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ABSTRACT

A central fallacy of traditional science education is its focus on laboratory science as the touchstone against which science teaching and learning should be compared. This approach teaches students to see the world with the eyes of science rather than to build their own view of the world; it favors students becoming conformist rather than autonomous. As a consequence, the needs of diverse groups of people--except white middle-class males--have not been met, leading to their exclusion from science. A study examined science education in a coastal British Columbia town where an environmental activist group, grade 7 students, and community members were documenting water quality in a local creek. Units were designed so that students could pursue questions of their own interests and use tools of their own choice. It was found that with such an approach, the disinterest and exclusion characteristic of traditional science courses did not become an issue and that what had been considered learning disabilities in some students did not become visible. Students learned science while participating in a community effort to learn about their creek. In this way, science education provided a starting point for uninterrupted life-long learning across the boundary of formal schooling. Science educators would do well to set up situations that allow a variety of participatory modes, more consistent with a democratic approach in which people make decisions about their own lives and interests. (Contains 57 references) (TD)

Rethinking Scientific Literacy: From Science Education as Propaedeutic to Participation in the Community

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ABSTRACT: In this article, we propose a radical redefinition of scientific literacy. Based on our three-year multi-site ethnographic research project, we propose scientific literacy to be characteristic of situations rather than an attribute of individuals. Framing our work in terms of activity theory, we provide descriptions of science as it is lived in the community. We also report on our research in a local school, where students learn science while participating in a community effort to contribute to the knowledge base about a local creek. The children's activities are continuous with those of adults concerned about environmental health. In this way, rather than preparing for life after school, science education allows students to participate in legitimate ways in community life and therefore provides a starting point for uninterrupted life-long learning across the boundary of formal schooling.

The means of pursuing scientific literacy suggested by current reforms do not seem to anticipate diverse groups of people who put science to use in broader, different, or socially responsible ways. (Eisenhart, Finkel, & Marion, 1996, p. 281)

Do we teach biology, chemistry, physics, mathematics or do we teach young people to cope with their own world? (Fourez, 1997, p. 907)

The concept of "scientific literacy" plays a central role in recent reform efforts in science education (AAAS, 1989; NRC, 1996). Science educators generally agree that general scientific literacy should be an important outcome of schooling. But despite its nearly 50-year history, scientific literacy has eschewed a precise or agreed-upon definition (DeBoer, 2000). One of the fathers of science education suggested that "a valid interpretation of scientific literacy must be consistent with the prevailing image of science and the revolutionary changes taking place in our society" (Hurd, 1998). For many, this has meant using the image of laboratory science as a template for what "science" is, independent of the epistemological paradigm brought to science education reform. Science courses are often a means of pushing students into the world of scientists rather than a way of helping them cope with their own lifeworlds (Fourez, 1997). As a consequence, as Eisenhart et al. (1996) point out in the opening quote, the needs of diverse groups of people—except white middle-class males—have not been met, leading to, by and large, their exclusion from science. Despite tremendous efforts, some argue that educational reforms have for the most part failed to produce scientifically literate citizens (Shamos, 1995).

Scholarly discussions of scientific literacy are often based on three generally unstated (and perhaps unfounded) assumptions: scientific literacy is an attribute of individuals, science is the paradigmatic mode for rational human conduct, and school knowledge is transportable to life after school. These assumptions lead science educators to ponder (a) how individuals can be made to appropriate (internalize) or construct specific scientific concepts, (b) what science content to teach, and (c) how to make students transfer science to out-of-school situations. In this paper, we propose to decenter the focus of scholarly debate by considering three alternative assumptions. First, scientific literacy is a property of collective situations and characterizes interactions irreducible to characteristics of individuals. Second, science is not a single normative framework for rationality but merely one of many resources that people can draw on in everyday collective decision-making processes. Third, students learn by participating in activities that are meaningful because they contribute to their community as a whole.

We begin our argument by articulating some of the core issues involving the concept of scientific literacy and by introducing a theoretical framework (activity theory) that is ideally suited to conceptualize, study, and compare human activities. Based on data from a three-year ethnographic study of environmental activists and the watershed-related activities and practices of various related groups, we then provide descriptions of science and scientific literacy in the life of one community. We continue by describing science and scientific literacy as they emerge from the activities of grade-7 children who seek to contribute to their community's knowledge about a local creek. We conclude this paper by reflecting on the similarities and differences between adult- and student-activities and by drawing implications for science education arising from our work.

Scientific Literacy

There is no doubt that since its introduction, the notion of scientific literacy has played an important role in defining the science education reform agendas. Reform projects and conceptual change research in science education "consistently define scientific knowledge in terms of 'concepts, principles, theories, and models that are important for all students to know, understand, and use in the fields or disciplines of science'" (O. Lee, 1999, p. 189). The need for a general scientific and technological literacy is often based on the argument that an effective workforce participation in the 21st century requires a certain amount of scientific knowledge (Hazen & Trefil, 1991; O. Lee & Fradd, 1996). As a result, the reform agendas focused on a general (for *all*) scientific literacy as an important goal to be achieved meeting (e.g., AAAS, 1989). Despite the rhetoric of scientific literacy for *all* students, science in schools remains virtually unchanged; students are confronted with basic facts and theories (Eisenhart et al., 1996). The standards of warrants for science knowledge claims often differ dramatically from the standards characteristic of First Nations people, residing in the authority of the cultural historical developments of oral teachings, or of women, who may approach science with "a feeling for the organism" (e.g., Keller, 1983). That is, the poor, people of color, and women may fail in school science exactly because of the nature of science practices and forms of knowing that are stressed in teaching (Rodriguez, 1998). Not surprisingly, science discourages minorities (e.g., African Americans, First Nations) and women because its ways of knowing and everyday practices privilege White middle-class and male standpoints (Eisenhart et al., 1996; Tobin, Seiler, & Walls, 1999). The pursuit of scientific literacy promoted by recent national agendas does little to address the diverse audiences, many of which have been squeezed out of science in traditional approaches.

Not everyone agrees that science could or should be for all, which is our own position. Some scientists are blatantly opposed to the possibility of a general scientific literacy, pointing out that science is an elitist calling and that "raw intelligence and special skills that far exceed what is to be expected of the average person" are required to attain it" (Levitt, 1999, p. 4). It may also be that making scientific literacy available to *all* poses a threat to the hegemony of scientific expertise in everyday affairs. Science for all is a threat because it is based on the "potentially counterhegemonic principle of equality" (Eisenhart et al., 1996, p. 271). In this article, we not only subscribe to the ideal that science is for all but we also propose that "science," "scientific literacy," and their role in society have to be redefined.

Although the debate over scientific literacy has been long and ongoing, there remains at least one fundamental assumption that has never been questioned: Scientific literacy is a property of individuals and can therefore be measured by means of traditional forms of individual assessment. Thus, the debate over scientific literacy focuses on knowledge, facts, and theories that individuals are expected to exhibit:

> To acquire information necessary for scientific literacy, individuals must comprehend, interpret, and evaluation information and conclusions based on scientific research. (Korpan, Bisanz, Bisanz, & Henderson, 1997, p. 516)
>
> It is generally agreed that a science-literate individual possesses a basic vocabulary of scientific concepts and terms, knowledge of the processes of science utilized to test our models for making sense of the world, and an appreciation of the effect of science and technology on society, to a degree sufficient to participate in dealing with the increasingly large number of science- and technology-laden public policy questions we face. (Flower, 2000, p. 38)

The notion of scientific literacy as the content of individual minds (episodic and semantic memory) is clearly illustrated, for example, in research that tests how much visitors recall from a museum visit (Medved & Oatley, 2000). Eisenhart et al. take up three metaphors for literacy previously proposed by Sylvie Scribner (1986): literacy as adaptation (proficiencies necessary for effective performance), literacy as power (enabling people to claim places in the world), and literacy as a state of grace (self-enhancing potential of literacy). Although these metaphors expand the traditionally rather narrow view on the topic, we propose that they do not go far enough.

Studies in public understanding of science construct an image of the interaction between scientists and non-scientists that is much more complex, dynamic, and interactive than the traditional opposition between "scientific expertise" and ignorance and rejection of scientific knowledge may lead us to believe (e.g., Irwin & Wynne, 1996). In the everyday world of a community, science emerges not as a coherent, objective, and unproblematic body of knowledge and practices. Rather, science often turns out to be uncertain and contentious, and unable to answer important questions pertaining to the specific (local) issues at hand (Jenkins, 1999). In everyday situations citizen thinking may offer a more comprehensive and effective basis for action than scientific thinking (Lee & Roth, 2001).

We therefore propose to thinking about scientific literacy in terms of "citizen science," which is "a form of science that relates in reflexive ways to the concerns, interests and activities of citizens as they go about their everyday business" (Jenkins, 1999, p. 704). In our research, citizen science was related to a variety of contexts, ranging from personal matters (e.g., accessibility to safe drinking water), livelihood (e.g., best farming practices), leisure (e.g., gardening in sustainable, organic ways), to activism or organized protest (e.g., S. Lee & Roth, in press). In contrast to the current ideology of scientific literacy as a property of individuals, we further propose to think about it as a characteristic of certain everyday situations in which citizen science occurs. This implies that science educators no longer seek to stack educational environments to coax individuals into certain performances, but that they would set up situations that allow a variety of participatory modes, more consistent with a democratic approach in which people make decisions about their own lives and interests.

Activity Theory

In most theories of human knowing, individual action is the central unit of analysis. However, these theories have difficulties accounting for the distributed and situated nature of knowing and learning and for the nature of human activity as mediated by artifacts and culture (Engeström, 1999). These theories also fail to address the "continuous, self-reproducing, systemic, and longitudinal-historical aspects of human functioning" (p. 22). In this study, we use activity theory (Engeström, 1987; Leont'ev, 1978) to frame the water- and watershed-related activities of adults and grade-7 science students.

Theories are based on a basic ontology, that is, a set of fundamental entities that define the domain. In activity theory, there are six such basic entities: human subjects (individuals or groups), objects (artifacts or motivations), tools, rules, community, and division of labor (Figure 1). In activity theory, activities constitute the unit of analysis; because activities involve more than one person and in fact entire communities, they are theorized as systems. Activity systems are defined and motivated by the relationship between individuals or groups (subject) and the primary object. For example, the grade-7 students in our studies decided to make Henderson Creek the *object* of their inquiry and to make facts and knowledge (*outcomes*) available to their community by contributing to an open-house event. Relations between the different activity-system constitutive entities are never direct; rather, all relations are theorized as being mediated by other entities. For example, the *tools* used by particular student research groups (*subject*) mediated their relation to Henderson Creek (*object*) leading to quite different knowledge facts (representations) of the creek (*outcomes*). Doing speed measurements and correlating these to animal species frequencies lead to different *outcomes* than audiotaped journalistic descriptions accompanied by photographs. To use another example from our research: the children's choice to focus on Henderson Creek was mediated by the *community* in the sense that the children responded to the call, published in a local newspaper, by an environmental activist group to contribute to the existing knowledge about the creek. Two further entities that are considered by activity theory are *rules* and *division of labor*. Rules, for example, include those that mediate the relationship between individuals and members of the community or those that govern tool-use within specific communities. Division of labor may refer to the different roles that students take within their research groups or the roles of teachers, parents, and other community members.

An important aspect of this theory is its endeavor to understand activity systems as historically constituted systems. That is, an activity system cannot be understood without an understanding its historical evolution and the cultural context that allowed it to emerge. Similarly, the identity of the subject (individual or group) is a function of all the mediated relations that operate in the activity system (Lave, 1993). Thus, the problem of environmental health that motivates the activities described in our study cannot be really understood without studying the historical changes that turned the area from tribal hunting and gathering grounds to a farming community, increasingly under pressure from the expansion of the urban communities.

