Portraying Epistemology: School Science in Historical Context

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ABSTRACT: Current debates over the nature of science in the school curriculum have centered on where the boundary between "traditional" science and other forms of knowledge should be drawn. What has been missing from these discussions, however, is a careful examination of how what lies within the boundary of "traditional" school science itself has been determined. Given the diversity of scientific practices and the inherent limitations of space in the curriculum, the portrayal of traditional science (its epistemology in particular) should be understood to be only a selective representation of the real-world practices of science. Such representations are inevitably shaped by not just what scientists do, but also by the social and political context in which they are developed. Taking a historical perspective, the curricular ideas of John Dewey and Joseph Schwab are used to illustrate the subtle ways in which epistemological portrayals have been influenced by this sociohistorical context and the consequences those portrayals have had with respect to the public's relationship with institutional science in the United States at two key points during the twentieth century. © 2002 Wiley Periodicals, Inc. *Sci Ed* **87:**64–79, 2003; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/sce.1055

INTRODUCTION

Too often the broad social goals science education strives to achieve are left underexamined. One gets the sense reading the research and policy literature that increasing the accuracy of student content knowledge or the overall level of scientific literacy (vaguely defined) is justification enough for our efforts to reform the way we go about teaching science. In surveying the research literature, for example, one cannot help but notice a preponderance

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of work that can be characterized not unreasonably as predominantly technical in nature. That is, much of what gets discussed concerns the diagnosis of some discrepant cognitive state or the efficiency of a given instructional intervention. Discussions about the societal role science education should play certainly occur from time to time (see, e.g., Brickhouse, 2001; Jenkins, 1992, 1994; Kolstø, 2001; Longbottom & Butler, 1999; Norris, 1995; Solomon, 1999), but these happen for the most part in isolation from the technical studies that make up the majority of the research publications. At the policy level, vague generalizations about the social value of understanding science seem to be the rule rather than the exception (American Association for the Advancement of Science [AAAS], 1990; National Research Council [NRC], 1996).

This inattention to ultimate goals is evident even when it comes to discussions regarding scientific epistemology, or the nature of science, in schools, which is somewhat surprising given that the topic is often viewed as a means of bridging the cultural gap between science and society (AAAS, 1990; NRC, 1996). To be fair, I should point out that this assertion is really only partly true. Recently there have been very active debates over the nature of science with respect to multicultural science education. Scholars advocating a more expansive view of science—one that includes various indigenous knowledge systems or other non-Western worldviews—are indeed motivated by a desire to alter the political landscape of science education (e.g., Hodson, 1999; Kawagley, Norris-Tull, & Norris-Tull, 1998; Snively & Corsiglia, 2001; Stanley & Brickhouse, 2001). Clearly social goals are driving these efforts to reformulate what science is. It is the intellectual activities on the other side of this debate, however, that I feel could benefit from more consideration of the social ends science education might serve. These activities consist of the less controversial process of defining an instructionally appropriate view of scientific epistemology that conforms to what might be called "traditional," or "Western" science. There may be social goals at work here as well—perhaps to fend off those who would dilute, undermine, or simply misrepresent "science." But most who seek to define science for classroom purposes would likely insist that their objective is to accurately represent, if only generally, just how science works—an understanding of which is deemed useful in modern society to be sure, but that is itself essentially free from social or political bias.

The most common approach to this task has been to abstract from the complex practices of science some set of universal descriptors, or underlying assumptions that figure in all scientific work. This is the tack taken by most prominent policy documents (AAAS, 1990; NRC, 1996) as well as a number of science education researchers (Adb-El-Khalick, Bell, & Lederman, 1998; Cobern & Loving, 2001; McComas, Almazroa, & Clough, 1998; Smith et al., 1997; Smith & Scharmann, 1999). Cobern and Loving assert, for example, that "there is a pragmatic view to science broadly acceptable in the scientific community and described in accounts by scientists themselves" that can reasonably represent what they call the "standard account" of scientific epistemology (p. 57). The assumption in these various efforts to define the essence of science is that such a definition (or description) can be adequately determined from the practices of science alone, that no other considerations or inputs are required. This is an assumption that I believe is flawed.

Given the limited space available in the science curriculum along with our increasing appreciation of the social and epistemic diversity of even traditional scientific practice (Cartwright, 1999a; Galison & Stump, 1996), two things should become obvious to anyone trying to put together an image of what science is: The first is that no single "nature of science" exists; and the second is that, even if one did, only a partial representation of it could ever be captured in the school experiences designed for students. Thus, the nature of science that appears in the curriculum is inevitably a selective representation of science writ large, and what has been left out of these consensus constructions is an *explicit* consideration of the various social and political factors that have provided the criteria for selection.

