Educating for Citizenship: Reappraising the Role of Science Education

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Abstract

New discoveries and technological inventions render the world increasingly complex. Fostering students' scientific and technological literacy has therefore become a primary goal for many science educators. Yet the concept of scientific literacy is itself not at all clear. In this article, we contest the dominant approach, which defines scientific literacy in terms of what scientists produce or do. We argue that a more viable approach begins by framing a more general project of (democratic) citizenship and asks what kind of scientific literacy can contribute to this project. The different parts of our argument are illustrated with data from a three-year ethnographic study of science in one community. These data feature adult residents participating in the contested issue of whether to extend the existing watermain supply a part of the community with water that currently has to rely on seasonally contaminated wells. Irrespective of their science background, these citizens engage scientists.

A politicized ethic of care (caring *for*) entails becoming actively involved in a local manifestation of a particular problem, exploring the complex sociopolitical contexts in which the problem is located, and attempting to resolve conflicts of interest. Preparing students for action necessarily means ensuring that they gain a clear understanding of how decisions are made within local, regional, and national government, and within industry and commerce. (Hodson, 1999, p. 789)

Democratic citizenship is a core concept in many societies—the discourse of citizenship education shows up in the policies and curricula not only of Canada but also of jurisdictions as diverse as Australia, Russia, Colombia, and Singapore (Sears, in press). Science education is often linked to citizenship. Our basic premise in this article is the contention that science education, in schools and as a life-long endeavor, is of little use if it does not allow students to care for and, in particular, engage in action. Recent scholarship in the social studies of science underscores the need of citizens to get involved in the decision-making processes concerning controversial socio-scientific and sociotechnical issues. In this article, we argue for a view of science that engages with the people in the community, not in terms of laboratory science, but on the citizen's terms. We provide one case study from a small community on the Canadian West Coast, where residents engage politicians and scientists to get access to the watermain that supplies the rest of the community. We see this case study as a model of the kind of citizens that we want students to become. These are citizens in the sense that Hodson outlined it in our opening quote. We conclude that it may not be necessary that all citizens have acquired the same stock of scientific knowledge but rather that all citizens have the competence to enter what ever knowledge they have into the public (political) discourse. It is only when science can participate in such conditions where other knowledge forms are equally considered that science has become truly democratic.

Introduction

There is an increasing public awareness of the ethical, practical, and political dimensions that characterize sociotechnical controversies, including those of mad cow disease (BSE), climate change, or the diffusion of genetically modified organisms. Modern science is deeply enmeshed with the personal and public issues of our times (Restivo, 1988), all the more so in the present controversial globalization (Held & McGrew, 2000) and in the context of what Beck (1992), Giddens (1994) and other sociologists have termed "risk society." The modification of our environment, and in fact, the modification of human nature, are issues that should concern all members of society. Science and technology, as any other domains that shape public and private life, should therefore become legitimate objects of reflection on the part of all citizens. That is why we believe that a central endeavor of science educators has to be the problematization of science and technology and the stance any citizen should take with respect to scientific knowledge and technological artifacts as they are socialized. Here we assume that it is only out of this problematization that we can reappraise the role of science education in the promotion and service of an informed and engaged citizenship.

In science education, the notion of citizenship has often been conceptualized and argued in terms of “scientific literacy” (DeHart Hurd, 1998; Laugksch, 2000). More so, in many countries, governments and other agencies have issued policy statements that stipulate the sciences as *necessary* ingredient in the development of an informed and engaged citizenship. For instance, concerned with the question of scientific literacy, its role in American society, and ways of achieving it, *Science for all Americans* (Rutherford & Ahlgren, 1990) contains an argument for science education that helps students become informed citizens capable with others to use science and technology wisely in order to solve the numerous global problems humans now face. But it is quite remarkable how science and technology are presented as unproblematic in such documents (Irwin & Wynne, 1996). First, science and technology are not contrasted with other legitimate ways of representing *nature*. Second, science and technology are often defined as human endeavors presenting certain limits but in this retain their supposedly universal character (Cobern, 1996) and thereby transcend the historically contingent and local conditions of their production. Third, the pertinence and value of science and technology in relation to the realization of personal and social goals is seldom called into doubt. All of this leads to the adoption of a scientistic attitude that overvalues a particular form of thinking adapted to the particular circumstances of scientific research but with little use in everyday life (McGinn & Roth, 1999). Finally, questioning only the applications of science and technology instead of scrutinizing the production of knowledge obscures the ideological dimensions and political ties that science and technology have to the financial, industrial, and military sectors of society.

In the science education community, one can notice the emergence of debates that question the foundations of traditional scientific literacy discourses either from a multicultural perspective (Lewis & Aikenhead, 2001; Stanley & Brickhouse, 2001) or a more sociological perspective (Désautels, 1998; Jenkins, 1999). In this article we, too, adopt a stance that differs from conventional science education as it is portrayed in literature on scientific literacy. We contend that one must begin with the notion of an active and critical citizenry and then problematize science and technology in its service. Drawing on the sociology of scientific knowledge we describe science and technology as contingent practices. Being built on contingent practices, science and technology are subject to interrogation of the assumptions that underlie their moment-to-moment decision-making processes. In so doing we deconstruct the arbitrary social hierarchy of knowledge (Larochelle, 2001; Quicke, 2001) that put scientific knowledge on top of the epistemic heap, and rehabilitate other forms of knowledge (including common sense, local expertise, and indigenous knowledge) as a powerful resources in the debates over sociotechnical controversies. Our case study of science in the community, which is centered on the quality of water in one Canadian community, illustrates the active participation of ordinary citizens in a democratic debate over sociotechnical issues and the reflexive stance to expertise and expert knowledge taken in the debate. In sum, we intend this article to be read as an argument for rethinking scientific literacy from the more general perspectives of citizenship and inclusive democracy.