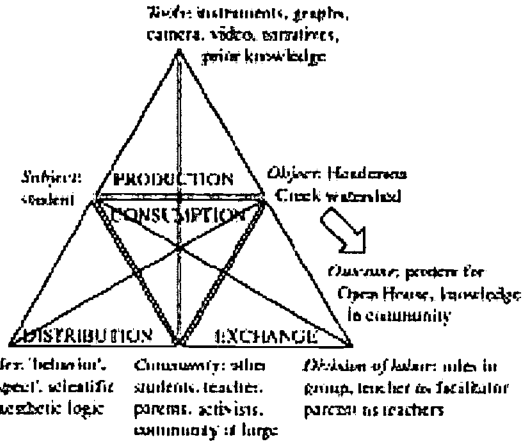

Figure 1. Activity theoretical model of grade-7 science student's activity in the community. Each possible triangle indicates a mediated relation that provides context for the activity and without which activity cannot be understood.

In activity theory, agency, knowing, and learning are not thought to be properties of individuals but are understood in terms of situated and distributed "engagement in changing processes of human activity" (Lave, 1993, p. 12). Furthermore, individual agency, knowing, and learning are understood to be subsets of generalized agency, knowing, and learning available to society (Holzkamp, 1991). That is, human activities, such as conversations, are irreducibly social phenomena that cannot be understood as the sum of the contributions of individuals. McDermott (1993) proposed the analogy of thread and the fibers that it is made of. Thus, in the thread of society, each human being is but a fiber. Although made up of fibers, the properties of the thread cannot be derived from the properties of each fiber. Furthermore, the properties of the fiber cannot be derived from the thread. There is therefore a dialectic tension between the nature of fiber and thread—and by analogy, between individual human beings and the society of which they are part.

In our analyses we understand (necessarily collective) activities and interactions, such as a public meeting, in terms of fibers and threads. A collective activity is analogous to the thread and individual contributions are no more than the individual fibers. Thus, scientific literacy can be thought of as something achieved by a group rather than as a property of individuals. Based on previous work relating to (democratic) science in the community (Lee & Roth, in press), we extend the analogy of thread and its fibers in a second way. In everyday collective endeavors over contentious issues, science is but a fiber along many other fibers such as politics, economics, aesthetics, sociology, philosophy, or everyday know-how. It is only through inter- and multi-disciplinary approaches that the increasingly difficult problems in an ever-more complex society can be solved in a satisfactory manner (Fourez, 1997; Maxwell, 1992).

Research Design

Our study takes place in the Henderson Creek watershed and in Oceanside, the community that lies within this small coastal watershed in the Pacific Northwest.[1] Henderson Creek drains the north end of the watershed, Gordon Creek the south, and they meet in a valley, forming the main

[1] We use pseudonyms throughout this article for place names and individuals other than ourselves. Only the general name for the First Nations people, the WSÁNEC', consisting of several communities, has been maintained.

stem of Henderson Creek, which then flows west, into the Pacific Ocean. The watershed is located about twenty-five kilometres from the centre of a mid-sized city that continues to expand, pushing suburbia into the rural and agricultural landscapes. We have now completed three years of ethnographic research in one community. Our research was generally focused on the role of science in a variety of settings within the community. Specifically, we were interested in science as it related to the activities of the Henderson Creek Project, an environmental activist group, and in science done by grade-7 students whose aim was to contribute to the existing knowledge about Henderson Creek.

Water Problems in the Community

In Oceanside, water has always been a problem. The climate has long favored hot dry summers and wet winters, with concomitant shortages and excesses of water available to the European residents, recent developments have exacerbated the issue by altering the water's flow over and through the ground. During many summers, insufficient water supply requires the community to limit the amount available to residents. Other residents, with individual wells that draw on the local aquifers, have found their water biologically and chemically contaminated and sometimes have to get their water from a gas station about 5 kilometers away. Water is shed much more quickly and The decline in water quality and the extremes of water levels (high in the winter and low in the summer) is in part due to changes in water movement across the land and through the ground. These changes are related to urbanization and the increase in impervious surfaces (pavement), straightening of the creek, loss of forest cover throughout the watershed and along the stream banks, loss of wetlands and recharge areas, and the loss of natural stream conditions.

The creek system within the watershed has been affected by human activity. There are small clusters of suburban development interspersed with the farmers' fields. Storm drains and ditches channel rainwater—along with the pollutants of suburbia, lawn chemicals and car leakage—into Henderson Creek and its tributaries and away from these newly developed areas. The municipality of Oceanside introduced an industrial park to the watershed, which is carefully contained within a four-block boundary. The drains of its machine shops and biotechnology labs empty into a ditch (affectionately called "stinky ditch"), which in turn, empties into Henderson Creek. To increase its potential to carry away water in a rapid manner, the creek itself has been deepened and straightened, and much of the covering vegetation has been removed, thereby increasing erosion and pollution from the surrounding farmers' fields. These physical changes have led to increased erosion and silt load in the wet winter months, and are responsible for low water levels and high water temperatures during the dry summer months when (legal and illegal) pumping for irrigation purposes taxes the creek.

The Henderson Creek Project

The Henderson Creek Project arose from the concerns about water quality of three watershed residents, a farmer, professor of environmental policy at the local university, and a research scientist working at a nearby lab, who obtained funding from a federal agency concerned with stream restoration. The Henderson Creek Project, headed by a coordinator and a 5–7 member steering committee, enlists the support of many other people (e.g., hired high school and university students doing summer jobs) and institutions within the region. The activists believe that they are working in and against an adverse political climate. The interests of farmers, industry, and other landowners are often opposed to those that motivate the activists. Since most of the land in the municipality is private, the activists feel that building and maintaining good relationships with everyone they possibly can is paramount to their success in bringing about desired changes.

Curriculum

In an earlier study, we had encouraged science educators to involve their students in ways that allow them to develop a keen appreciation of the places where science and technology articulate smoothly with one's experience of life (McGinn & Roth, 1999). Given the water-related problems in Oceanside, it was not difficult to convince teachers to participate in a study where students would learn science by investigating the Henderson Creek watershed. Over the past two years, we have assisted in the teaching of science to three grade-7 classes over two- to four-month periods. In these classes, students design and conduct their own research in and along Henderson Creek with the intent to report their findings at an open-house event organized each year by the Henderson Creek Project. The underlying idea in these science classes is to get students to become active citizens and to contribute to the knowledge available in and to the community. Other students at the middle and high school also conduct research in the watershed as part of their involvement in regionally funded "Streamkeepers" program or in science fair competitions. In this way, students already participate in creating knowledge available to the their community and the activists. Members of the Henderson Creek Project, the authors, parents, and First Nations elders contribute in various ways to the teaching of the children by providing workshops, talks, and assisting them in framing research and collecting data.

When we began our project in school science classrooms, we still believed that all students should engage in their activities in ways that would foster scientific practices. That is, our model for school science was influenced by the science of scientists. However, we soon realized that requiring all students to measure series of variables, and to represent correlations in the form of Cartesian graphs or histograms excluded particular groups of students such as girls and indigenous students. While these students still participated in the data collection, the subsequent data analyses and activities that focused on mathematical representations generally turned them off. Taking our lead from other activities in the community, where different representational forms were legitimately used, we began to encourage students to investigate on their own terms, choosing their data collection and representational tools that best fit their interests and needs. Audio-recorded descriptions, videotaped records of the watershed and student activities, photographs, drawings, and other representations began to proliferate. This change provided forms of knowing and learning that led to an increasing participation of previously excluded students. It also meant that we had to abandon our traditional conception of what science and science education might look like in the community. Ultimately, the children presented the results of their work at a yearly open-house event organized by the activists focusing on environmental health in the Henderson Creek watershed.

In this school, there a substantial number of students are designated as having "special needs" (the school receives funds for special instruction). For example, in one of the classes we taught there were 27 students (15 male, 12 female), five of whom designated as "special needs students" (LD) and four were from the local First Nations band. In the course of our three-year study, we observed that a considerable number of aboriginal students appeared uninvolved, resigned, and often achieved low grades. We had been invited to conduct a workshop in a summer science camp for aboriginal children normally taught by aboriginal people, we were able to see a drastic difference in the involvement of the same children when activities were framed in their native context.[2] At the grade-7 level, the students were often far apart developmentally, some boys and girls having more the appearance of young adults (about 6 feet tall), others looking more like grade 5 students.

Parents, activists, aboriginal elders, scientists, graduate students, and other community members were an integral part of the science units. For example, every other week the classes spent one entire afternoon (noon – 2:30 p.m.) in and around the creek. Parents assisted both in driving children to the different sites along the creek and participated in teaching by asking productive questions, scaffolding, and supervising children. Members from the environmental activist group also contributed giving presentations, assisting in teaching kids how to use particular tools and how to do research in the creek, and in analyzing data and organisms brought back to the classroom. Students from classes that had already completed or were near completion of their unit talked about their work in another class that was just beginning, and assisted their peers during fieldwork and data analysis.

This involvement of community members therefore integrated the children's activities with activities in the community in two ways. First, the community came to the school, assisting students and teachers in their activities. Second, the student activities were concerned with a pressing issue of the community; the science lessons took children out of the school and into the community. That is, the children's activities were motivated by the same concerns that drove the activities of other community members. In terms of our activity theoretic model (Figure 1), there is therefore legitimate (peripheral) participation because the motivation that drives the activity system share many elements.[3] It is this overlap with the activity system characterizing everyday life in the community (motivation, subjects [community], and tools) that makes the children's work "authentic." Rather than preparing for a life after school or for future science courses, children participated in and contributed to social life in the community. It is in the process that learning—belonging to the various conversations of which individual persons are part (McDermott)—was occurring.

Researchers

We observe and understand the events in Oceanside, the Henderson Creek Project, and at Oceanside Middle School from different positions and points of view. One of us (Stuart Lee) conducts participant-observation from the inside of the Henderson Creek Project. Both a former research scientist with a master's degree in biochemistry and a former volunteer and worker with a number of environmental organizations, he is a long time acquaintance of and co-campaigner with the coordinator of the Henderson Creek Project. He volunteers with the Project, attends steering committee meetings, and assists in organizing open houses and restoration activities. He also participates in creek restoration activities, co-writes grant proposals, designs stewardship

[2] Aboriginal students have a choice to attend a local tribal school or to attend the public middle school. About 10% of the municipality's student population have First Nations status.

[3] It is true, students also enjoyed the science unit because it broke them out of the strict routine and control imposed upon them within the school building.

packages, and advises on the subject of scientific strategy in an ongoing water use controversy. Stuart also works on a book representing the watershed, its history and environment and potential options for the future. The other author (Wolff-Michael Roth) lives in the community, where he also works with teachers at local middle and high schools interested in environmental issues. He does not only plan lessons with the teachers, but actively teaches alongside (at the elbow of) the regular teacher within a coteaching model (Roth, Masciotra, & Boyd, 1999).

Each in our own way, we are activists who believe that our participation can make a difference in the community, and therefore believe in the fundamentally human power to shape its lifeworld rather than simply being constrained, or worse, determined by it. We believe that we cannot stand on the political sidelines and pretend to write our object through an impartial narrative. This approach is consistent with the subject-centered research methodology advocated by critical psychology, a variant of activity theory that focus on the societally mediated nature of human agency (Holzkamp, 1991b).