The goal of this paper is to demonstrate that these external factors do indeed matter. Not only do they provide the often tacit means for selecting what to highlight in school science portrayals of epistemology, but they serve, in turn, as the social and political context in which these epistemological representations are designed to function. They are, in other words, created with specific social goals in mind. Recent sociological work by Gieryn (1999) provides an analytical framework for making sense of how public images of science are tied to specific social ends that proves useful in looking at the school setting. I use this framework to examine the curricular visions of John Dewey and Joseph Schwab, two pivotal figures in the history of twentieth-century science education. Both Dewey and Schwab sought to portray the epistemology of science in ways that advanced particular social and political interests. What I argue through these cases is not that political or social factors should be minimized in portraying the epistemology of science in schools. On the contrary, such factors—which shape the social ends to be achieved—are constitutive of the curriculum development process; they cannot be eliminated. What is needed rather is a greater awareness of the social and political consequences that differing views of science embody and more open discussion of the social goals science education should serve when all is said and done.

I have chosen to examine historical examples over contemporary reform efforts for two primary reasons. For one, using cases from the past provides important intellectual distance that allows the unique social and political contours of the time and place in question to become more apparent. Often analyses of the present suffer from being too close to the common assumptions of the day; it is often difficult in such cases to be able to step outside what seems natural, what we take for granted about how things are in society. Second, and not unrelated to the first, I would like this essay to make a case, however small, for the importance of the history of science education. Understanding how past portrayals of scientific epistemology were influenced by the contexts of the time is important, I would argue, not only for seeing the antecedents of present efforts to articulate an appropriate image of how science works, but also sheds light on more enduring questions regarding the broader role school science has served as a mediator between institutional science and the public at large over the course of the previous century. There is much to be gained and important issues that can be raised from the long view a historical analysis such as this provides.

THE MULTIPLE CONSTRUCTIONS OF SCIENCE

Before examining the nature of science in the school curriculum, it is worth looking at its treatment in other societal venues. Among those who make their living in academia writing about scientific practice, there are multiple competing, oftentimes contradictory, views regarding everything from the most desirable unit of scholarly analysis (the laboratory, extended research program, discipline, etc.) to the basis of the scientific knowledge claims themselves (e.g., Barnes, Bloor, & Henry, 1996; Boyd, 1984; Callon, Law, & Rip, 1986; Fine, 1996b; Kleinman, 1998; Knorr-Cetina, 1999; Lakatos, 1970). The various representations of science that are advanced in these discussions, as the philosopher of science Rouse (1996) and others (Fine, 1996a; Shapin, 1999) have argued, coalesce around questions regarding the ultimate legitimacy of science as a way of knowing about the natural world, or, more plainly, the extent to which our truths about the world are invented or found, socially constructed or read directly from nature. These philosophical debates about the foundations of scientific knowledge, however, intersect rarely, if at all, with a good deal of daily science and science-related work. As historian and sociologist of science Shapin has plainly observed, "both everyday worlds and technical subworlds [i.e., science] seem to go on their knowledge-producing and knowledge-assessing ways without the benefit of such theories and definitions [of truth]" (Shapin, 1999, p. 1).

The issue of legitimacy, however, is important in other ways outside the universities. Though questions about the foundations of scientific knowledge are seldom asked in the everyday world, what is often contested, according to Gieryn's sociological analysis, are its boundaries, what sorts of things should be granted the label "scientific" or to what domain science can be said to apply. And this bears paying attention to, for here much more is at stake. Given the rhetorical power science has in the public sphere, what is repeatedly negotiated and renegotiated in classing some things as "science" and others "nonscience" is the attribution of "epistemic authority"—that is, the treatment of certain knowledge claims as reliable, almost as a matter of faith, over others which remain suspect, if not discredited entirely.

The process of assigning epistemic authority is by no means straightforward, and it rarely involves careful consideration of the epistemological processes underlying the claims in question alone. As Gieryn explains, "when credibility is publicly contested, putatively factual explanations or predictions about nature do not move naked from lab or scientific journal into courtrooms, boardrooms, newsrooms, or living rooms." Rather, as they make their way into the public, "they are clothed in sometimes elaborate *representations* of science—compelling arguments for why science is uniquely best as a provider of trustworthy knowledge, and compelling narrations for why my science (but not theirs) is bona fide [emphasis original]" (Gieryn, 1999, p. 4) (see also Toumey, 1996). It is in these representations that the boundaries of science are drawn. More importantly, in each case, the images of science are constructed in ways that are socially and politically useful to those doing the constructing. "Questions of accuracy," Gieryn argues, "can only be answered in terms of pragmatic utility" (p. 11).

The question of utility in these instances is not an idle one. Deciding which among the often conflicting images of science to embrace in any given instance has real consequences, especially since such decisions are usually made in venues—legislative hearings, courts of law, medical consultations, etc.—where some other, perhaps momentous, decision hangs in the balance. The lasting effects of having one's characterization of science accepted over one's rivals, in addition to the immediate legitimacy such acceptance accords, include the allocation of prestige, and often financial resources, favorable government legislation, and the like. Inevitably benefits accrue to some and not to others based on how the boundaries of science are drawn.