Science: From Cathedrals (Citadels) to Real Laboratories and the Polis

Recent decades have seen a shift in the appreciation of science. Initially similar to religious dogma (Lewontin, 1991) celebrated by high priests in "cathedrals" (Fuller, 1997; Knorr-Cetina, 1992) and "citadels" (Martin, 1998), science has become associated with the messiness of real laboratories and finally with the everyday life of the polis (Brown & Michael, 2001).[1] It is only when science is part of the polis that citizens will be empowered because their dependence on scientists as the sole normative force has been ended—as related analyses on the democratization of state and market have shown (Fotopoulos, 1999b).

From dogma...

For many years, philosophers granted the sciences (and medicine) a form of "epistemological exceptionalism" (Bimber & Guston, 1995; Freidson, 1970). Epistemological exceptionalism explains why sociologists of science were not allowed to study the production of scientific knowledge. It is certainly the case that sociologists were allowed to study the organization of science (promotion system, invisible colleges, ethical and cognitive norms, etc.) but they were forbidden to critically reflect on the nature of scientific knowledge, which was thought to transcend its conditions of production. Although scientific knowledge was produced by social beings, it appeared to acquire quasi-divine properties (neutrality, universality, transcendence, etc.) in a process resembling "Immaculate Conception" (Fuller, 1997). Those who practiced this form of epistemological asceticism were thought to develop a personality reflecting those very properties. Scientists became socially disincarnated neutral beings capable to bracket their subjectivities and access the true nature of things.

[1] Polis is the term for the Greek city-state. It is associated with a sense of community and direct and economic democracy, where issues where often discussed in public forums (Fotopoulos, 1995).

to enigma…

In recent years, sociologists and anthropologists who studied scientists at work have largely debunked this image of science and contributed to the transformation of the epistemological dogma of science into a social enigma. In painstaking and meticulous detail, these studies described how scientists negotiate the criteria that underlie their judgement about what will be recognized as a successful experiment, a valuable result or interpretation, and the trust and value of a specific piece of work (Pinch, 1990; Lenoir, 1993). Furthermore, science is not something that occurs in laboratories entirely detached from the rest of the world. Rather, scientific research depends on tremendous networks of actors and agencies that connect and suspend laboratory activities in everyday life more broadly. Thus, scientists have to trust those who supply them with standardized products, produce scientific instruments and the theories they materialize and also, trust their colleagues from other disciplines who make judgements about the value of the various forms of knowledge that they use in their work. Not only is trust a necessary ingredient for the maintenance of the network of scientific activities, but also this trust has to be given knowing that not a single person or even a group of persons can have a clear picture of the whole of the network. The complexity of the situation can be gauged from the fact that there are more than, 20,000 journals in biology and the U.S. Library of Congress receives more than 80,000 scientific journals. In this context, having conducted climate-change-related research for many years, Ungar (2000) suggested: "after a decade of clipping articles from *Science* and *Nature*, my sense that climate change is real ultimately boils down to picking the experts you think you can trust" (p. 297).

It is within this context that one can say that the various forms of scientific knowledge are marked by the contingencies (material, symbolic, economic, social, etc.) that constitute the local conditions of their production. Therefore, their so-called universal character, which presupposes scientists' abilities to adopt a god's-eye view of their object of study, is a kind of mystification. In the same way, the idea that scientists follow a step-by-step scientific method to solve the problems is inconsistent with what they do when they are observed: Scientists' theoretical and empirical practices are better described as a collective, intellectual, and material bricolage (Pickering, 1995). Only in a retrospective, when stable facts have emerged from the mangle of practice, do things become clean cut and exportable elsewhere. In real-time activity, the messiness and complexity of the (laboratory) world renders any prediction about the future state of affairs improbable. No sociologist or anthropologist of science has noticed at work a disincarnated mind that, in solitary confinement, thinks of a theory or realizes an experiment.

With all this contingency, how is one to explain how these contingent products—published as statements which refer to their conditions of production (IF *a, b, c*, ... THEN... *x, y, z*)—acquire a certain robustness, a regional acceptability and, in some instances, an international recognition? The aura of universality that frequently surrounds scientific knowledge is a consequence of scientists' activity, which contributes to the construction and maintenance of worldwide networks of human and non-human actors (Latour, 1999). The stability and universality of scientific knowledge is a direct consequence of the stability of these networks. In participating in these network activities scientists around the world come to agree, for instance, that all bodies fall under the influence of gravity or that the ozone layer is being depleted. Instead of focusing on the mystifying notion of universality, researchers are now interested in levels of generality (Callon, 1999). This generality is a function of the extension of the networks that allow for their re-production or mobilization for certain purposes. In other words, the generality of scientific knowledge depends on the possibility to transport their conditions of production into new situations.

One can draw several epistemological lessons from this sketch of science. Science and technology, through and through social practices, construct knowledge that bears the conditions of its production. Because knowledge is contingent, it can be interrogated. Scientific knowledge can no longer claim epistemologically exceptional status but has to interact with other forms of knowledge on an equal footing. As social practices, science and technology do not simply affect society but they literally produce the social. Thus, scientists produce entities (bacteria, hormones, materials, etc.) in their laboratories that enter in the composition of our common world and reconfigure social relations. Society is no longer the same after genetically modified plants have been released in the environment or after a specific virus (e.g., HIV) has been identified.

… and into polis.