Data Sources

The data sources we collect include extensive field notes, publications produced and appropriated by the activists, videotapes of public events, audio-taped interviews, newspaper clippings, informal interviews, and texts and inscriptions from the region that relate to the issues of watershed management and ecological restoration. On several occasions, we videotaped groups of activists and other interested local residents who walked sections of Henderson Creek with different consultants. The activists drew on these consultants for advice on how to improve the creek, find the best trout habitat, and how to expand the healthier sections of the creek. We used two cameras to videotape all classroom instruction—having obtained the equivalent of one entire school year of science instruction, spread over three classes. We interviewed a range of participants in the Henderson Creek Project, students, and local residents—all interviews were audio- or videotaped.

Interpretation

Our analyses, grounded in semiotics and hermeneutic phenomenology, are based on the assumption that reasoning is observable in the form of socially structured and embodied activity (Garfinkel, 1991). In our analyses, videotapes, transcripts, and artifacts produced by the observed individuals are natural protocols of their efforts in making sense of, and imposing structure on, their activities. Following those who treat culture, particularly local knowledge (Geertz, 1983), and action (Ricœur, 1991) as texts, these protocols constituted our texts that we then elaborated in analyses.

We began by independently reading transcripts and viewed videotaped lessons, public events, and interviews before meeting for collaborative analysis. We subsequently conducted extensive collaborative analyses. For example, in the analysis of videotapes, replay was stopped whenever one of us thought a significant event had occurred. This person then stated an assertion before the event was reviewed as often as necessary for a full exploration by both researchers. We then reviewed other episodes to check the degree to which they confirmed or disconfirmed the assertion. On the basis of these checks, we reformulated initial assertions until they were representative of the data. We then discussed personal constructions, subjected them to critique and analysis, and tested them in the entire data set to evaluate fit and plausibility. In a similar way, we conducted independent and collaborative analyses of transcripts. The understandings reported here emerged from many such iterative processes of engagement with the data sources.

In our analyses, we follow conversation analysts who take conversations as irreducibly social phenomena that cannot be understood as the sum-total of individual contributions (ten Have, 1999). Thus, we analyze conversations by thinking of them, consistent with our theoretical framework, as threads that cannot be understood by adding the properties of individual fibers.

Science and Scientific Literacy in the Community

The nature of science and scientific knowledge are usually described and defined in terms of what happens in scientific laboratories, as defined by those that inhabit them and the philosophers who described scientific processes in terms of scientists' publications. School science has not changed significantly in response to more recent research that shows science and scientific knowledge as the outcome of social processes: science educators still want students to learn about scientists' science. The image of the social construction of knowledge is fine as long as students learn it in its authorized form. Although most educators have become sensitive to the damage that cultural and social, hegemonic domination of one culture does to another, science educators and reform agendas continue to adhere to ideal that one sub-culturally specific form of knowing, one form of literacy, is appropriate for all citizens ("science for all"). That is, the characteristics of one fiber of social life (science) are proposed as the standard for all fibers.

For the past three years, we conducted extensive (ethnographic) research in a variety of settings within one community that struggles with issues around water. Some residents of Oceanside do not have access to water of sufficient quality or quantity to suffice their needs. Farmers are in continuous search of water during the summer, depleting groundwater levels and Henderson Creek, and cannot get the water-storm waters sufficiently fast of their fields in late winter and early spring. (In the past, farmers had damaged the health of Henderson Creek by straightening it to carry the water away faster.) The farmers also use fertilizers, some of which are washed into the creek, and cattle graze so close to Henderson Creek both damaging the shore and polluting the water. Although small in number, some local industry damage the creek by emptying their wastewater into a contributory affectionately called the "stinky ditch." The Henderson Creek Project, an environmental activist group, has the objective to bring about changes in Oceanside (shaping policy documents), residents' water-related practices (e.g., unhooking downspouts), and actively modifying Henderson Creek (by building water-oxygenating riffles or strengthening and planting riparian areas) to improve the health of the watershed. A First Nations community is also located in the watershed, but to date, its inhabitants have shown little interest in participating with the activists in restoring the creek, which historically had been a source of food and a spiritual resource.

As we researched a variety of events involving different members of the community, we came to understand that science is but a fiber in the thread of social life in the community. Even when scientists participated in an event, their contributions were interacting with those made from different epistemological positions, and therefore were but an aspect of the work by means of which groups and the entire community entered into conflict over its problems. Our activity theoretic framework makes it quite clear that Henderson Creek shows up in different activity systems, which focus on different individuals or groups (*subjects*) and their tools; yet the representations, which are the results (*outcomes*) of the activities, are quite different (Table 1). Depending on the particular instances of mediating entities (tools, community, division of labor, rules), different discursive and inscriptional representations were produced and subsequently contributed to a variety of interactional forums (e.g., S. Lee & Roth, in press). Furthermore, the same individuals could participate in different activity systems or take different roles in the respective division of labor. As Table 1 shows, some of instruments (*tools*), such as the dissolved-oxygen meter and colorimeter, are used in different activity systems perhaps aspiring to the same standard uses (rules), but for different intentions.

Table 1
Different activity systems in the community and their relation to the Henderson Creek watershed

Subject	Object	Tools	Community	Rules	Division of Labor	Outcome(s)
Environmental activists [Meagan, Karen]	Henderson Creek	machinery, rocks, gravel, dissolved oxygen meter	Oceanside	ecological and hydrological dicta	director, voluntary,	healthier creek, and watershed; changed living practices
~	Henderson Creek	Forms, dissolved-oxygen meter, measuring tape, colorimeter	Activists within Oceanside	Accuracy, honesty, carefulness	Students with summer jobs	creek-bed profiles and cross-sections, habitat and water-quality assessments
Farmers	Fields	fertilizers, machines, Henderson Creek water	Oceanside	Maximizing yield, profits	farm hands, water technician	Crops, ability to live in a certain place a certain way, historical identity
~ environment-conscious Oceanside Farms, water technician [Karen]	Henderson Creek	Water monitor station, dissolved oxygen meter	Oceanside	Maximizing yield, protecting water license rights	Environment Canada technician	yearly water-level graphs, water throughput statistics
First Nations people	Cleansing	culture, language, Henderson Creek water	WSÁNEC' community, within Oceanside	respect for the land, respect for other people	chief, elders	Spirituality
Participants in public meeting	water supply	language, reports,	Salina Point residents, Oceanside	Critical discursive practices in a public forum	Scientists, Water Advisory Council, audience	information
~ Consulting engineer [Lowell]	Groundwater in wells	pH meter, colorimeter	Salina Point, Oceanside	"scientific methods" of sampling, analyzing	Lab technicians	Report: no biological contamination; some aesthetic values not achieved

In the following parts of this section, we describe five different situations that exhibit scientific literacy not as an individual but rather, a collective property. By using activity theory to foreground the emergent and interactive nature of each 'literate moment', we build a portrait of what 'citizen science' looks like as it is enacted.

Walking the Creek in Search of Suitable Trout Habitat

One of the central interests of the environmental activists is upgrading Henderson Creek to make it suitable as trout habitat. Suitable trout habitat has all the characteristics of a Pacific Northwest hydrologically healthy stream—meandering channel, plenty of large woody debris and boulders, overhanging vegetation, cool temperatures and high oxygen levels. Thus, restoring a creek to trout-bearing capacity is also a move to restore many of its other aspects to what they would be were the stream a healthy one. Before beginning this project, the steering committee of the Henderson Creek Project invited a consultant, Tom, to walk the stream with them and suggest rehabilitation strategies. Tom was a member of a group that restored another, near-by stream from a sorry state where there was no water, no habitat, and no fish, to one that had its own salmon run.[4]

Despite his experience, Tom did not attempt to dominate the conversation as the group walked several hundred meters along different parts of Henderson Creek. Tom pointed out that he was not a biologist, but someone with more than 15 years of experience working on another, nearby stream to restore it as a viable salmon habitat. During the conversation, Tom never claimed to be the all-knowing expert. Indeed, he answered some questions by suggesting the group consult other sources for their information.

Meagan: What is their lifecycle, Tom?
Tom: I don't know, you'll have to look it up. But certainly, there is two age classes of fish in here. Probably a bit more, there are probably a few big ones in here [pool] too.

During the walking of the creek in search of suitable trout habitat, expertise and scientific literacy was distributed across the group. Bob, one of the activists present to learn from Tom, had a Ph.D. in ecology and was a lecturer at the local university. Meagan, had a bachelors of science degree in environmental studies, was an experienced environmental activist and campaigner, and was the (paid) coordinator of the Henderson Creek Project. Sally worked on the steering committee of the Henderson Creek Project and took notes throughout the trip for constructing a report. Karen was also an activist in addition to her job as a (trained) water technician at Oceanside Farms. Geoffrey, as a local farmer, knew about farming practices and particularly about the impact cattle can have when they graze close to the creek.

Together, the group walked areas that could potentially be modified to allow the spawning of fish, and they looked at other spots where they were able to detect the presence of fry of different age classes. Tom pointed out particulars of each setting and explained what types of additions would change the existing stream into an ideal habitat for trout ("This is the right kind of stuff for them", "This is all good stuff for them"). Participants picked up bottles and plastic bags that were floating by or hanging in the brush.

Meagan: It is so clear today. Normally, it is so brown.
Bob: When there is a bit of fall of rain.

[4] Tom's knowledge about salmon was considered adequate for the group because both trout and salmon are fish of the salmonid family and share a number of habitat requirements.

Tom: The reason is because it is a bit of a steady, like that. But I don't think it is all that bad.
Michael: Do you think that there is enough oxygen for trout?
Tom: Well, it has got water in and water out. But that would be something interesting to do.
Meagan: We've been monitoring the O_2 levels in through here.
Bob: And its not bad?
Meagan: Well, up in through there, just after it comes through Oceanside Farms' dam it was, you did it the last time, about 10?
Karen: Yeah.
Meagan: But it gets down to about 5 when we come down towards that dam.
Tom: So if there was any fish in there, it would be more towards this [upper] end?
Meagan: Yeah.
Tom: The temperature probably goes up down here too.
Bob: Despite of the overgrowth?
Meagan: Yeah.
Tom: I think this has more value just as it is.
Meagan: So you think that they could use this as habitat, but they couldn't spawn down here?
Tom: Oh, no, they wouldn't spawn down in here. There is not enough water supply, there is no gravel, and there is no water coming up through the gravel. But if there is larger fish, they could actually stay in this pool. You have cover over there, and there is lots of riparious stuff in there. I would just leave it.

In this conversation, the value of the stretch of creek emerges from the interaction of all utterances rather than from the analysis and assessment of a single (expert) individual. Bits of information emerge from the question-answer and comment-comment turns. For example, the creek is not only "normally brown," a comment invoking historical knowledge of the creek, but particularly when there is "a bit of rainfall." Oxygen levels have not only been monitored, but in the exchange involving Meagan, Bob, and Karen, specific levels between 5 and 10 (ppm) became available to the group as a whole. Meagan and Karen had measured these levels during the previous year using a dissolved-oxygen meter, an instrument that was also used by summer work-study and middle school students. Finally, the temperature of the creek in this reach does not just increase, but does so "despite of the overgrowth" (also "cover" or "riparious stuff") that shaded the spot where the group currently stands. In the final exchange between Tom and Meagan, the entire conversation concerned with the stretch became summarized in the assessment as a suitable trout habitat but not suitable as a spawning ground. Scientific literacy and expertise with respect to the assessment of the suitability of the reach as habitat and spawning ground was distributed across the individuals and situation.