The school curriculum is no less a site where negotiation of the scientific image occurs, though it remains almost uniformly overlooked by historians and sociologists of science (Shapin, 1990). It possesses unique characteristics that make the construction of science there particularly significant. For one, the curriculum is the one place that society has set aside specifically for the purpose of systematically conveying to the public just what science is. Moreover, the view of science advanced has a depth and solidity not found in the more short-lived written deposition or oral testimony Gieryn describes. It is articulated and given life through carefully designed laboratory exercises, multimedia presentations, and extended textual and oral exposition—to be learned and then tested to ensure its assimilation. In its dissemination via the state-supported school system, this nature of science is given official status, which further underwrites its legitimacy. Images of science so produced and sanctioned have an intellectual inertia, a permanence that leaves a lasting impression on the public consciousness. It is this official sanction that is at the core of the multicultural/traditional debates over what counts as science and what does not. These particular debates, however, as I noted at the outset, have been concerned with how far beyond the traditional to extend the border of science. Though this is undoubtedly an important question, there is much to be learned by looking inward as well, at the multiple representations of *traditional* science that have continuously occupied a place in the curriculum over the last 100 years.

Traditional accounts of school science epistemology have less often been concerned with the sort of overt boundary work described above. The goal of these representations is not to help students decide where they can find the most reliable knowledge about the natural world in any specific instance. Without question *science*, as traditionally presented in schools, *is* the source of reliable knowledge. (Though some might disagree, this is, of course, the reason science is accorded such prominence in schools.) Science education—as it relates to the nature of science—has the more general, second-order goal, it seems, of helping the public understand just what it is about the processes of the science we take for granted that ensures the production of reliable knowledge independent of any specific context (on this goal in science, see, e.g., Fine, 1998). That is, science education purports to lay bare the inner workings of the process for all to see. But the portrayals of those *inner* workings vary just as the outer boundaries of science do. In this regard, the curriculum is no different than any other public space where images of science are negotiated. And even though the political and social purposes of these seemingly decontextualized internal portrayals of epistemology are not readily evident—at least not on first inspection—they are present nonetheless. The connection Gieryn makes in his work between accuracy and pragmatic utility in this instance needs to be taken seriously.

TWO CASES OF SCHOOL SCIENCE

The extent to which portrayals of scientific epistemology have changed over the past hundred years are illustrated here with the educational philosophies of John Dewey and Joseph Schwab. The analysis of the work of these two individuals in particular enables us to appreciate the profound social implications of subtle differences in epistemological portrayals. Both Dewey and Schwab sought to convey to students an understanding of traditional science, the "standard account" of their time; they both appreciated and strongly advocated a central role for science in society; and in their educational recommendations both placed a distinct emphasis on process over content. But there were significant shades of difference, and what one sees going from Dewey's curricular formulation of science early in the century to Schwab's in the 1960s is a relocation of the epistemic authority described above from the lay person, as manifested in the universally accessible scientific method, to the scientific community and its arcane theoretical knowledge. It is these variations in representations of how science worked to produce reliable knowledge, when placed in historical context, that prove instructive in understanding the deep-seated, unavoidable relationships that exist between views of science and the particular social implications those views embody.

Dewey and the Scientific Method

Nearly all the recommendations of the science education establishment made during the first half of the twentieth century bear the mark of Dewey's thought in one form or another. Although not a scientist by training, throughout his life he felt compelled to argue for a particular kind of science teaching, admittedly trespassing where he had "no rights save by courtesy" (Dewey, 1910b, p. 121). His authority to pronounce on this subject was no doubt grounded in his eminence as a philosopher and educator, as well as his tireless advocacy of the scientific worldview. The publication of his address to the National Education Association in 1916 entitled "Method in Science Teaching" (Dewey, 1916b) as the first article in the inaugural issue of *General Science Quarterly* (what was later to become the journal *Science Education*) provides some indication of the esteem in which his ideas were held among science educators. The wholesale adoption of his book *How We Think* (1910a) by the teacher-training institutes in the United States as a guide for teaching the scientific method further indicates his influence in educational circles and, more importantly for this essay, highlights the essence of his view of science as preeminently an intellectual process (Ryan, 1995).

Throughout Dewey's career he railed against educators who sought to cast science as "so much ready-made knowledge, so much subject matter of fact and law" (Dewey, 1910b, p. 124). Science, as it was commonly taught then, consisted of a fixed body of technical information which varied from one discipline to the next. Instruction that aimed at student mastery of this material was, in Dewey's eyes, a poorly conceived enterprise indeed. According to Dewey's instrumental theory of knowledge, scientific content (the facts and laws) was only intellectually useful within the context of inquiry (Shook, 2000). "Atoms, molecules, chemical formulae, the mathematical propositions in the study of physics," he explained, "represent instruments for the carrying on of science." Such technical knowledge needed to be understood both as a product of scientific research and as conceptual tools for conducting additional research. "As in the case of other tools," he noted, "their significance can be learned only by use. We cannot procure understanding of their meaning by pointing to things, but only by pointing to their work when they are employed as part of the technique of knowledge" (Dewey, 1916b, p. 222).