Once science has lost its exceptional status, more equitable, direct and inclusive participation of citizens in controversial issues becomes possible. The hierarchy among different forms of knowledge gives way to the development of a critical distance towards expertise. Common sense and local (traditional) knowledge become salient as inescapable resources to be mobilized in those circumstances since they are no more considered as inferior or worthless types of knowledge. But a certain number of citizens did not wait for sociologists to debunk the myth of science and to get permission for involving themselves in the messy world of the sociotechnical controversies as shown by recent studies in the field of *public understanding of science*. There are a number of other instances reported in the literature (McGinn & Roth, 1999) relating the influence of citizens on the orientation of research efforts.

Studies now show that when science moves from the confines of the laboratory into the world, scientists often loose their grip on knowledge construction. Increasingly, ordinary citizens with stakes in some issue contest scientists' epistemological exceptionalism (Rabeharisoa & Callon, 1999). In the ensuing controversy and negotiation, science often changes heretofore-accepted practices and develops new methodologies that take into account local knowledge and needs. For example, AIDS activists gained sufficient and different forms of credibility and thereby become genuine participants in the construction of scientific knowledge (Epstein, 1997). They participated in the construction of "valid method" and "clinical protocols," which were therefore no longer the prerogatives of credentialed scientists. In this, they effected changes in the epistemic practices of biomedical research and in the therapeutic practices in the medical care of the disease. The case shows that the politicization of AIDS has brought about a multiplication of possible ways in which the credibility of individuals and groups can be established. This constitutes a diversification of personnel in scientific knowledge construction beyond the highly and institutionally credentialed scientists, which in turn leads to more and more diverse trajectories of fact construction and closure in controversies. Other research within the AIDS community showed that the notion of science as clean and elegant is a myth that can be upheld only when it remains in the laboratory and unconcerned with real life. Outside of the laboratory, science is messy, impure, and ambiguous and is caught up in the economical, political, historical, or ethico-moral dimensions of everyday life (Epstein, 1995; Lee & Roth, 2001).

In fact, the AIDS studies and our own research show that the very notion of "scientific knowledge" needs to be questioned: Does knowledge, whose construction crucially involved the participation of non-scientists, deserve the adjective "scientific." If it deserves this label then the very nature of science has changed. It is no longer the sole prerogative of a special cadre of individuals but involves individuals and groups with expertise other than that traditionally described as "scientific." A traditional take on science is that decisions concerning technical issues should be left in the hand of experts (Rowe & Frewer, 2000). In the deficit model, the public is not involved because, so goes the argument, it does not understand the salient issues and concepts or the processes of science. Scientists operating in the spirit of this take "bludgeon publics with 'certain facts,' often ignoring the public's own culturally embedded understandings"

(Brown & Michael, 2001, p. 18). However, democratic ideals, particularly those of consistent with inclusive democracy (Fotopoulos, 1999a), imply a greater involvement of the public in policy-making issues that pertain to or involve science and technology. Over the past decades, it has become increasingly evident that in risk management related to genetically modified organisms, those involved make value judgements at all stages of the risk management process. There exists therefore an "increasing contention that public participation in policy making in science and technology is necessary to reflect and acknowledge democratic ideals and enhance the trust in regulators and transparency in regulatory systems" (Rowe & Frewer, 2000, p. 24).

Public participation involves a group of procedures designed to consult, involve, and inform the public to allow those affected by a decision to have an input in that decision. Rowe and Frewer compared and evaluated eight of the most formalized public participation methods. These include referenda, public hearings/inquiries, public opinion surveys, negotiated rule making, consensus conferences, citizens' jury/panel, citizen/public advisory committee, and focus groups. After an extensive evaluation, the authors concluded that there is no one best method for involving the public. But, public hearings, because they have the potential to add balance and depth to information collected by other means such as using surveys, are an important and widely used mechanism in democratic countries. In the following case study, we show how scientific literacy becomes *enacted* as praxis in one public hearing. Science and scientific method are no longer the prerogative of scientists but are open to reconfiguration.

Interrogating Scientists and Science in the Community: A Case Study

In this case study, we show that ordinary citizens can be involved in questioning scientists and science, and thereby actively participate in the way in which various forms of knowledge contribute to the solution of real problems. We do not argue for a demise of science but that its status should be open to interrogation from a variety of perspectives and therefore be relativized in a democratic process where all forms of knowledge undergo equal scrutiny. Its value has to be negotiated in a process that should include the people most concerned and affected by the decisions made and in a process that has to include other forms of knowledge on a par.

This case study was constructed from materials that were collected as part of a three-year ethnographic effort in one Canadian community on the West Coast. This effort was designed to increase our understanding of science in the community, including the science of grade-seven students who exhibited what they had learned about the health of a watershed during an open-house event organized by an environmental activist group. Our database includes field notes, videotapes, and audiotapes documenting various ways in which the people of Oceanside[2] and environmental activists pursued activities relating to the health of the watershed in which they live. Here we focus on the participation of citizens in one particular audiotaped event, a public hearing concerning the problematic situation of the drinking water in one part of Oceanside. As a public hearing, the events reported here constitute an example of the ways in which ordinary citizens can participate in policy- and decision-making regarding environmental and health issues. We have obtained all publications pertaining to the drinking water, municipal documents, scientific (consultant) reports, reports by various agencies, and copies of letters by the representative of the Salina Point residents.

Background

The public hearing was held in the community of Oceanside, where a variety of water issues are and have been central and ongoing concern. In this particular case, the media had repeatedly reported on the situation in one part of the community, Salina Point, which is not connected to the watermain. All properties of Salina Point supply their own water from wells on their properties and from cisterns. Because the wells are recharged mainly through precipitation, the water supply depends on weather patterns; very dry summers lead to depletion of the aquifer and a correlated increase in the mineral contents and contamination by biological organisms. Repeatedly in the last several years, local newspapers have carried stories about the fact that the water quality in these wells had been declared unfit for consumption without prior boiling, forcing residents to drive five kilometers to get their water from the next gas station.