Scientific Representations in the Community: Decentering Control

When someone in the respective audience decided to ask a question, the control over salient issues changed. We observed this change of control over scientific representation in different contexts, including the open-house event organized by the Henderson Creek Project. Although the scientists and, in the present example the water technician Karen, were still in control of the graphical display (qua experts), the settings to which the graph pointed were no longer under their control. What was relevant at the moment and how the information from the graph related to the world more broadly emerged from the interaction between the presenting person and the audience. The present episode had been recorded near the open-house exhibit that Karen used to introduce members of the community to the variations in the water quantity throughout the year. For this purpose, she had joined several rolls of graph paper from a water monitoring station and mounted them on the walls around the room. She guided visitors along the graph, explaining its features, and relating specific events (rainfall, opening of a dam) to the particular shape of the curve. In the following transcript, Karen had begun to point to a step-like change in the curve, explaining that on this day the people on her farm began to irrigate the field.

Karen: These very, you know, 90° angles in the lines, that's definitely straight, straight drops. That's definitely irrigation activity, people are all stopping at the same time, starting at the same time. Depending on the conditions, it's dry for a while here. *Points to the rainfall chart.*
Walter: Yeah, a lot of hay, people are into the hay and stuff.
Karen: Yeah, a lot of people cut it at the same time
Walter: Further, you go towards the Fox's farm, down Henderson Creek. Because once you get past Fox's, it stops. There is corn. But of course, nowadays, there is late corn, too.
Karen: Yeah, they grow different varieties.
Walter: I think they grow mostly early corn (*Gestures toward earlier parts of the graph*) on the fields that are around Henderson Creek.
Karen: Corn definitely has a lot, requires lots of water, doesn't it? Compared to hay.
Walter: Well, say, I guess, as you know, the structure of the material of the soil material in the valley is... So, like they say, it is the best place in the world to have septic fields. From the point of view of a person putting one in, not necessarily for the rest, if all they wanted was go down the first number of feet, they don't necessarily think what else I have to have in.
Karen: Yeah, they don't think beyond that.
Walter: That's right, but it's sort of a lot of sand, and coarse soil so it's...
Karen: A lot of clay in the valley.
Walter: It drains well. So, that's probably why they have to pump so much water here compared to over on Gordon Creek where Marie Flats are. I don't think that they have to pull that much...

As a whole, our recording shows that Karen wanted to move people through the exhibit rather quickly, explaining the (to her) salient parts of the entire chart, and move on to the next person. In this interaction, Walter's questions (like those of other people present) codetermined what was interesting and being talked about. Walter was interested in more than simple propositions about step-like changes in the curve that are produced when different farmers simultaneously begin to irrigate. Walter had lived in the community for 17 years. He was familiar not only with farming practices in general, but with the particular crops specific farms along Henderson Creek are and have been growing. That is, Walter was much more familiar with the historical changes that the watershed has undergone than Karen, who had come to the area only recently when she took her job as water technician in one of the farms. But we do not want to suggest that knowledge is necessarily attributable to either individual but highlight the fact that through their interaction, considerable detail about the context that led to the current water crisis in the community was brought to the light of day.

When the conversation is analyzed as an irreducible phenomenon in its own right, scientific literacy becomes a property of the situation. The environmentalist's open house, and Karen's exhibition of the water-level graph, occasioned the possibility for conversations about the water problem in the Henderson Creek and the watershed it drains. Here, then, water levels were mediated not only by farmers who all begin irrigating at the same time, but also by the differences in water needs of different crops. Characteristics of the soil, ideal for septic fields, allow the area to drain well and for farmers to pump more water than in other parts of the watershed (Marie Flats). This excerpt also exemplifies our more general observation that when scientific discourse and representations enter public fora, they are no longer under the sole control of scientists and the restrictive discursive repertoires characteristic of scientific laboratories (Lee & Roth, 2001). Rather, we can think of discursive elements and representations as being taken up into a more heterogeneous discourse, including many different concerns (ethics, politics, or economics), characteristic of the discourses that emerge over contentious issues. From the level of the conversation as a whole, or discourse as a heterogeneous phenomenon, the scientific repertoire turns out to be no more than one fiber among many fibers—no more or less than other fibers that contribute to the strength of the thread. Here, we understand the strength of the thread as coming from the integration of many different fibers.

The WSÁNEC': A First Nations (Historical) Perspective

The WSÁNEC' people (also "the saltwater people") have lived in the watershed for centuries. Henderson Creek, the ocean shores where it drains, and the surrounding ocean been central to their way of life. Yet in the local media, the WSÁNEC' and their elders seldom feature as the principal agents of activism. All efforts to restore the Henderson Creek watershed appear to be initiated and driven by non-natives; at best, aboriginal elders are featured in supportive roles of projects and meetings organized by others.

We were standing with Dan Daniels, an elder from the local First Nations people, looking down over the watershed, to the hillside where the reservation reaches down to Henderson Creek. Dan talked about the different ways in which the WSÁNEC' people related to Henderson Creek, the watershed, and the ocean into which the creek flowed. Nowadays, as the environmental activists have found out, the WSÁNEC' are difficult to enroll in their efforts of restoring the creek to become habitat as it had been decades ago. The reluctance of the WSÁNEC' to become involved can be understood as the outcome of historical processes that valued Western approaches to dealing with the environment at the detriment of their own ways of knowing.

Dan emphasized that their knowing is based on the oral tradition. Within the context of the oral tradition of the local indigenous band, place names are irrevocably related to their narratives, which are teaching stories and historical accounts at the same time. Furthermore, each name that is evoked in narrative stands for an idea that is more general than the actual account told by the storyteller. The meaning of words and stories, however, do not reside in the story or the intent of the storyteller. Rather, the meanings are thought to be stored in the listener, the only source of the wisdom. Because family histories expressed through oral tradition are often intertwined, each family maintaining its unique perspective of a shared event, the history of a people exists only in and as of the collective.

> Once, long ago, the ocean's power was shown to an unsuspecting people. The tides began rising higher and higher than even the oldest people could remember. It became clear to these people that there was something very different and very dangerous about this tide. [...]
>
> The seawaters continued to rise for several days. Eventually the people needed their canoes. They tied all of their rope together and then to themselves. One end of the rope was tied to an arbutus tree on top of the mountain and when the water stopped rising, the people were left floating in their canoes above the mountain.
>
> It was the raven who appeared to tell them that the flood would soon be over. When the flood waters were going down, a small child noticed the raven circling in the child began to jump around and cry out in excitement, "NI QENNET TŦE WSÁNEC'"—Look what is emerging!" Below where the raven had been circling, a piece of land had begun to emerge. The old man pointed down to that place and said, "That is our new home, WSÁNEC', and from now on we will be known as the WSÁNEC' people." The old man also declared, on that day, that the mountain which had offered them protection would be treated with great care and respect, the same respect given to their greatest elders and it was to be known as ȽÁU,WEL,NEW—"The place of refuge." Also, arbutus trees would no longer be used for firewood. (Paul, 1995, p. 2–3)

The WSÁNEC' have a deep respect for the Henderson Creek watershed and all the plants and creatures inhabiting it, including themselves. That is, the culture and land of the WSÁNEC' are inextricably bound together. The rich resources of the Inlet had fed the WSÁNEC' for hundreds if not thousands of years. The environmental activists recognize that the knowledge of the WSÁNEC' with respect to seasonal cycles, tides, and water movement was essential for their survival and have set the incorporation of this knowledge in restoring the health of Henderson Creek to be an important goal of their own future planning.

The WSÁNEC' depended on Henderson Creek and the wetlands in its watershed for their food, everything from ducks to sources of medicinal plants and weaving materials. It is therefore not surprising that the WSÁNEC' were considerably affected by the draining of the wetlands and other changes to the watershed over the past 140 years. As one elder recalled his mother's comment, "This place [Henderson Creek watershed] will be no more good to us" (Elliot, 1983, p. 17).

The availability of seafood, a traditional food source for West Coast First Nations, has slowly dwindled over the last couple of decades. Contaminated shellfish beds and fish-bearing streams have become all too common. Although many traditional shellfish closures result from the naturally occurring contamination of certain marine organisms, or biotoxins, other contaminants such as sewage, oil, antifreeze, detergents, paints and solvents are all finding their way into the marine environment and causing a different kind of contamination. (Peninsula News Review, December 13, 2000, p. 12)

To the WSÁNEC', Henderson Creek (the mouth of which they call "whale" in their language) was not only a place for food (Reimche, 1998) but also a place of cleansing, and therefore an integral part not only of their physical environment but of the very definition of themselves as people. The cleansing ritual was related to "skwinengut" (basic spirit). If a person did not have the basic spirit, s/he was considered to be an "empty shell." Because the seeker of skwinengut had to be clean, sexually and physically, s/he was before seeking skwinengut, usually by retreating to the nearby mountain, that the individual would bathe in the saltwater at the mouth of Henderson Creek. Bathing in the creek was also an important part of the rite of passage from childhood to adolescence (Jennes, undated mimeograph).

The WSÁNEC' know that Henderson Creek is no longer the same place. The brook trout, which had fed them as long as they their collective histories reach back, have gone. So have the humpback, gray whales, and orcas that had given rise to the aboriginal name K'ENNES for the mouth of Henderson Creek. The rich marine environment fed by freshwater among others from Henderson Creek has been killed off by rising levels of chemical contamination (fertilizers and heavy metals) and due to silting from the quickly draining straightened creeks. No longer does the actual state of the creek inspire cleansing and cleansing rituals as it used to be. They do not need the scientifically measured coliform counts, which are more than 10 times the level appropriate for swimming, to know that the creek is unable to provide and sustain them as it has in the past.

In fact, for the WSÁNEC', science may have ended with the coming of schools. The coming of schools brought a separation of education from schooling. Thus, one elder writes:

In our homes and in the privacy of our longhouses we continue to observe the wisdom of the past. The more we learn about the old ways the more we realize that science, mathematics and social studies did not begin with schools. For some of us it ended. (Claxton, 1993, p. 27)

In their ways, the W̱SÁNEC' feel that they have much to offer for an ecological approach to living on the Peninsula: "If we bring back a deep respect for nature we can be an example to everyone and prevent our beautiful land from being destroyed" (Elliott, 1983, p. 18). But the W̱SÁNEC' do not necessarily consider the environmentalists' activities as appropriate. Simply returning the creek to the state in which it had been some 100 years before does not address a more fundamental issue concerning the relationship between people and their lifeworld. An aboriginal friend, who has lived in and is familiar with the situation in the Henderson Creek watershed, made this point very clear.

The activists are doing the same thing that the farmers did when they first cleared the forests, drained the swamps and channeled the stream. They perpetuate the dynamics of colonialization. They haven't taken the time to educate themselves through dialogue with the Coast Salish people who've lived there for hundreds of years and who probably have stories about the birth of the creek. They've spent a summer measuring it with their meters and yardsticks and now they've got their machines in there, changing it. They haven't taken time to build relationships with the people who first inhabited the land. I do not understand how this can be called a democratic process.

Student Summer Projects

One summer, the Henderson Creek Project employed five high–school-, college-, and university-level students to survey the Henderson Creek watershed and collect data for future stream restoration work. Their work started at Henderson Bight and included profile surveys of the creek bed, cross-sections of the creek, habitat assessments, water quality testing, and landowner research. The students spent the summer collecting data, and then entering it into a database at the Project headquarters. For the in-stream work, Henderson Creek and its two contributing arms were divided into sections called "reaches." Abrupt changes in landscape, such as a transition from a field to a forested area, or at significant landmarks such as culverts, are used to demarcate a reach. The length of the reaches varied from 70 to 110 meters. In each reach, a series of tests were conducted. The ultimate goal was to eventually assess the entire creek system.