The heart of science, its very essence, was for Dewey this process of inquiry—the method of scientific reasoning. "It consists," he specified, "of the special appliances and methods which the race has slowly worked out in order to conduct reflection under conditions whereby its procedures and results are tested" (Dewey, 1916a, p. 189). Most important for Dewey was that the application of this type of reasoning was not limited to the traditional subject matter of science. Indeed, "it represents the only method of thinking that has proved fruitful in *any* subject [emphasis added]" (Dewey, 1910b, p. 127). According to one of his biographers, "Dewey often comfortably used science as a synonym for reason, intelligence, and reflective thought" (Westbrook, 1991, p. 141). And therein lay its educative value. The intellectual practices of science were to serve as the model for rational thought in all affairs regardless of their domain. Simply put, Dewey insisted, "without initiation into the scientific spirit one is not in possession of the best tools which humanity has so far devised for effectively directed reflection" (Dewey, 1916a, p. 189). Thus it was clear that instruction in scientific thinking, not science *per se*, "should be the primary aim of the science teacher" (Dewey, 1909, p. 291).

In order to place the proper emphasis on method, a Deweyan science classroom would begin not with the esoteric knowledge of the formalized scientific disciplines, but rather the common stuff of everyday experience—be it "varnishes or cleansers, or bleachers, or a gasoline engine" (Dewey, 1916b, p. 6). With such things students would explore the interactions of nature, discover the various cause-and-effect relationships that exist, and through these experiences be led to the underlying scientific principles, which serve as the foundation of the powerful abstractions on which the further advancement of science depends. Using the situations and phenomena of everyday life over the technical content of traditional coursework as the objects of study, for Dewey, both allowed the process of scientific reasoning to be easily identified as the instructional goal to be accomplished and, equally important, made the application of such reasoning to the student's everyday world that much more likely. In his article in *General Science Quarterly*, Dewey lamented that the emphasis on content so often found puts the cart before the horse. The goal of science teaching should be "to hitch the horse of concrete experience . . . to a cart loaded with specialized scientific knowledge," he went on, extending the analogy. "It is not the business of high school science to pack the cart full . . . . It is its business to make such a good job of the hitching that every pupil who comes under its influence will always find in himself a tendency to turn his crude experiences over into a more scientific form, and to translate the bare sciences he reads and hears back into the terms of his daily life" (1916b, pp. 8–9).

This view of science comported well with Dewey's social goals. Scientific thinking had become in many ways the driving force of Western civilization. Indeed, the ability of science to meet the material needs of humankind testified to its superior status as a way of knowing. "The wonderful transformation of production and distribution known as the industrial revolution," Dewey pointed out, "is the fruit of experimental science" (1916a, p. 224). But the rapid industrialization that was occurring in the late nineteenth and early twentieth century brought with it profound social dislocations as well. Urbanization and the rise of the factory system had removed people from traditional means of production, which in turn subverted longstanding patterns of social organization and interaction (Kliebard, 1995). It was clear to Dewey, at least, that mastery of the natural world had outpaced mastery of the social world.

Nothing demonstrated this more early in the century than the outbreak of World War I. Previously many had believed that science inevitably generated human progress. But, in this case, the belief was hardly justified. Science, Dewey observed, "has not only rendered the enginery of war more deadly, but has also increased the powers of resistance and endurance when war comes" (1916c, p. 313). Yet as devastating as these technical advances had shown themselves to be, the only way to ameliorate their effects, in Dewey's mind, was not to abandon science, but rather to more completely embrace it. "The indispensable preliminary condition of progress has been supplied by the conversion of scientific discoveries into inventions which turn physical energy, the energy of sun, coal and iron, to account . . . . The problem which now confronts us, . . . is the same in kind, differing in subject matter," he explained. "It is a problem of discovering the needs and capacities of collective human nature as we find it . . . and of inventing the social machinery which will set available powers operating for the satisfaction of those needs" (1916c, pp. 317–318). In other words, what was needed was the extension of scientific thinking from the material domain to the social and political. "When there is the same energy displayed in applying knowledge to large human problems as there is . . . in applying it to physical inventions and to industry and commerce many of our present problems will be well on their way to solution" (1934, p. 4).