The town council of Oceanside felt that the estimated cost of $850,000 for extending the currently existing water lines in order to supply Salina Point was too high to be covered through its allocated and available budget. A total of six reports had been commissioned prior to the public hearing. These reports included one by the Regional Health Authority, a preliminary report by the Oceanside Water Advisory Task Force, the report by a consulting hydrologist, the final report by the Water Advisory Task Force, a minority report submitted

[2] Although this was a public hearing, recorded and documented by the media, we will use pseudonyms to protect the identity of the community and the individuals involved. Also, subsequent data from our studies among school children have been rendered anonymous.

by a subgroup of the Water Advisory Task Force, and a report by the municipality. The mayor of Oceanside had called for a public hearing, including the authors of the technical and scientific reports. These authors would first provide a sketch of their work and subsequently avail themselves to questions and comments from the public. Furthermore, the hearing was to provide opportunities for members of the community to ask questions and to make presentations.

From the presentation of one expert

In this case study, we focus on the presentation of one expert and his interactions with the audience. The moderator of the session, a member of the engineering staff of Oceanside, introduced Lowell as "a professional engineer and a professional geologist." The moderator explained that the town council and the regional health authority had chosen Lowell as an independent consultant because the research done by the regional health authority had been questioned for its scientific integrity. Some members of the Water Advisory Task Force had questioned whether the sampling was rigid enough to determine that problems occurred within the original houses or not or within the aquifer itself, that means down within the bedrock water in the wells. The moderator explained that Lowell had sampled nine wells, which in the consultant's professional opinion were representative of the ground water. Lowell had been asked to simply test the water and to provide the community with a report about the quality of the well water at Salina Point and an opinion about what might be done concerning the quality issue. After being invited by the moderator, Lowell presented his report, from which we excerpted the following statements pertinent to citizen questions that we present and discuss below.

We chose the representative wells by their distribution in the area, well depth, well yield, and sampling history to get a representative cross-section of wells. We selected some wells because they were deeper wells, some wells because they were shallow wells, higher yielding wells, and lower yielding wells to get a good cross-section of wells that were in that area… The sampling methodology was, "sample as close to the well as possible an, at an outside tap or right at the wellhead." We tried to avoid house plumbing and cisterns as much as possible. So we pumped the wells for as much as fifteen minutes and as much as one hour to get a fresh water supply coming straight from the aquifer and not coming from storage. The results of our testing show that according to the Guidelines for Canadian Drinking Water Quality, there are no concerns related to health. None were identified in the parameters that we tested. Some aesthetic objectives from the Guidelines for Canadian Drinking Water Quality were exceeded for some of the wells. Aesthetic objectives are for … certain parameters in the water may cause the water to be corrosive, deposit forming, or unpalatable. These are given a separate category because they are not a health concern but they are a concern. Total dissolved solids, that is one measure of water quality, four out of nine wells exceeded that parameter; turbidity, one of nine wells exceeded that; aluminum, one out of nine wells; iron, two out of nine wells; manganese, four out of nine wells; zinc, one of nine wells. For all of the bacteriological testing done, no wells were found to be unacceptable.

Lowell had made his presentation by drawing on the rhetorical registers that characterize science and engineering: It was very factual, presented those aspects of the methodology that supported claims about the generalizability of the results from the nine sampled wells to all wells at Salina Point. He described the point of sampling to support claims that in fact well water had been tested rather than water that had remained in pipes, storage tanks, or cisterns. The privileged status of this expert witness was established by presenting him as "a professional engineer and a professional geologist," including him into the ranks of other scientific experts, some of whom were introduced with their degrees. ("Mr. Yin has a Masters of Science degree, and has significant experience with water quality issues and he has been involved extensively in both reports in the sampling episodes.") This, of course, is a classical tactic for constructing exceptional status of the claims by the individuals thus elevated.

From the questioning of the expert: Situation 1

After the different scientists and representatives of the Water Advisory Task Force had presented summaries of their report, the moderator of the public hearing encouraged members of the audience to ask questions and make comments pertaining to the technical issues of the reports.

Hays:	You took water samples from our property. Now, I was told that you let the water run. The problem is, first of all, at any source you get the water is coming out of a cistern that is two or three thousand gallons. It's had a chance to settle out, number one. Number two, the water you've got has been mitigated through a water softener. Number three, it has been mitigated under a U-V system to kill bacteria. How can you say we can mitigate our water? I mean how much more mitigation can we do?
Moderator:	Dan [Lowell], can you? Do you know about that particular well, whether you tested it right at the well head or whether it was through the system?
Lowell:	I don't know of any well that we tested that had any kind of treatment. We went to the cistern to get the water but we went to where the water came into the cistern from the well. We didn't, uh I think there might have been one well that we tested from the cistern 'cause there was no other way to test it but all the others were uh before the cistern, and before any kind of treatment.

Hays: Are you sure of that? We have, an in-ground, basically a septic tank. We have a very low water flow and it has to go into a septic tank and from there. Unless you went through a lot of blackberry bushes, which I didn't really see them disturbed, you'd have to go through quite a bit of bramble to get to it. It comes out of there, goes through the pump house, goes through a UV filter and goes out from there to the taps. And I assume it was taken from the taps. So it's gone through a UV filter to kill bacteria because we have water levels that are near septic fields. It's gone through a water softener and a through a filter and it's still reading pretty nasty high levels. So I don't, I don't personally feel that mitigation means much to me since we're already mitigating the hell out of the water as it is.

Lowell: Yeah, if that sample was treated before we got it that would mean that one of the samples isn't exactly what we thought it was. But it wouldn't change the conclusions of my report.