As part of their work, students conducted profile surveys, drew cross-sectional diagrams, assessed habitats, and evaluated water quality. Before they could begin their work, the students had to obtain permission from landowners before surveying could be done in the creek. They located landowners, found out mailing addresses, and sent out letters requesting permission to survey. They did not survey a reach unless full consent had been provided by a landowner.

The objective of conducting profile surveys was to develop an elevation survey of the entire creek, reach by reach, starting at sea level and ending at the headwaters. Students conducted the profile surveys drawing on a variety of tools such as surveyor's level and rod. They took measurements every few meters in the deepest part of the creek, usually going from the bottom of the reach to the top. The number of cross-sections in a reach varied depending on the length of the reach. Usually, there is one cross-sectional survey every 50 meters. Looking at all the cross-sections in order allows the activists to see trends in the creek bed (Figure 3, bottom).

We tried to do flow rate and discharge measurement. But this didn't turn out too well because our flow meter was in the fritz.... The bankfull[5] you have to kind of guess how high the water gets, because we are not here in the winter. And this is very difficult, because I don't know how high the water gets. (Lynne, university student)

Habitat assessments were done once in every reach, and included information on the percentage of gravel and silt in the creek, the size of the riparian zone, the types of vegetation in the riparian zone, the number of pieces of large woody debris, rooted cutbanks and bank stabilization, and the percentage of channel covered by overhanging branches. Taking all these into account, one can come up with a habitat rating for each reach. Habitat assessment requires many situated decisions, which the students learned to arrive at by working in groups. Students used a variety of forms as tools that allowed them to enter their estimates for the different dimensions that contributed to an assessment. In the same way, attempting to assess water quality could have been an insurmountable task had it not been for the variety of tools available for this activity. Thus, students used pinpoint-, dissolved–oxygen-, and colorimeters in conjunction with different forms that required entry of instrument readings and asked for particular calculations to be done. Thus, the quality of the water in each reach was determined testing temperature, dissolved oxygen, turbidity and pH. As with habitat assessment, a water quality rating for each reach was obtained by using a form, the water quality assessment form, to combine different readings, conduct calculations, and compare the outcome to an established calculation-outcome to quality conversion (Lee & Roth, 2001).

Our main ones are oxygen meters, which measure dissolved oxygen and temperature. And you stick them into the water and wave them a little bit around and it gives you the results. And the pinpoint meters you just stick in and they give you the results. And the colorimeters are the big squinky things where you actually take a sample and you stick it in and it does, I think spectroscopy... it does a spectral analysis of the different components. But the colorimeter usually involves a lot of in-lab analysis, you can't just stick your colorimeter into the water. (Lynne)

The results from the students' work were not simply ends in themselves, stored in the Project office. Rather, they were used as informational sources to guide their creek restoration work, to talk about the creek to different community members and landowners, and to persuade funding agencies to financially support additional projects in the creek specifically and the watershed more generally. For example, Figure 2 shows an excerpt from a proposal written to municipal council, requesting access to the creek as it passes through a local park, drawing on the type of data collected and produced by the summer students.

Figure 2 must be further understood within the particular political climate that stream restoration work finds itself in, in this part of the world. Both federal and provincial agencies support restoration work through funding, supervisory personnel and specialized course called "Streamkeepers." The approach that funding agencies take to stream restoration is based in standard stream ecology practices and discourse. Thus the organizations that wish to successfully apply for funding learn that they must approach their work by appropriating this discourse. Their discourse and practices, therefore, are rooted in this ecological way of representing the world.

[5] Bankfull is a term to describe the highest point of water in a regular season.

Excerpt from proposal

Water quality tests were taken. Results are recorded in Table 2. The results indicate water quality in Reach 1 to be poorest of the Centennial Park reaches (temperature and turbidity levels the highest and DO was the lowest). This is likely the influence of the open, chanellized reach upstream.

Table 1: Channel Characteristics, Reach 1.

length (m)	slope (%)	mean bankfull width (m)	mean bankfull depth (m)	width/depth ratio	mean paving material size (cm)
290 m	0.35	3.26	0.66	4.93	2

Table 2: Water Quality Conditions Reach 1

Dissolved Oxygen (DO)	Temperature	Turbidity
6.34 mg/l (65.6% saturation)	16.5 0 C	22 FTU

Limiting Factors for Reach 1

1. *Reduced overall habitat complexity due to channelization*
   The process of deepening and straightening the channel through this reach has removed habitat features such as deep pools, riffles, meanders, and off channel habitat.
2. *Reduced juvenile and adult habitat due to removal of large woody debris and stream bank vegetation.*
   Loss of these features results in an overall reduction in the amount and quality of habitat available to juvenile and adult cutthroat.
3. *Increased sediment transport and decreased water quality due to bank instability and erosion.*
   The vertical banks, lack of rooted vegetation, and loose soils throughout this reach have resulted in severe erosion. Sediments from these banks are deposited in pools and spawning gravel through the reach and downstream, reducing the quality of spawning, rearing, and adult habitat.

Prescription for Reach 1:

1. *Increase pool and spawning habitat:*
   Deepen pools by placing 3 'Newbury' riffle structures where reformation of small riffles is occurring. These features mark the natural deposition and behavior patterns of the stream, indicating the logical locations for enhancement structures. Add spawning gravel at downstream end of pools.
2. *Increase habitat complexity via the addition of large woody debris and boulder clusters:*
   Place woody debris and boulders at appropriate locations within new and augmented pools.
3. *Stabilize banks and increase habitat complexity:*
   Limit the access to stream banks and channel. Plant the stream banks paths with appropriate native vegetation. Provide interpretive signs to explain the restoration objectives, gain public support, and request cooperation from park users in keeping back from the stream channel.

Figure 2. The excerpt from a proposal written for municipal council, of Project activities contains data of the type collected by the high school and university students who were employed during the summer, paid out of another grant that the Henderson Creek Project had obtained.

Public Meeting

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 meetings, 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. One of the many forums documented in our research was a public meeting concerning the water in one part of Oceanside, Salina Point, which was not connected to the water main. During some summers, the ground water levels are very low increasing the concentration of biological and chemical contamination in wells to such an extent that the residents have to get their drinking water by driving to the next gas station (e.g., Woodley, 1998). After six different reports had been issued on the topic, the town council decided that there should be a public meeting where the sometimes conflicting discourses about cost, municipal intent, historical relations and scientific details could be clarified in a situation where many of those involved could be present.

According to some residents, the town council was heavily influenced by the majority report of the Water Advisory Taskforce, which in turn had based its report on the report by an independent consultant Dan Lowell. Our research shows that the scientists generally attempted to restrict the discursive repertoires to a decontextualized kind of discourse that does not account for the particulars of the situation (Lee & Roth, 2001). (Bakhtin [1981] refers to such discourse as monoglossic.) Further, what were real concerns in the everyday lives of the people affected by the unusable water became mere "aesthetic objectives" in the discursive repertoire of science. Because public meetings, as all dialogic forms of interactions, involve many different people, who bring their own quite different concerns and ways of understanding, the public meeting, as an interactional forum, allows the emergence of rich forms of collective scientific literacy. To illustrate this, we pick one controversial issue, the problem of high chromium levels in the drinking water.

The chief environmental health officer, whose report had recommended connecting Salina Point to the water main, suggested that when he and his team had taken measurements in the well, there were unacceptably high levels of chromium.

We had a problem and a high level with our chromium levels. Chromium can be a problem when it combines with chlorine and goes to the trivalent state. This is when a carcinogen is formed. Chromium as it generally occurs in the water system is fine. It is a nutrient. But when we have to chlorinate a water system that's where we have the potential for some problems. (Chief environmental health officer, regional health board)

The consultant Lowell hired by the Water Advisory Taskforce, reported that he had not found excesses of chromium levels and recommended that any metal contamination, which he called to be mere "aesthetic concerns," to "be treated with in-home treatment systems." When the public came to ask questions and make comments, Lowell's report came under close scrutiny. In the first four utterances of the following exchange, which involved Lowell and a resident (Naught), a claim to scientific expertise was constructed.

Naught: Let's turn to treatment of downstream water. Are you… is that your area of familiarity and expertise?
Lowell: I've worked with groundwater and water treatment for over 25 years.
Naught: So, so you, so you would consider yourself an expert in that area?
Lowell: Not in all aspects. An environmental engineer who's an expert in water treatment would know more about it than I do.
Naught: Would, do you know, for example whether chromium can be treated?

Lowell: Yes, yes I do.
Naught: Successfully?
Lowell: Yes, it can with ion exchange filtrate, a filter. I phoned the manufacturers of certain systems and they assured me that that can be done.
Naught: And that's good enough for you?
Lowell: Well, I read it in publications as well.
Naught: Oh, there's a publication that we have here that says it has, that says there is no commercial treatment for chromium.
Lowell: Again there wasn't any concern for chromium identified. So I'm not sure what point you're making.
Naught: Well it seems to me that the report is relying, Mr. Magee's [WTF majority] report is relying on very heavily on your information which would suggest that it doesn't matter what the problem is with water, it can be treated. I would beg to differ on that because I think that when you do something to the water, you affect it regardless of what the treatment and where the treatment. And that it affects the water in another fashion. And so therefore this business of treating water is only a marginal thing with respect to water qualities.

The subsequent exchanges construct the possibility that chromium contamination can be successfully treated. Lowell claimed to have called manufacturers and read publications whereas Naught pointed to one concretely available publication that suggested the contrary. Lowell's response that there was no chromium contamination attempted to shift the issue but in his response, Naught pointed out that the non-negligible effect of Lowell's report on the decision-making process warranted greater attention to the nature of the recommended treatments. Chromium had been found in the first sampling episode done by the scientists from the regional health authority.

The claims that there were no problems with chromium levels contrasted not only those of report by the regional health authority, but were further mediated by information subsequently entered into the meeting by other residents. For example, one resident said that the water samples taken from her home were "beyond the one that was done by Mr. Lowell, have always tested very high in the negative areas, the one in particular is chromium." She elaborated to have learned

about chromium after reading the [health board's] report that said it could possibly be carcinogenic… part of the poisoning was through skin absorption which was exactly what happens with the chromium in its carcinogenic state…. The high pH encourages scale formation and decreases the efficiency of chlorine in disinfecting the water, which we can't use anyway because of the high chromium content. [Resident]

Similar to the contributions by other residents, some of whom had hired their own consulting firms, this resident's comments contributed to the construction of problems relating to chromium. When the public meeting is considered as an irreducibly social phenomenon, rather than consisting of the sum-total of individual contribution, we understand high chromium levels as a contested issue. There are both pros and contras to the presence of high chromium levels. Not only the presence of chromium levels were contested but also the claims that chromium could be treated. Finally, even the very status of scientific expertise was contested in contradictory claims about what the scientific literature says about the possibility of treating high chromium levels in drinking water.

Where is scientific literacy in this public meeting? Is it restricted to the scientists present, some of whom have master's degrees in their field? Is scientific literacy an attribute of residents such as Naught and others who interrogated Lowell in ways that another presenter called a "cross-examination"? Here, we take a different route to scientific literacy. Paraphrasing McDermott's

(1993) answer to a similar question about LD, we suggest that scientific literacy is all over the public meeting and the other situations that we described. Every person in the episodes is in some way related to scientific literacy as it emerges from the situation; and yet this scientific literacy enacted in and as everyday praxis, cannot be reduced to any single individual. Every participant is a part of the choreography that produces moments of the public appearance of scientific literacy. As we have shown with our excerpts from the meeting, scientific literacy, rather than being confined to an individual person or to sum of several persons, arises from the dialectic relations among the entities that constitute the activity system.