Events over the next 30 years served only to reinforce Dewey's view of science and its proper role in society. The economic tragedy of the depression and the ensuing international instability that erupted into World War II provided all the evidence he needed to demonstrate that the social applications of science had been too long neglected. Some conservative critics of the period had begun to argue, though, that, far from solving the world's problems, science, in its advocacy of cultural and moral relativism, was one of the primary causes. They insisted that science be subordinated to the humanities, the great literary works of which would serve as the proper foundation for a just social order (Purcell, 1973). These attacks on science provided the stimulus for the republication in *Science Education* of Dewey's classic piece, "Method in Science Teaching" in 1945. In a new introduction, Dewey tellingly located the critics' disenchantment in their fundamental misunderstanding of the nature of science. "The entire cogency of their position," he wrote, "depends upon identification of science with a certain limited field of subject matter, ignoring the fact that science is primarily the method of intelligence at work in observation, in inquiry and experimental testing; that, fundamentally, what science means and stands for is simply the best ways yet found out by which human intelligence can do the work it should do" (Dewey, 1945, p. 119)—that work being for Dewey the solution of the social problems that the natural sciences had created.

Science education directed toward the greater deployment of scientific reasoning, Dewey had always believed, was one of the key means society had for ameliorating the social condition in which humanity found itself. Working toward this goal was in his words nothing less than, "the supreme intellectual obligation" (Dewey, 1934). Society had little need for more technically-trained experts (the state of material progress was more than sufficient, if not downright problematic), teachers needed instead to proselytize for inquiry, to demonstrate to students the power of scientific thought in realms beyond the natural world, realms such as the social and moral. The ultimate success of science education, Dewey argued, should be measured not by the number of scientific specialists produced, nor by the increasing mastery of nature. Such goals, he felt, led only to the perpetuation of specialized science. The real measure of effective science education was to be found in the extent to which the public at large adopted and was guided by the methods of scientific thinking in all things. From this, Dewey never wavered. "The future of our civilization depends upon the widening spread and deepening hold of the scientific habit of mind," he wrote. "The problem of problems in our education is therefore to discover how to mature and make effective this scientific habit" (1910b, p. 127). It was this habit, after all, that made science what it was in its purest form.

Schwab, Science, and Enquiry

The years following World War II saw significant changes in both the relationship of science to modern society and the proper conception of the role of science education in mediating that relationship (Geiger, 1992; Kevles, 1990). Those involved in postwar education reform, many of whom were professional scientists, departed sharply, to say the least, from the Deweyan point of view. They specifically took issue with what they perceived to be an overemphasis on and rigid formulation of the scientific method in the school science curriculum. Few documents capture this difference of opinion better than the science section of the Harvard report, *General Education in a Free Society* (Committee on the Objectives of a General Education in a Free Society, 1945). The authors stated unequivocally: "Nothing could be more stultifying, and, nothing is further from the procedure of the scientist than a rigorous tabular progression through the supposed 'steps' of the scientific method, with perhaps the further requirement that the student not only memorize but follow this sequence in his attempt to understand natural phenomena" (p. 158). The purpose of these open attacks on what was really a distorted caricature of Dewey's views of science education was to correct what these scientists felt was a misrepresentation of the nature of scientific work. Science, they insisted, was more complex than the simplistic method promulgated in the nation's science classrooms.

Of all these reformers, Joseph Schwab provided without question the most extensive and intellectually nuanced account of what science was and how it might best be conveyed to school children (though it should be acknowledged that his ideas in that regard shifted somewhat in later years). Schwab's scientific credentials were unimpeachable. He studied physics in his undergraduate years at the University of Chicago and went on to earn his Ph.D. in genetics under the eminent population geneticist Sewell Wright. His professional interest in science education was evident early on (he did a postdoc at Teachers College in New York) and allowed full expression upon his appointment in the undergraduate college at Chicago in 1937. The view of science Schwab had drawn from his first-hand experience with scientific research differed from Dewey's, though the differences were by no means stark. In fact, Schwab's thoughts on science were significantly influenced by Dewey's philosophical work (Westbury & Wilkof, 1978).

Like Dewey, Schwab held that the active process of inquiry was central to science. He too rejected the seemingly ineradicable content fetish of traditional science teaching, which resulted in what he termed a "rhetoric of conclusions." Such an emphasis, he argued, imposed a "false impression of literal and irrevocable truth" (Schwab, 1962, p. 25). In true Deweyan fashion, Schwab explained that scientific conclusions "are unintelligible or misleading unless they are known in the context of inquiry which structured and bounded the matters to which they refer" (1958, p. 375). Where Schwab and Dewey parted company was in the degree to which they believed the methods of inquiry could operate independently of disciplinary content. While Dewey claimed that the methods of science were ultimately applicable across any phenomenological domain, Schwab argued that scientific methods were discipline specific, that all inquiry in science was guided by a prior conceptual structure, specifically, the current theories and concepts governing the phenomenon in question. This intellectual apparatus Schwab termed the substantive structure of the discipline, and it was the substantive structure that determined "what data are relevant, what further data are wanted, [and] what experiments ought to be performed" (1964, p. 38). In Schwab's formulation, science proceeded only through the intimate association of method and content, the process of reasoning *with* the theoretical apparatus of the discipline. To speak of using scientific methods outside of a disciplinary context was, for him, to no longer speak of science at all.