Whereas scientists are often portrayed as the guardians of scientific methodology, of which everyday folk are ignorant (Brown & Michael, 2001), the community members in this meeting, here exemplified by Hays, did not appear to be overly impressed by the scientists, their articulated degrees, or their expertise. In fact, an important dimension of all the questions was the appropriateness of the methodology used and the validity of the data to draw the conclusion that the independent consultant Lowell had presented.

The first exchange opened with Hays' questions about where the water samples had been taken. Hays suggested that the sheer water quantity in his cistern would have implied that Lowell tested water that had been stagnant for a while, and therefore allowed any substances to settle. Stating the holding capacity of his cistern, 2000 or 3000 gallons of water contrasted the 15 minutes of letting the water run at the tap. Common sense tells any listener that a water tap running for 15 minutes does not empty, 2000 gallons of water necessary to have access to the water from the well. He thereby made salient a potential problem in the methodology, which implicitly raised questions about the validity of the findings 'no wells were found unacceptable'. Further, the water samples would have already been mitigated through a water softener and a bacteria-killing system based on UV irradiation.

Lowell attempted to defend himself by saying, consistent with his initial presentation, that to his knowledge all water tested came from the wells rather than from cistern (with perhaps one exception). Hays questioned the veracity of Lowell's statements thereby portraying them as claims rather than as matters of fact as it came across in Lowell's presentation and initial response. Hays subsequent question again put the authority of Lowell's description of method into relief by stating that there had been no evidence on his property that Lowell had actually accessed the water at the only place where it could have been sampled in unmitigated form. Therefore, there is a strong possibility that Lowell's data were not unbiased. Nevertheless, he claimed that even if he had not conducted *these* measurements appropriately his overall conclusion would not change.

Here, we see an ordinary citizen questioning the legitimacy of a scientific report. The transcript does not allow us to think of Hays as an ignorant person. For example, although Hays probably had a conception of what a solution might be that is different from what Lowell proposed, he could participate in the debate quite efficiently. In these circumstances, it makes us acknowledge a person who, through his public participation in the hearing, produces knowledgeability about the operation of water softeners, UV filters and their action on bacteria (but not on other aspects of water quality), and the effect nearby septic fields have on drinking water. (In rural areas, many homes still use septic fields where wastewater is allowed to move through a special bed made of rocks, pebbles, and sand to enter the ground water.) This episode quite clearly illustrates how "lay expertise" and common knowledge can be mobilized in order to clarify what is at stake in the context of a sociotechnical controversy.

From the questioning of the expert: Situation 2

In the following excerpt, another local resident, Naught, asked the expert Lowell to evaluate his own results in the light of those apparently contradictory ones presented by another scientists in the service of the regional health authority. Here, the major issue was whether Lowell's data represent an average value or whether they have to be interpreted as a short-term, best-case scenario. Naught not only asked the expert to make this evaluation but also, as his further questioning shows, brings out the pertinent issues that have led to the contradictions between the two reports authored by Lowell, on the one hand, and the scientists from the regional health authority, on the other.

Naught: How do you feel about your results now that you've heard the... person from the Ministry of Health describe what he feels could affect the readings. You seem to rely very heavily on the readings that you took. Okay, which seems to be explained by the difference in rainfall. Now are you in agreement, for example, that the aquifer and the water coming from the wells is largely the result of rainfall?

Lowell: That's right. It's all the result of rainfall, not just largely.

Naught: OK, well there's a buffering effect, there's an immediate effect. I mean, well I shouldn't say that there's an immediate affect, a slower affect, one that occurs as a result of a longer period of time. We'll say, predominantly two, three to five months?

Lowell: All the water that got, all the fresh water that got in the aquifer came from rainwater, originally.

Naught: Yeah, but–

Lowell: Some may have been in the ground longer than others- a longer period of time and water that has been in the ground for a longer period of time can have a higher mineralization because it absorbs minerals from the rocks.

Naught: Of course. And what we have- Can you tell me the years that you have charted here, what years were those logged for?

Lowell: Yeah. The, the observation well has been in service since, nineteen seventy-nine but I can see here, and that's from October ninety-seven and we had data up to June of nineteen ninety-nine.

Naught: OK, so what is your understanding of what happened last fall and this spring with respect to the water amounts of rainfall? Was this a heavy period or a normal period?

Lowell: I know that it was a record period per rainfall but it's not reflected in water levels in the area because the peak water levels in the aquifer in, nineteen eighty-eight were higher than in the winter levels in nineteen ninety-nine.

Naught: Just a minute. You just said that it was a direct result of water and we've just had a record rainfall and it doesn't affect it? Well, there's something missing here.

Lowell: That means that only a certain amount of the rainfall can get into the aquifer being the heavy rains are running off. That's my interpretation.

Naught: Well, it could also–

Lowell: There's a limiting factor as to how much can get down into the–

Naught: Well, it's okay, this is true but the thing is that what we've experienced rainfall in the order of 522% on average, as far as monthly averages are concerned, increase over the summer months. In other words what we've got through the winter period, through the 5 months previously preceding your test results... If you took that and compared that to an average summer month, a month through that period, there were 522% more. Now, it would seem to me that we're probably not dealing on an average result with your tests, we're probably dealing on the hydrostatic head feeding that aquifer up in the higher, very much higher ends, so that the readings that you're getting are very much diluted.

Lowell: The hydrograph that we have shows that the water levels are average in late April, early May and I put the average water level on the hydrograph here and the–

Naught: Could it be an error? Could you be in error here?