Beyond Propaedeutics: Children's Science in and for the Community

School science is often conceived as propaedeutic—preparatory study for subsequent science courses and for life. The project *Scope, Sequence, and Coordination* (NSTA, 1992) is explicitly based on the decomposition and proper aligning of curriculum content across grade levels. Despite research in other fields, such as mathematics, which shows that there are considerable discontinuities between school and everyday activities and knowing, science educators have yet critically examine the assumption that school learning actually relates to everyday out-of-school activity. This question is paramount if science education is to contribute at all to a more general project of life-long learning in science, which appears to imply continuous forms of learning across the boundaries of schooling.

A range of studies that are usually classified under "situated cognition" have highlighted how little bearing school knowledge has in everyday practice; performance of everyday mathematics, for example, is often unrelated to the amount or quality of school mathematics an individual was exposed to (e.g., Lave, 1988; Saxe, 1991). Research in the education for a profession, such as teaching, also highlights the break between the knowledge acquired during formal schooling and the everyday practices on the job (e.g., Roth, Lawless, & Tobin, 2001). It should not come as a surprise, then, that for many students, the knowledge taught in schools is not very compelling. Teaching a small set of key scientific concepts and theories—often incompatible with everyday knowing and common sense—in better ways does not significantly change the situation. Some argue that even if all students learned scientific concepts, they would not automatically use science in socially responsible ways (Eisenhart et al., 1996); there is no evidence that trained scientists do so (Roth & Désautels, 2001). Furthermore, it does not change the social costs often associated with doing well in school, where non-adherence to middle-class values and interactional patterns often leads to resistance and subsequent failure (e.g., Eckert, 1989; Tobin, Seiler, & Walls, 1999; Willis, 1978).

Influenced by these considerations and by results of our own work over the past decade documenting and theorizing the situated nature of cognition, we assisted teachers in designing units that provided grade-7 students to learn science in the process of generating knowledge for their community. In designing the unit, we took our cues from the activities of others in the community concerned with the health of the local watershed and its main water-carrying body, Henderson Creek, and allowed students to pursue investigations of their own interests. Because people in the community created and used various representations of the watershed, creek, and the pressing issues, we changed from an initial focus on "scientific representations" (e.g., graphs) and encouraged students to create representations that best met their needs of expressive forms.

The science units began with articles from the community newspaper that described aspects of the environmental and water-related problems in and around Oceanside. For example, the following excerpt from one of these articles highlights that a revitalization of the ocean surrounding the peninsula where Oceanside is located needs to begin with improving the health of Henderson Creek and its tributary.

Group is a bridge over troubled waters

If the waters of the Pat Bay and Georgia Straight are to be revitalized, the streams and creeks that feed them must be save. A group at [Oceanside] wants to begin the process by breathing life back into [NAME] Creeks.

The damage [...] was caused by channeling the creeks and removing gravel from the area. Straightening the creeks (ditching) not only makes the water move through the remaining culvert too quickly to support rearing beds, but removes the surrounding vegetation. That, in turn, erodes the environment on which birds and other species depend for survival.

Chief [...] spoke about the abundance of fish, shellfish, and other wildlife in the area during his youth...

But for the long-term work, project coordinators said the wider community must be involved... (Reimche, 1998, p. 9)

The teachers would read the article with the students, asking questions about the need for revitalizing the ocean (children have no difficulties in answering given that some of their parents were fishing as a hobby or for livelihood). The discussions of the article ended with the question how the particular class, as part of the "wider community" should become involved. The students began generating ideas, often related to cleaning up the creek and to finding out more about Henderson Creek and its problems. After a field trip to different sites along the creek, the students began framing initial investigations and even entire programs of research.

Although the activity–system-defining object was the same in most instances for all student groups, Henderson Creek and the watershed it drains, different tools and rules mediated the relations in different ways leading to very different outcomes (Table 2). Nevertheless, the various outcomes ultimately contributed in their own ways to the totality of the findings generated by one or more classes. We understand the students' activities authentic in the sense that their activities were motivated in the same way and by the same concerns that other activities in the community were motivated. Table 2 also shows how different members of the community in general and the activist group in particular participated in the activity system that describes the students' activity. Other similarities with the activity systems in the community (Table 1) are some of the tools (colorimeter, rules). Not surprisingly, some of the *outcomes* of the student-centered activity system were therefore similar to those in the activity systems in the community. For example, the use of colorimeter, pH meter, or dissolved-oxygen meter all let to numeric representations of stream health. Similarly, middle school students and students working of the Henderson Creek Project as a summer job produced very similar graphical representations—such as stream cross-sections (Figure 2). Similarly, forms designed by scientists (water quality assessment, physical assessment) assisted students in their summer job and middle-school students in producing representations (*outcomes*) that could be used by the environmental activists to pursue other goals (e.g., getting grants, proposing restoration work).

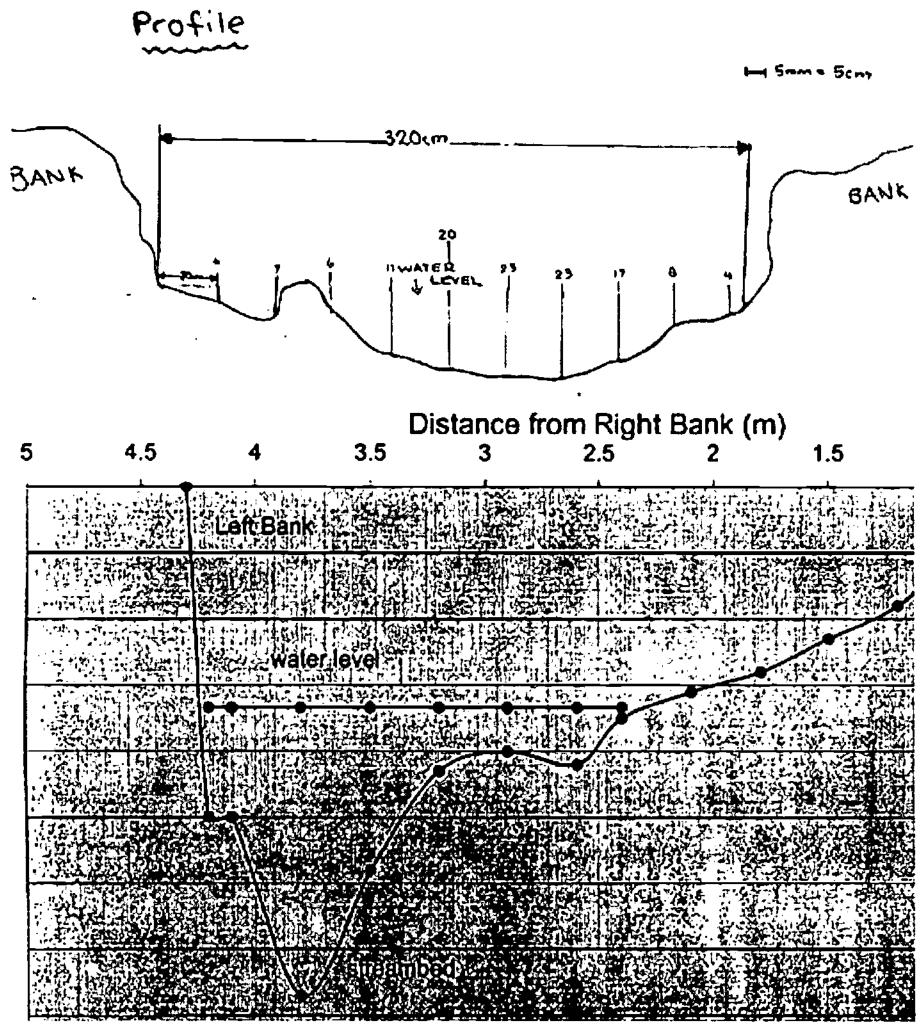

Figure 3. Top. Cross section of Henderson Creek produced by grade-7 students as part of their science class. Bottom. Cross section in a different part of Henderson Creek produced by summer work-study students.

Similar to the previous section, we focus on a variety of situations that exhibit scientific literacy as a collectively achieved phenomenon, all involving grade-7 students. In particular, we provide evidence that these science lesson where students generate knowledge in and for the community, constitute situations that do not make visible learning disabilities that are made visible, and therefore are evidence of, problems in other situations. Furthermore, if the situations allow students to pursue questions of their interest and to use representational tools (instruments, camera, discourse) of their own choice, disinterest and exclusion characteristic of traditional science courses (e.g., Eisenhart et al., 1996) do not become an issue.

Table 2
Outcomes in an activity system (grade-7 science class) as mediated by the tools

Subject	Object	Tools	Community	Rules	Division of Labor	Outcome(s)
John, Tim	Henderson Creek	stop watch, tape measure, ruler	Oceanside, parents [Mr. Goulet], activists, scientists	repeated timing and averaging	timer, releaser, measurer	correlation between speed and profile
Davie, Steve	Henderson Creek					
Grade-7 students [John, Len et al.; Lisa et al.	Henderson Creek	Tape, stopwatch; Serber sampler	teachers, students from other classes [Davie]	for use of stopwatch, tape, sampler		Classification and frequency of organisms; stream speed
Michelle et al., Kathy et al.; Chris	Henderson Creek, shore	cassette recorder, camera	Teacher, Michael, Stuart		roles in research team	radio-like reportage, slides, web site
Gabe	student researchers	videotape				Processes of investigating environmental health
Jodie et al.	Henderson Creek	Dissolved oxygen meter, Serber sampler	Teacher, Michael, Meagan, community			Dissolved-oxygen levels, organism-type/oxygen-level correlations

Diversity of Projects and Representational Forms

Students who frame their own research agendas, have control over their research questions and the form of the representations, articulate what they have learned in a great variety of ways.

We are studying Henderson Creek to find out about what water and creatures are like at the different sites. One of the things we are trying to find out is the quality of the water. The water quality determines what creatures live there. The quality depends on the depth, the width, the bottom (whether it is sandy, rocky, or gravelly), the temperature and the speed of the current. We will take samples of the creatures and then the next day count them and look at them under a microscope. We will make graphs displaying all the different information we got. There will be professors there with us to help us and tell us how to do it. (Magda, May 5, 1998)

Kathy and her teammates conducted a series of interviews to find out "what the community thinks." They interviewed the mayor of Oceanside, the coordinator of Henderson Creek Project Meagan McDonald, a W̱SÁNEC' elder, and other community members. They transcribed and analyzed the interviews. The transcriptions of the interviews were subsequently made public as part of one of the posters during the open-house event.

Kathy: Has it been just the last ten years that the fish have been dying off?

Meagan: Actually, it has been the last fifty years that the cut throat trout have declined in size, in range, and in numbers. So there is still a dwindling population of fish, but they are not as healthy as they were or should be.
Kathy: Did people ever fish in Henderson Creek?
Meagan: Yes, they did. We know that because of the anecdotal information and first-nation history. The last time people really fished there was around 30 to 40 years ago. It was the settlers and First-Nations people who fished there.
Kathy: What polluted Henderson Creek?
Meagan: There used to be a large wetland area in the middle of the Henderson Creek watershed that was drained in the late 1800s, then converted to ditches. So in that loss of the habitat from the draining, the gradual decline in water quality from things like losing the tree cover, the water temperatures would increase because there was not enough shade for the water.

Scientific literacy is not something that is taught to Kathy by Meagan. Rather, scientific literacy arises from the order of interaction, the relation between questions and answers. Meagan's answers, which allowed a historical perspective on the problems of Henderson Creek to emerge, were occasioned by Kathy's informed questions. It is the interview situation, in the context of the children's Henderson Creek projects, that allowed a scientifically literate conversation to appear rather than chitchat about some other topic.