Schwab's prescriptions for the classroom centered on demonstrating for students this interdependence of method and disciplinary content. The most efficient means of accomplishing this was to study the work, in various forms, of scientists themselves. He described a number of potential instructional approaches in his essay, "The Teaching of Science as Enquiry"—his classic and most comprehensive treatment of the inquiry approach. These included organizing laboratory investigations, which would have students explore carefully selected phenomena in order to demonstrate the difficulties involved in making sense of raw data; or allowing students to conduct their own simplified programs of inquiry, during which they would experience the "unresolved debates, continuing diversity of problems and methods, and, above all, continuing differences in concept and interpretation that make up scientific work as it actually occurs" (Schwab, 1962, p. 56). Schwab also advocated the classroom use of original scientific papers in order to provide students with "instances of good enquiries yielding scientific knowledge worth possessing" (p. 75) or, in cases where the original papers might be too complex, narrative reconstructions of past scientific work. Along these lines Schwab even developed a set of brief written scenarios—"Invitations to Enquiry"—which presented students with a data set of some sort along with key conceptual constructs. Using this material, students were expected to analyze, interpret, and draw what conclusions they could (Biological Sciences Curriculum Study, 1963).

The expectation in all of these classroom activities was not that students would learn the skills necessary to pursue real scientific work themselves. The primary goal was instead to convey to students the nature of science—what was involved in real scientific research, "science *as* enquiry" as Schwab called it. On this point he was clear: "Of the two components—science as enquiry and the activity of enquiry—it is the former which should be given first priority as the objective of science teaching in the secondary school" (Schwab, 1962, p. 71).

The historical events of the period factored heavily into Schwab's formulation of science and science education. During World War II programmatic scientific research and development had emerged as an important instrument of national advancement. Scientists, with the help of massive amounts of federal funding, had manufactured the decisive technologies, such as radar, the proximity fuze, and of course the atomic bomb, that ultimately helped secure the allied victory. With the subsequent onset of the Cold War and the launch of the Soviet *Sputnik* as a political catalyst, the federal government sought to further expand the nation's scientific research capacity as a means of ensuring American technological superiority over the Soviet Union (Geiger, 1997; Jones, 1982). Thus, by the early 1960s, the United States was supporting a research enterprise of unprecedented size. Science had become, according to science policy analyst Don K. Price, permanently mobilized. "It had to be organized and professionally staffed. It required the continuous managerial supervision by government . . . and the continuous subsidy by government of the higher education of scientists and others" (Price, 1965, p. 39). Moreover, the technologies that inevitably flowed from the hard sciences increasingly became seen not only as the *sine qua non* of national security, but also as a universal means for human advancement. The new technologies, many felt, would undoubtedly contribute to everything from the eradication of disease to improved education (Rudolph, 2002; Weinberg, 1966). For scientists, such widespread public faith in their work converted directly into growing levels of prestige, greater influence on government policy, and, of course, more public funds to pursue their research (Kevles, 1992).

Many scientists, Schwab included, while recognizing the central role science had assumed in American society, sensed also, perhaps more than we can fully appreciate today, the fragility of their professional status (Hollinger, 1990). As in any democracy, political support and the funding that often comes with it is subject to the whims of the electorate. And given the increasingly dependent position science was in, Schwab felt it was essential that there be no misunderstanding regarding just what it was the public was buying. He was specifically concerned that the public not be disillusioned or confused by the rapidly changing face of scientific knowledge. "Consider a student who has garnered the impression that science consists of inalterable truths," he invited the reader in his essay "The Teaching of Science as Enquiry." "Five or ten years after graduation he discovers that many of the matters taught him are no longer taught . . . . They have become obsolete and been replaced by other formulations." The likely result, Schwab imagined, is that "the former student, now a voting member of the polity, can do no better than to doubt the soundness of his textbook and his teacher. In a great many cases, this doubt of teacher and textbook becomes a doubt of science itself . . . . [He] has no recourse but to fall into a dangerous relativism or cynicism . . . [concluding] that experts are untrustworthy, parading the doubtful as certain, or even that they promulgate particular views as true because it is to their own interest that people believe in them" (Schwab, 1962, pp. 46–47). Thus a curriculum that presented science as a static body of knowledge, regardless of how accurate and up to date, Schwab believed, contributed to "a climate of opinion inimical to science" (Schwab, 1960, p. 185). With science now the "foundation of national power," what was essential and "perhaps most important" was the "need for a public which is aware of the conditions and character of scientific inquiry, which understands the anxieties and disappointments that attend it, and which is, therefore, prepared to give science the continuing support which it requires" (1962, p. 18, p. 38). Bringing the public to this enlightened view—developing "a public which can support science"—Schwab asserted, "constitutes the main burden of the secondary school" (1962, p. 44).

IMAGES AND CONSEQUENCES

It takes little in the way of critical analysis to see the similarities that run through the writings of Dewey and Schwab. Both clearly saw science as an active process rather than a fixed body of knowledge, and both sought to convey to students some understanding of this through particular constructions of the science curriculum that ranged far from that found in traditional science courses. Given Schwab's acknowledged intellectual debt to Dewey this is not surprising. In this way their ideal classrooms were informed directly by their views of the intellectually active nature of science. There were, however, key differences—differences that can be attributed more to social context than to science itself.