Lowell had argued that his data—taken at a water level in the aquifer midway between its minimum and maximum values—represented an average and therefore representative value of the biological and chemical parameters of water quality. The scientists from the regional health authority suggested, on the other hand, that there are fluctuations in water levels such that during one half of the year, the quality values are in fact below the Health Canada standards. In this excerpt, Naught questioned Lowell about the variations, the level of water in the aquifer at the time Lowell conducted his measurements. In this, this interaction was a moment where the contradictory claims of acceptability of water quality were made salient again in public.

Naught is but another resident of the area. He asked Lowell to reflect on the results of his own readings after having another report, which had come to different conclusion. In particular, Naught asked Lowell to attend to and interpret the effect of sampling moment to the amount of rainfall at and prior to the time of testing. In response to Lowell's description that all the water in the wells and in the aquifer comes from rainfall, Naught stated that there should be a buffering aspect. That is, changes in the aquifer do not directly correlate with the rainfall but are delayed by three to five months.

As Lowell made another categorical statement that all water came from rain, Naught's interjection "but–" made Lowell if not retract so to modify his earlier statement. He now admitted that water would increase in dissolved minerals if it stayed for longer amounts of time in the ground. Naught's subsequent question aimed at eliciting from Lowell a statement about the groundwater levels; Lowell had to admit that there were record water levels but attempted to argue that these rainfalls did not affect the groundwater levels. However, Naught questioned this claim by contrasting it with a previous, seemingly contradictory one. Lowell attempted to argue that there are limits to absorption and that much of the rainwater would be carried away as run-off. Naught was unsatisfied by this response. He suggested that there is a 522% increase in rainfall from the summer to the winter months. The water levels could not have been average as Lowell had claimed in his report and that therefore, the concentrations of substances would generally be lower (more diluted) than under normal circumstances. Lowell, however, responded that the hydrograph had shown an average reading. We notice in the last excerpt that Naught was unsatisfied by this answer. He first cast doubt on Lowell's conclusion by evoking the possibility that an error could have been committed in using the average water level registered by the hydrograph in the months of April and May. More so, in a clever or astute rhetorical move, he squarely attributed the responsibility to the expert, "Could you be in error here?"

In this episode again, we see a member of the general public question the content of a scientific report on water quality, the methodology for gathering the data, and for the inferences made on the basis of the data. Hays and Naught, and all the other individuals who asked questions, did not appear to be intimidated by the social status usually attributed to scientific experts (here, several scientists were introduced by mentioning degree and rank in their respective institutional hierarchies). They pursued their lines of questioning which put into relief what otherwise were presented as authoritative statements about the quality of the water they were using. Indeed we have here a good example of the "good use of experts," which, according to Fourez (1997), constitutes one of the competencies individuals should develop in the context of their education in the sciences conceived as social practices.

Other exhibits of scientific literacy

The authority of the scientific report was also questioned by rather personal accounts of having to live with the water from the wells. For example, one resident stated that if he watered his flowers, they would burn. Their water pipes, dishwasher and washer corrode so that they have to be replaced frequently.

> Expertise Labs tested our water that was shortly after we moved in 'cause we were concerned then. We were over the acceptable limit of arsenic, five times the acceptable limit of lead, plus other problems. Their comments were included that continuous arsenic ingestion in high amounts is toxic. Sources of arsenic in water include industrial discharge, mineral dissolution, and insecticides. Lead. Lead is toxic and accumulates in body tissues. Lead may come from old lead pipes, which we don't have, solders or industrial discharges. Even small amounts can contribute to learning disability in children. (Bruner, local resident)

Lowell had claimed that the levels of toxic substances were below the official permissible limits. Yet the resident, who had hired their own consulting firm, presented data that were inconsistent with Lowell's data and conclusion. Consistent with the claims of the local health authority that the water is unacceptable during some parts of the year and contradicting Lowell's claims that water quality is acceptable based on his sample representing the average situation this contribution provided another description of the presence of toxic substances and their effects. In this situation, local people did not just wildly complain and express their displeasure, but knew to find an appropriate agency (Expertise Labs) that would provide them with a report the contents of which they could subsequently use in the presentation of their case about the water.

Knowledgeability with respect to finding and drawing on a variety of resources is a central aspect of scientific and technological literacy as social practice (Fourez, 1997).

What can we learn from the public hearing?

In these excerpts from the public hearing, we can observe ordinary but concerned citizens engage scientists and science in exchanges over the nature of the water problem and the way in which the data documenting the levels of water quality had been established. The citizens ask scientists to reflect on their own test results in the light of other results that had been made available during the hearing or that the contributing individual made available. Furthermore, evidence that was either omitted or labeled as unimportant by scientists was emphasized and therefore made salient by the citizens. Thus, the to Lowell apparently unimportant aesthetic indicators are major problems in the lives of the residents—dying plants, corroding pipes and appliances, toxic levels of arsenic and lead—whose sole water supply, other than trucking this resource, lies in the wells. In contrast to the scientists, the people are experts with respect to local and historically situated knowledge concerning the water in this area, its changing levels throughout the years, alternative supplies, increasing salination of the resource, and so forth. Truly democratic decision-making processes take into account these local forms of expertise, which constitutes remains "largely a hidden and untapped resource for understanding the complicated, shifting connections between human behaviour and environmental conditions" (Bowerbank, 1997, p. 28). Citizens are actively involved in the construction of the facts concerning the water, health, and environment in the area covered by Salina Point. Science in this case is not clean but tied up with the economics of the situation, the costs of the varying solutions (status quo, constructing water main, trucking, recycling wastewater) and the different ways of covering the costs (Salina Point residents, Oceanside residents). We may ask, what can science education do to support the making of concerned and involved citizens?