Gabe, an aboriginal student, who hardly engaged in any school-related task, did not want to work within a peer group. He was not interested in conducting investigations as others did. However, he was interested in working with a video camera to document the activities of others and to interview them about their investigations while they were actually collecting or analyzing data.

Gabe: Can you talk about your observations.
Nicole: Right now, we are taking the moisture and pH of the soil in different locations.
Liza; And we are trying to find out whether it is any different when we are going through the plants.
Nicole: Yeah, and we are looking at the bugs and stuff as well. We are having a good time.

Mr. Goulet, the parent of a female student enjoyed the project activities and requested to come along on every field trip. He did not consider his task as one of supervising and watching out for children but one of scaffolding student investigations. We talked to him about the importance of letting students frame goals and asking productive questions that lead to further inquiry rather than to definite answers. He took every possible occasion as a starting point for allowing students to learn. For example, he worked with a group of boys who had decided that they would find out the relationship between the cross-section and speed of the water. He questioned the boys attempting assist them in coming up with creative means for measuring the width of the creek although it was too deep to step into it let alone cross it. He actively participated in measuring the depth of the stream, swollen by the recent winter storms. Ultimately, the group decided to measure the width of the creek by tying a piece of wood at the end of a string and launching it to the other side of the creek. By pulling, they brought the piece of wood to lie on the bank, which allowed them to mark the string at their own side. They measured the length of string between the mark and the end of the string after the wood had been pulled across. The fact that the wood had floated gave rise to a "teachable moment."

Goulet: Why did it float instead of sinking?
John: Like this one is too big but if it was smaller
Goulet: It would have sunk?
John: Yeah, but if it was heavier, then it would have sunk.

Goulet: Right, so how would you figure out whether that would sink or not?
Tim: We'll say, this will generally sink.
Goulet: What would be a way to find out? Why would this [hammer] sink?
Tim: Because this is more compact in weight.
Goulet: So, if I compare this to the same amount of water, I would be heavier. So?
John: It would sink.

Here, in the context of Mr. Goulet's questions to John and Paul, a conversation about sinking and floating emerged. The transcript shows that a qualitative theory involving the notions of "compactness in weight" and "relative weight to water" came to explain sinking and floating. Here again, scientific literacy characterizes the situation and might have not been observable if aspects of the situation had been changed (e.g., written test about "density").

Open House: Featuring the Results of the Science Unit

Given the different tools that the children had used to conduct investigations and construct their representations, the variety of the displays came as no surprise. There were maps, photographs, drawings of invertebrate organisms, instruments and tools, live invertebrates and microscopes to view them, larger organisms in a glass tank, interview transcripts, and a variety of scientific representations (graphs, histograms). The type of representations used was little different from those used in the various exhibits by the environmental activists. That is, the children's representations were a reflection of those that are characteristically used in a community-based science. We provide several brief descriptions and transcripts to articulate scientific literacy in the community involving children.

Michelle and her three (female) teammates had been interested more in qualitative than in quantitative representations of the creek. For example, one of their projects involved a tape recorder, used to record verbal descriptions of several sites along the creek, and a camera for saliently depicting some issue identified by the girls. Accordingly, their exhibit contained many photographs, exemplifying, for example, the differences between the creek where it had been turned into a ditch and where it was in a natural state. The work they had conducted in the field was represented in narrative form. The following explanation is characteristic of the information provided as results from her research.

There were no fish in the ditches, just some little bugs, but no fish. But in the creek, in Centennial Park, there were cut throat trout and stickleback. And the creek is much cleaner, because the ditch is next to the road. And people who are driving by are dumping garbage into the ditch, out of their cars and as they are walking by. So we found much more garbage, like we found pop cans, drinking things from McDonalds, French-fry cases, and things like that. (Michelle)

An important aspect of the open-house event was that students came to interact with visitors of all ages. The interactions between the grade-7 students and children younger than themselves were as involved as interactions involving adult visitors. In every situation, aspects of scientific literacy emerged in often unexpected and surprising ways. Thus, in his regular classes, Chris interacted very little with his peers. They saw in him a "computer nerd." Teachers often found it difficult to work with him, "get and keep Chris on task," or to get him to achieve to his potential. On the other hand, Chris thrived in the science unit, where he built a web site using his own and other's photos and texts. During the open-house event, there were many interactions involving Chris that allowed scientific literacy to become visible. It is in and through the interaction that the adult comes to use the stereo microscope properly and to see an entity as "arthropod" rather than as a "mosquito larvae."

Adult: Have you got any insects?
Chris: Yeah, yeah. But don't move it [glass container under microscope] around so much because I got it focused.
Adult: (*Approaches microscope*) You got it focused?
Chris: Yeah. (*Adult only views through one lens of the two-lens stereomicroscope*) You can look through both. Then you can see them better.
Adult: What's these little ones in here. Are these mosquito larvae?
Chris: No, there are no mosquito larvae in there.
Adult: You see the little ones (*points towards glass*)?
Chris: Yeah, the little ones that are swimming around, those are arthropods. They like to swim on the side first. They are neat critters.
Adult: Yeah, and that is what the trout feed on, aye?
Chris: Well, I guess.
Adult: (*Looks at drawings on display, points to one*) Oh, this is what fly larvae look like. Thanks.

This excerpt exhibits the choreography of an interaction in which Chris contributed in a significant way to produce the appearance of scientific literacy rather than its opposite, the "scientific ignorance" other authors (e.g., Shamos, 1995) seem to detect in the general population.

In another situation, Jodie came to interact with Miles Magee, one of the cofounders of the Henderson Creek Project. Unbeknownst to Jodie, Miles Magee is a political scientist living in the community interested in assisting local people in empowering themselves concerning the environmental health of their community. Miles was very interested in the outcomes of the students' investigations and interacted with a number of them. In one instance, he asked Jodie about an instrument on exhibition, the same type of instrument that the summer work-study students have been using in order to conduct and produce water quality assessments. In the course of their interaction, knowledgeability relating to a particular instrument and its operation was being produced.

Miles: What is this?
Jodie: A calori... meter. It measures the clarity of the water.
Miles: Ah! A calori... a colorimeter?
Jodie: You take the clear water and you put it in this glass and then here [puts it into instrument] (*Pushes a few buttons*) and you take the standard which is like the best there is. And then you switch this (*takes different bottle*) and put the one with the water from the creek. (*Covers sample*) And then you scan the sample. And then you see what the things floating in the water is.
Miles: Over-range, what does that mean?
Jodie: (*Pushes a number of buttons*)
Miles: Oh, it is when it is over the range, I see.
Jodie: First I have to do the standard again. (*Does standard*) Then I take the creek water. (Enters bottle into instrument. Pushes buttons.)
Miles: Oh, I see. This is really neat.

This interaction did not lead to a contrast between an all-knowing adult (expert) and a child; there was no belittling. Rather, the conversation involving Miles and Jodie allowed the articulation of an honest request for understanding and an illustration of the operation of the device. Scientific and technological literacy emerged from the dialectic tension between a request for information and the production of an answer in the form of a demonstration.

"Measures" of "success"

The interactions at the open-house event involving students, activists, and community members not only led to the emergence of scientific literacy but also to the emergence of the legitimacy of the children's activities. From the perspective of the environmental activists, the children had contributed in a significant way to the success of the open house by contributing to its content and by being a drawing factor—the children's presence encouraged the participation of many parents and relatives alike. That is, the activists recognized the contributions of the grade-7 students as the outcome of a legitimate activity of the type that they had called for in the (earlier featured) newspaper article. The results of the students' investigations were mentioned in a newspaper article and in a web publication.

The goal of the [Oceanside School] study was to determine the health of the benthic invertebrate community at three different sites, provide information to the community about the health of [Henderson] Creek, and provide students from [Oceanside] School a focus for ecological research and hands-on exposure to stream ecosystems. Preliminary data loosely suggests the site just below [COMMUNITY] Park [...] was the healthiest. Further studies are required for more quantitative data than was gathered on these days. Overall, the study was highly successful in terms of the education and experience it provided to the school children and their parents. It also provided a general indication of the health of the various sites. The class also participated in the Henderson Creek Open House held in April and has set up a web site on their work in Henderson Creek. Other classes at [Oceanside] School, as well as other schools, are keen to begin similar initiatives or activities around Henderson Creek. (Web site)

When it comes to the [Henderson] Creek-KENNES watershed Project, [Meagan McDonald] says, it's the people who will have to make the difference.... The open houses will have numerous exhibits including... a display by [Oceanside] Middle School Grade 7s on their invertebrae work done in [Henderson] Creek.... "What we want to see happen is that the community embraces the concept of a healthy watershed and takes it on themselves," she said Sunday from the banks of [Henderson] Creek, adding that water quality decline and habitat loss in local streams has severely influenced the range, numbers, and size of trout over the past several years.... For the past two months, [McDonald] has been working with students at [Oceanside] Middle School in an ambitious attempt to identify and count invertebrae—another barometer of water quality—at various sites on the Peninsula. Early results show the section of stream below [name] Park in Oceanside is in the best shape.... (Clarke, 1998, p. 8)

These publications, which emphasized the contribution of the children's work to the overall project of environmental health in the Henderson Creek watershed, added further to underscore the legitimacy the activity. When considered in terms of the notion of "legitimate peripheral participation" (Lave & Wenger, 1991), the children contributed in more than marginal ways to knowing and learning available in their community about environmental health.

In the lived experiences of the children, the interactions in and with the community played an important role. When asked to reflect about what they had done and learned, many children spontaneously talked and wrote about the relation between community and their own activities.

I worked very hard on the map and proceedings. During this course I learned about fieldwork: I learned how to collect samples of the creek and take temperatures and speed. I also did some work with the community. It taught me about working with others and working in the community. I noticed that ever since our Henderson Creek article was published in the *Peninsula News Review* that the public has begun to notice the creek. (Sally)

In the Henderson Creek group the work that I have done and help with includes: Worked on the model of the creek, typed out the descriptions of the sites with help from Davie, Brandon, and Steve cut them out. I was at the cultural center. What I've learned from all this is about the problem of the creek, how to work with the public (community). The thing I learned was how much other people knew about Henderson Creek. Like Mr. Herbert as the Mayor of Oceanside he knew lots about it. How to work productively and still have fun with your friends. How to use special equipment like "D" nets, microscopes, colorimeter and all sorts of things. (Jodie)

Sally had noticed that the (above-mentioned) newspaper article had led community members ("public") to notice the creek which some (including teachers) did not even know to exist. Sally's comment may also imply how important the newspaper article was to the gratification she (and her peers) received from being acknowledged in a public forum and therefore as a legitimate contributor to the social life of the community. Jamie's comment also addresses his emergent awareness of existing knowledge and expresses a certain amount of pride in being able to participate in the use of scientific equipment

Knowledgeability and Learning Disabilities

In his moving plea to rethink the meaning of knowing and learning, McDermott (1993) suggested that "learning disabilities" are more the result of situations than attributes of individuals across situations. There is strong evidence that this is also the case in our research. Children who are labeled as learning disabled or as having special needs (e.g., aboriginal) do not exhibit learning problems or learning disabilities when their activities are integrated into the larger concerns of their community.

In their regular curriculum, both Steve and Davie experience learning problems. In fact, Davie is labeled "LD" and receives special services, for which he is often pulled out of the class. Yet this science unit was such that it did not bring the disabilities and learning problems to the foreground. As it turned out, Davie in particular became such an expert that he assisted in teaching the class of grade-7 students to conduct research in and alongside the creek. In the following excerpt, Davie and the teachers Lori and Michael introduced students from another class to some fundamentals of working with Serber samplers and D-nets, used for capturing invertebrates.