The crucial difference between Dewey's formulation of science and Schwab's was in the ultimate source of scientific validity, that is, where each of them located epistemic authority within science. As I mentioned at the outset, one of the primary aims of science education is to demonstrate for students just why scientific practices are so highly valued, how they work to generate knowledge that can be counted on to serve our needs. Dewey recognized this goal, noting in his discussion of science teaching that "unless [science] is so taught that students acquire a realizing sense of what gives it its superiority, something is lost" (Dewey, 1916b, p. 3). For Dewey, that superiority derived solely from the method of scientific reasoning. And, although Schwab concurred with Dewey on the importance of understanding that process, he made a subtle yet extremely significant distinction. The real authority of science, Schwab argued, consisted "not in possession of information [a point with which Dewey would have agreed], but in possession of competence in enquiry" (Schwab, 1962, p. 48). In other words, legitimacy came not solely from method, or enquiry as Schwab preferred, but only the *competent* exercise of method, which, as we have seen in Schwab's vision was wrapped up with the complex theoretical knowledge (the substantive structure) of the various scientific disciplines. Thus only experienced scientists—those that possessed the arcane knowledge of the relevant discipline—could properly utilize scientific methods.

This view of science was one commonly held by scientists of the time. The chemist and philosopher Michael Polyani, for example, argued strongly against the Deweyan notion that scientific methods could be easily taught. Such work, Polyani wrote, was rather "an art which cannot be specified in detail" and therefore "cannot be transmitted by prescription, since no prescription for it exists. It can be passed on only by example from master to apprentice" (Polyani, 1958, p. 53). In this conception, science was guided by craft knowledge and the ultimate authority rested with the members of the scientific guild.

These divergent views of the essence of scientific legitimacy strongly influenced the sorts of curricular approaches developed—Deweys' emphasis on a decontextualized method left him free to engage students with varnishes, cleansers, and gasoline engines, while Schwab's approach required narrative reconstructions or concrete examples of real scientific work as the vehicle for demonstrating the scientific reasoning process. Their understandings of science, however, influenced more than just the curriculum—there were social consequences as well. For the individual student, the relocation of epistemic authority from process to the professional community of scientists had a decidedly disempowering effect. Rather than seeing science as an intellectual resource or tool anyone might use for their personal, social, or even political benefit as Dewey advocated, students, according to Schwab, were to learn enough about science to appreciate its legitimacy, but also its inherent complexity, a complexity that placed it beyond the intellectual grasp of the lay public. This lesson, properly learned, would result in public deference to the authority of an expert class—an outcome Dewey had worked to guard against throughout his career (Westhoff, 1995).

The curricular reconstruction of the nature of science had broader policy implications as well. In the years following World War II, as science and scientific research were hailed as the key to American prosperity and progress, questions regarding the most appropriate funding arrangements were raised by a host of government officials (Kleinman, 1995). The public at large and the federal government in particular highly valued scientific expertise to be sure. Differences of opinion emerged, however, as to how best to make use of this powerful intellectual resource. Here images of science clearly mattered. Dewey had always been a strong proponent of expanding the scientific enterprise to include all public affairs. But his instrumental conception of science as a tool applicable to any domain, even the social and political, appeared to invite external control and direction. If the power of science lay simply in the process, surely federal funds could be targeted in ways that would ensure that those processes be directed to meet pressing social needs. The process was after all, in Dewey's portrayal, completely independent of any topic or domain.

State control of science, however, was just what the American scientific community feared. By outlining a view of science that required insider expertise for its most efficient advancement, scientists and educators such as Schwab worked to ensure that the scientific establishment would continue to benefit from public funding without the strings of accountability or outright direction that some groups desired (Hollinger, 1990). Scientists of the period heartily concurred with the sentiments expressed by National Science Foundation director Alan T. Waterman that "basic research is a highly specialized activity; it is not one where the judgment of laymen has validity." Its oversight and planning, regardless of who provides the funds, he insisted, "must be left in the hands of competent and experienced scientists" (National Science Foundation, 1963, p. xix). This politically autonomous portrayal of science was rapidly assimilated into the public consciousness in the years after the war. By 1965, science had succeeded in its mission; it had become, in the words of one policy analyst, "a set of institutions supported by tax funds, but largely on faith, and without direct responsibility to political control" (Price, 1965, p. 12). The school science curriculum was, though not responsible for, certainly party to those results.