Citizenship and Science Education

In the past, science education, scientific literacy and science curriculum have been theorized from the perspective of an asocial and fictional view of the sciences. Given the substantial disaffection with the sciences among students and the problematic nature of scientists' contributions to the problems of the world, this approach to science education has to be questioned. Here, we propose to take the notions of citizenship and inclusive democracy as starting points for theorizing science education. In other words, we want science education to contribute to citizenship and inclusive democracy rather than being a selection mechanism for the formation of a scientific elite (e.g., Brookhart Costa, 1993) operating within the citadel that towers over the public.

Science and scientific productions (facts, theories) used to be the exclusive domain of discipline-based experts. However, science and its productions have not only become open to discussion in socio-political arenas but cannot reasonably be thought as pure forms separate from economy, politics, ethics. The old idea of the appeal to facts and their interpretation by accredited experts has been eroded by the increasingly obvious limitations of experts and expert knowledge in resolving issues of public controversy (Berlan & Lewontin, 1998; Martin & Richards, 1995). With this realization, the role of the active citizen, who participates in policy-setting and decision-making processes, has taken on increasing importance. Becoming scientifically and technologically literate cannot mean the acquisition of some definitely acquired and definite skill but is akin to acquiring "a certain autonomy," "a certain capacity to communicate," "coping with specific situations," and "negotiating over outcomes" (Fourez, 1997, p. 906). This, so Fourez, requires the construction of "interdisciplinary rationality islands" that are useful when people make decisions about unique and distinct situations and make use of knowledge that derives from many disciplines and from the know-how of everyday life. The question therefore is not to think citizenship from the disciplinary perspective of science education, but to think science education from the perspective of citizenship. What can science education contribute to the more general project of educating the engaged and responsible citizen?

What kinds of activity prepare scientifically literate and engaged citizens?

In recent years, researchers from sociocultural perspectives on cognition suggested that activities designed for students to appropriate practices (Rogoff, 1995) have to be authentic in as much as they are "ordinary practices of the culture" (Brown *et al*., 1989, p. 34). Authenticity, according to activity theory, arises from a match between individual and societal motives characteristic of an activity (Roth, 2002). Yet authenticity is also often being defined in terms of the family resemblance between the practices of professionals in a target domain, scientists or mathematicians. But, given that the overwhelming majority of students will never become scientist or mathematician, using these professional practices as priority referents for thinking about the curriculum appears to be inappropriate.

In our public hearing, the citizens were engaged in authentic activity. There was a direct concern for the citizens involved—the outcome of the decisions to be taken would have direct bearing on their lives and that of the community, not the least being who pays how much for the solution to the water problem. Rather than passively accepting their fate, however, the residents of Salina Point actively interrogated scientists, science and scientific method. Science educators might think that modeling such events constitute suitable contexts for learning science. For example, in one teaching model, students are provided "with experiences in thoughtful decision-making on controversial socio-scientific issues" (Kolstoe, 2000, p. 645). Yet in our view, this approach limits what students learn for there are no stakes and consequences in whatever decisions are made. However, in an authentic activity the stakes and investments made by the subject considerably shapes the situation, both what is salient figure and what is considered the ground. Thus, the level of expertise in dealing with school case studies does not predict the level of expertise in real situations of which the cases are said to be models.

From the perspective of cultural-historical activity theory, society and culture mediate the motive of activity (Engeström, 1999; Leont'ev, 1978). But when the individual subject who enters a relation with the activity-defining object of activity does not subscribe to the motive, there then exists a hiatus and sometimes a contradiction. These disruptions in the narrative lead to "work-arounds" in the sense that the motive of the activity is subverted. For example, middle-class students adapt their language and motive to that of the school (e.g., Eckert, 1989) and thereby successfully enter into a reproductive cycle of the middle class. Working-class students, on the other hand, often engage in actions that are inconsistent with the motive underlying schooling, are not successful, and thereby contribute to the reproduction of the working class (Bourdieu, 1994; Willis, 1977). Thus, if school activity is to be authentic, the activity has to be legitimate both at the societal as at the individual level. As a consequence, participating in "authentic" activity leads to the development of knowledgeability—rather than the (short-term) storage of isolated facts. Knowledgeability, knowing one's way around the world more generally, is routinely in a state of change and is central to the identity of the subject who participates in the activity (Lave, 1993). Knowledgeability is related to the identity of a person—which, for a particular student, may lie to a greater extent in his competencies on the skateboard rather than in factoring polynomials. Routine collective (authentic) activity includes as much the production of failure as the production of average, ordinary knowledgeability. Knowledgeability and authenticity are linked to the notion of legitimate peripheral participation (Lave & Wenger, 1991). Both knowledgeability and authenticity are achieved when people participate in ongoing activity, which derives its motive from a larger collective, but their participation is at a level matched to the existing competencies of the individual. Authentic activity therefore leads us straight into community, society and participation in inclusive democracy.

These ideas also extend to science education as a lifelong and informal endeavor. Thus, the citizens did not only participate in the public hearing, but also set themselves up for changing their participation in subsequent events. Changing participation in a changing world is equivalent to learning (Lave, 1993). That is, the very participation in the public hearing provides opportunities for lifelong learning and informal science education. Participation in community affairs, as some studies have shown (e.g., Roth, 2002), provides students with similar opportunities to learn and take control over the life conditions.

Why go into the community?

If we were to take a simplistic approach and ask students to enact a public hearing about a pressing water issue in their community, they would still do this in the context of schooling. The outcome of their debate would not have any bearing on their community but simply be another school-related activity. The activity would be inauthentic. However, if students were to engage in activities that directly contribute to community life, that is, if they were to enact citizenship in practice, they also contribute to their development as citizen. Their activity would be authentic. That is, paraphrasing Hodson (1999) we argue that the value of science education should be discussed in terms of its potential to engage students in a politicized ethic of care, the degree to which it allows students to become actively involved in local manifestations of particular problems, and their knowledgeability with respect to resolving conflicts of interest.

