.

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