What is important here is not who was right. Attempting judgments of this sort serve no substantive purpose in this instance. In some sense both were. Science does indeed proceed by means of the inquiry process, the success of which depends upon the rigorous application of method (though there are certainly more than one) as Dewey insisted. And there is no reason why these processes, defined with sufficient generality, might not be fruitfully applied to any manner of human problem. Science, however, is also dependent on the judgment and expertise of a community of practitioners as Schwab and the postwar scientists insisted. These divergent takes on science simply illustrate the multiform nature of the collective practices that we commonly refer to as science. No single representation of them can ever be counted as accurate. Science is not a single thing; there is no "essence" to be found. Gieryn persuasively articulates this argument in his treatment of the cultural mapping of science. Whatever science is in practice, he explains, "it is both too much and too little to determine its place on a cultural map." The problem is not that there is no "real science" behind the representations, but that "there are too many 'real sciences' "—an observation in line with recent scholarship emphasizing the ineffably plural nature of scientific practice (Cartwright, 1999a, 1999b; Galison & Stump, 1996; Harding, 1998; Knorr-Cetina, 1999; Rouse, 1996). Moreover, these maps, or images of science, Gieryn explains, by their very nature "must not only simplify, distill, and reduce their referents, but then reconfigure, distort, and embellish them" (1999, p. 19). As true as this is with respect to characterizing science out in the world, it is doubly true when it comes to the school curriculum, where simplification and distillation are the most common methods of fitting content to student audience.

What needs to be fully appreciated, and what I have attempted to illustrate by historical example, is the connection between the images of science constructed and the social consequences of those images—particularly as they relate to the provenance of scientific legitimacy, or epistemic authority, within science. Whether one favors a Deweyan social vision or a Schwabian one, or any other for that matter, is not the issue (at least not in this paper). The point to be emphasized here is simply that there are no *socially neutral* images of science, all have inherent consequences of some kind or another. These images, as Gieryn observes, "are contextually tailored selections from a long menu, where 'context' is defined by the players and stakeholders, their goals and interests, and the arena in which they operate" (1999, p. 21). We would do well, I would argue, to spend more time reflecting on this as we struggle to portray the nature of science in schools.

CONCLUSION

Over the past 10 years there has been a rapidly growing interest in the nature of science in schools among science education researchers, science studies scholars, and policymakers (see, e.g., AAAS, 1990; Costa, Hughes, & Pinch, 1998; Jenkins, 1996; Lederman, 1992; Matthews, 1994; McGinn & Roth, 1999; NRC, 1996; Turner & Sullenger, 1999). The technical work of revising curricula, designing instruction, developing assessments, probing student and teacher conceptions, and so on, in order to realize the renewed emphasis on scientific processes in schools as well as to come to terms with the challenges of increasing cultural diversity has stimulated much discussion and no small measure of disagreement regarding just how the scientific enterprise should be represented in all this (e.g., Alters, 1997a, 1997b; Brickhouse & Stanley, 1995a, 1995b; Eflin, Glennan, & Reisch, 1999; Good, 1995; Lederman, 1995; Lewis & Aikenhead, 2001; Smith et al., 1997; Smith & Scharmann, 1999; Stanley & Brickhouse, 1994; Suchting, 1995, 1996). Perhaps this is to be expected as researchers struggle to define and clarify the foundations of their research program. But more careful scrutiny of the literature seems to reveal few signs of any developing consensus. Indeed, the disagreements seem to exhibit a studied resistance to being resolved and may even be increasing in intensity. This intellectual discord is undoubtedly related to the fact that such a heterogeneous array of human activity falls under the label science. But, more to the point of this paper, this problem is aggravated by the fact that only part of the situation is being taken into account.

In *any* portrayal of science—and most importantly in the portrayal of school science—at least two things should be considered: (1) what it is scientists actually do in the myriad research settings that exist, and (2) some vision of what the appropriate relationship should be between science and the public. It is this second factor, I would argue, that should provide the guiding framework for culling, reorganizing, and finally presenting the practices of science to students in the classroom. This does not mean, of course, that the nature of science can be packaged in any way whatsoever, that it can be shaped exclusively by social and political interests (however worthy those interests may be). As pliable as the curricular image of science is, it is not infinitely so. But it must be realized equally that we cannot be guided solely by what science is in some essentialistic sense. The recent science studies scholarship described above has shown this goal to be illusory.

Dewey and Schwab were fortunate to have clear social aims in mind as they worked to formulate their curricular presentations of the nature of science. Such is the luxury of working alone, and with strong conviction. Shared understanding and shared social goals are, admittedly, much more difficult to come by. It would seem, however, that a good deal of disagreement and confusion over what science is and what it should be for children could be eliminated if less time were spent on the nature of science as a thing-in-itself and more time critically examining the social dimension of the problem. The first step is to acknowledge the inherently political nature of the task before us and to recognize that the answers are to be found not in science, but rather amongst ourselves. This requires bringing to the surface the tacit social aims and assumptions that are constantly in play in the development of the school science curriculum as well as carefully considering the social consequences, intended or not, of the curriculum produced. What follows is the hard work of reaching some reasoned consensus about what function we wish science education to serve. Only then can we proceed with the business of crafting the appropriate epistemological image to match.

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