The individuals who questioned Lowell, the engineer and professional geologist, enacted average knowledgeability that is not likely to be achieved by doing more of the same that students currently receive in many science classes. Hays, Naught, and the other individuals questioned the very scientific methodology that was employed by Lowell and provided evidence that there were flaws in what the expert had done. A simulacrum of a public hearing staged as part of a science class, is but another school activity. While it may be different and more interesting than what has been done before it still does not contribute to the life of the community. The activities and their outcomes have no consequences to anything than classroom life—unless, as happens in a few cases, a student is inspired and takes the school activity as a starting point for a greater and deeper involvement in related issues outside schools.

The literature on situated cognition can be used in support of this notion of authenticity. In the past decade, much has been learned about the situated nature of cognition. Some of the research conducted in mathematics in school and at work (dairy factory, street markets) shows that schooling contributes very little to the nature of mathematical competence outside schools (Lave, 1988; Saxe, 1991). Similarly, despite their high school physics classes, many physics and engineering students talk about motion phenomena in ways incompatible with standard physics (Clement, 1982). Yet the high grades these students had received appeared to affirm that they had learned standard physics. There are only tenuous relationships between students' expertise on school-related tasks and their competencies on problems as they arise from everyday contexts after school. Such findings therefore question the assumption that school activities directly prepare students for activities after they have left high schools. The schooling experience makes students good at being successful in school-related tasks but do not necessarily make them more successful than unschooled individuals on tasks normally encountered outside schools.[3]

Thus, if individuals get good at what they do for a considerable amount of time and if the objective of education is to assist students in becoming active citizens with a critical stance to all sorts of knowledge claims, then students should already participate as citizens in the affairs of the community.

The case has been made that "Learning is not in the head of people but in the relations between people" and that "learning does not belong to individual persons, but to the various conversations of which they are part" (McDermott, 1993, p. 292). Scientific literacy is therefore not something that is acquired by the child and then carried around into other settings, or carried into the life after school. Scientific literacy, as citizenship, belongs, to paraphrase McDermott, to the various conversations of which people are part. It is not so much that Lowell, Hays, and Naught are scientifically literate, each in his own way, but that the situation of the public hearing allowed *scientific literacy to emerge as a recognizable and analyzable feature of human interaction*.

[3] We do not deny that students develop knowledgeability in their current science classes. However, this knowledgeability relates to being successful in school science and the tasks students encounter there. It also relates to being successful at the university. As the comments of many employers we have been talking to attest, many graduates are unprepared for what waits for them in the workplace.

Does everyone have to achieve according to a particular predetermined norm?

In schools, norms encapsulated in curricular objectives such as “students will be able to state that water is a basic constituent of life,” because they make statements about all individuals irrespective of social location, contribute to the production of failure. Here, those students who do not produce particular statements in situations where they are cut off all of the resources that are normally available to them are constructed as lesser or as failures in the attempt to make them scientifically literate. Equal competencies are not the norm in everyday life—furthermore, different individuals contribute in their own ways to make events recognizable for what they are. For example, those present in the public hearing participated in different ways. Some actively asked questions or interrogated a presenter. Others provided their perspectives and evidence from their daily lives that made salient the problematic nature of well water in the area. Yet others simply listened or provided supportive “yeahs” and applause. These participants are not to be taken as scientifically illiterate but as important participants in the context that allowed scientific literacy to occur. Every one contributed to make this event recognizable as a public hearing, which led to the emergence of scientific literacy. It is the very context of a public hearing, which include speakers, moderator, and audience, experts and lay people, individuals with stakes in the outcome and ‘impartial’ consultants that makes visible and thereby allows the identification of scientific literacy. Paraphrasing McDermott (1993), we might say that everyone was part of the choreography of a public hearing that produces moments for the public appearance of scientific literacy and citizenship. Potential problems in Lowell’s methodology, and therefore the fact that scientific expertise can be questioned, were produced in this hearing as much as the cunning abilities attributed to individuals such as Hays and Naught to expose these problems. The applause and supportive utterances, which contributed to making visible problems and cunning abilities, were as much part of the production of the public hearing as the questions and responses and therefore the very phenomenon of scientific literacy and engaged citizenship exhibited.

Citizenship is often mentioned in connection with the necessity of science, technology, and economy to live in today’s society (e.g., Brown & Michael, 2001; Fotopoulos, 1999b). However, almost all science and even science-technology-society courses take an approach where what students do in the classroom *should be* applicable to their immediate and future lives rather than being immediately part of it. Furthermore, in actual practice, courses that are designed for students to make connections between science, technology, and society are intended for those students who have difficulties mastering technical material, that is, scientific concepts as treated in textbooks, and mathematics. We believe that this aspect of science education has to be rethought as well.

Teaching for citizenship and scientific literacy as praxis has the potential to challenge traditional separations in the school curriculum that relegates science into science, technology, mathematics, and social studies into separate classrooms, each concerned with the subject in a more or less pure form. Not every science educator will be comfortable with that because treating science as but one of the many different strands that make everyday life threatens existing aspirations of science, scientists, and science educators to have a privileged status in society. However, studies of science in everyday life show that it is intertwined with economics, politics, power, and values more generally. Science in society as enacted by citizens cannot be separated neatly and cleanly from the other subjects. Rather, central concerns and motives govern activities and people (scientists and non-scientists alike) draw on the resources that they deem to be most appropriate in the situation. We believe that the time is right to rethink science education and scientific literacy—we propose here to do this by positing citizenship and inclusive democracy and to teach science accordingly.

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