Davie: See, and you only do it in there [within metal square of Serber sampler] to find out in that one area how much bugs there are. And you have to do it really good when you use this one, because you want to find out exactly how many bugs there are. This one [D-net] you can just try and estimate the area in front, but because it is not accurate, you are just trying to get much bugs in there.
Lori: Davie, how long do you get your hands in there and rub?
Davie: I don't know exactly. I just move around in there, about a minute or two, just to get everything.
Michael: With the D-net, you should take about one square foot, because otherwise we won't be able to compare the counts across sites.

In this episode, not only Davie's classmates were shown how to use the two tools, but Lori, who had not used the two tools before, found out about the procedure for collecting samples. This situation, as many others involving him that we were able to document, did not produce the public appearance of a "learning disability." Being both an individual subject and an aspect of the context for others, he contributed to the learning in the situation involving students and adults (e.g., teacher, parents) alike. Later during the same lesson, Davie assisted two groups of students at the same time. One group of three boys had decided to measure the speed of the stream. A group of girls working next to them collected invertebrate samples.

Davie: OK, you guys choose a spot. Maybe go along there [shore]. Then you have to measure how deep it is. And then make a breakdown.
John: Is this (strong) exactly five meters?
Davie: Yes, it is. You guys, put this [Styrofoam] in the middle of the stream, where the water is flowing a bit. And then you just throw it in there and measure how long it takes. (*Moves to Lisa's group*) And you put the net

in like this, and you move around like this (*washes rocks with his in front of Serber sampler*) and you will get lots of bugs in there.

Lisa: And they will go into the net?

Davie: Yes, the water flow will take them in. You also will probably have lots of sand.

John: We could have the string, and then multiply the time by two.

Davie: Yeah that would work. Just pull the string. Who has the stopwatch?

John: I do.

Davie: You put the hand on zero, and when you let the ball go, you press the start.

Len: Will be check for the bugs?

Davie: Later, first we measure how fast the water goes.

Even if we were to attribute knowing and learning to individual students, the present episode would support the contention that Davie is scientifically literate rather than learning disabled. Again, the situation supported the emergence of scientific literacy and did not create and make visible any learning disability. All we can see are children in the pursuit of their investigations, scaffolded by the participation of a child who has had more experience participating in such investigations than the others. Subsequently, sometimes with the assistance from teachers or other adults, students created graphs that showed the relationship between stream speed and the number of a particular organism living in the creek (Figure 4).

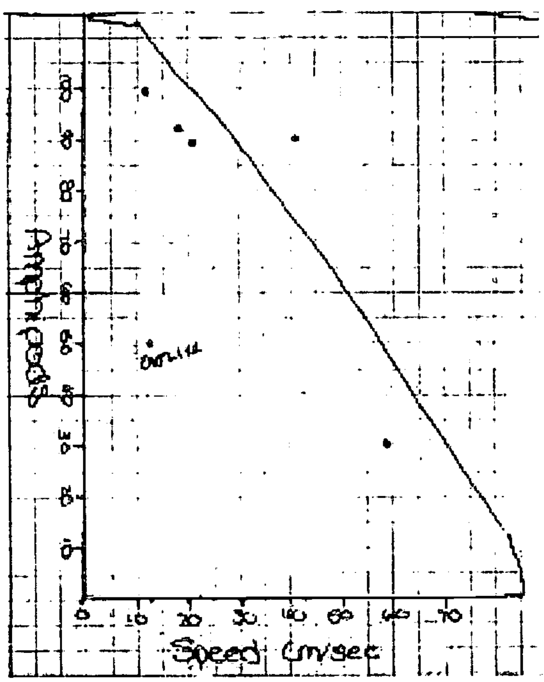

Figure 4. Correlation between stream speed and the number of amphipods in a section of Henderson Creek.

Steve and Davie also participated in the open-house event. Here, the talked about their project to visitors of all ages, adults and children who were younger than they were. Again, the situation did not contribute to bring disability and learning problems to the foreground. Rather, both students were experts in their own right, recognized by their peers and by the visitors to the open-house event. For example, Steve tended to a poster featuring a map and photographs of the research sites, a list of tools, drawings of different invertebrates, and a bar graph of the

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frequencies of different organisms. An adult approached the poster and asked what he was presenting. As Steve began to talk about the project, Davie joined into the interaction with the adult visitor.

Steve: We have gone out to three different sites, Centennial Park, Malcolm Road, which is right by [NAME] School, and [Oceanside] Farms. You know where this is at?
Adult: (Nods) Yeah.
Steve: And we counted them (*points to histogram they had constructed, Figure 5*). Like we collected all these samples (*points to invertebrate drawings*) and counted them and we plotted them (points to graph). And we found these sorts of bugs (*adult looks at drawings*).
Adult: Are those (*points to stone fly larva*) around now? Or those [fly larva]?
Davie: We might have one of those right now. I am not sure. But I know that we have lots of these, lots of mayflies, and amphipods.
Steve: And worms…
Davie: And we also got crayfish…
Steve: And the ones that are called blood worms.
Davie: These are very common in some spots. Some spots there are like lots of worms, and at other spots there are none. Usually, we don't get very many mayflies at that time of the year.
Adult: How did you catch all of them?
Steve: Like that (*points to photograph showing student with Serber sampler*) or with D-nets. Like see, we have tools there (*points to displayed list of tools*), and a D-net is a net that looks like a D. It has a flat side that sits on the bottom. And we just brush the rocks in front of it (*waves with hand*), and the bugs fall in. And then we just pick up the net (*points to photo*) and throw it into the bucket. Then we take it back to school and look at it.
Davie: (to adult) Come over here, I put one under [the microscope], so you can take a look at it. (*Goes to microscope, puts it into focus for the adult*)

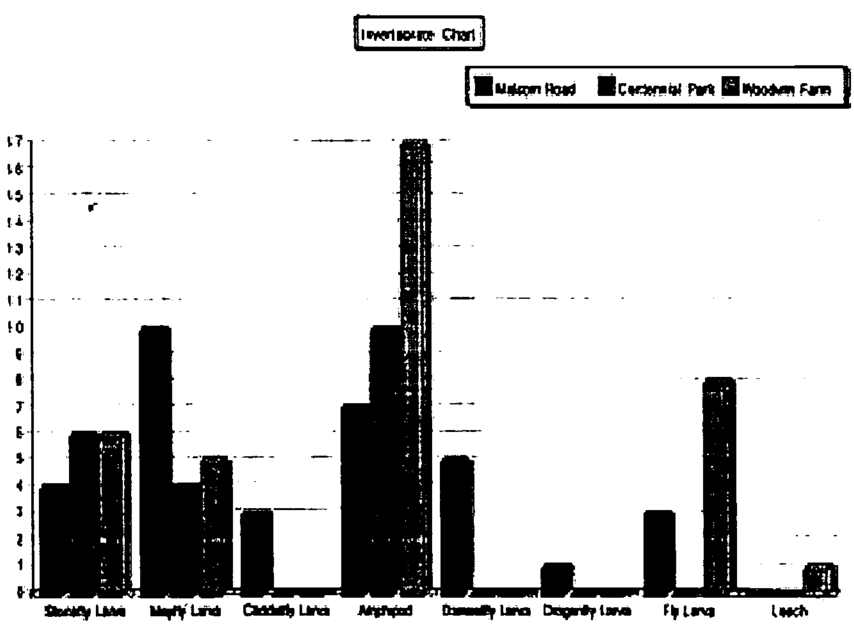

Figure 5. Histogram constructed by the Steve and Davie, showing the number of invertebrates per square foot at three sampling sites along Henderson Creek.

In the context of this open-house event, where community activists presented posters from their own work, and where visitors of all ages moved from exhibition to exhibition, Steve and Davie were legitimate contributors to a public event. Evidently, the conditions that made their learning problems and disability become visible in the regular school contexts did not exist here. Rather, their participation contributed in important ways to the very emergence of the phenomenon in which we are interested here—scientific literacy.

Summary of Student Section

Eisenhart et al. (1996) suggested that educators need to find and built alternative activity systems in which the mediational entities that influence learning in and of diverse student populations. They recommended activity systems that would sustain a broader vision of scientific literacy than the narrow view currently enacted in schools and policy alike. In this section, we presented evidence from our three-year research within school science classes that enacted a curriculum consistent with the motivation of other activities in their community. In the process, learning was made possible as students *exchanged* knowledge and tools with others and *produced* knowledge for the community, where this knowledge was *distributed* and which "*consumed*" the knowledge (Figure 1). Our analyses showed that in this unit, the activity system focusing on the students shared many similarities with the activity system that focuses on other individuals in their community. Thus, in everyday water- and watershed-related activities, adults defined purposes, goals, tools, division of labor, rules of interaction, and so forth. Similarly, we found that the motivation behind children's activity integrated well to other immediate lifeworld aspects; this, as critical psychologists and educators have repeatedly pointed out (e.g., Freire, 1972; Giroux, 1992; Holzkamp, 1991a) are indications of an empowered citizenship.

Our study showed that children participated in activities with similar motivations as those of adults, and they participated in a variety of forms of conversations with adults other than the regular teachers. These conversations therefore broke the mold of normal modes of schooling, opening up the possibility for life-long participation in such activities and therefore the possibility for life-long learning without the discontinuities that characterize the transition from formal schooling to other aspects of life. If the motivation underlying school science and environmental activism, stewardship, or volunteerism are similar, based on the nature of tools, rules, divisions of labor, and community, we can expect individuals (subjects) to move along trajectories that do not exhibit discontinuities characteristic of other transitions. Children who participate in activities that contribute to the knowledge available in their community will develop into adolescents and adults, continuing to participate in the activities relating to environmental health. The possibility for such transitions is clearly indicated by a variety of situational organization that foster the participation of students and non-students alike. For example, as a result of our work in the schools, middle and high school students conducted science–fair-related investigations. As part of their career preparation some local high school students choose to participate in "Streamkeepers," a program fostering the recovery and restoration of ecosystems, and open to any individual or group. Three national youth teams worked together one summer to help the Hagan Creek Project to improve the watershed by moving native plants before clearing 11,000 square meters for a pond and wetlands that will help improve the water quality in the area (Lavin, 2000). High school and university students contribute to the data collection as part of funded summer work projects. Masters students at the local university become key people in constructing community surveys to yield multi-layered (GIS) representations, involving maps that display ground-cover (vegetation), surficial geology, soil, aquifers, topological, and present land-use (housing, zoning, or cadastral) information.

Discussion

In this study, we used activity theory as a frame for reporting about and theorizing community-based activities in which science was an important (but not exclusive) strand. In its focus on motivations, objects, tools, and the location of different individuals (subjects) in a variety of activity system, our study highlighted similarities between some everyday out-of-school activities and those of school children who constructed knowledge about the health of a stream. By contributing to an open-house event, dutifully reported in the local newspaper, and by having the results of their investigations, the children became legitimate participants in the (adult-oriented) social life of their community. In turn, community members participated in children's activities—including activists, biologists, First Nation elders, peer coaches, teachers, parents, and ourselves—creating situations that led to the emergence of scientific literacy as outcomes of collective activity systems.

Conversation as activity: Scientific literacy as indeterminate outcome

Conversations can be understood as activities, described here in terms of the framework of activity systems, in which differently located individuals participate. The interacting individuals constitute the subjects focusing on some topic (object), such as Steve, Davie, and the adult talking about the students research results. In the process, the conversationalists draw on (the same or different) discursive repertoires, diagrams, drawings, and graphs (tools). Division of labor refers to the different roles of listener and speaker, which the individuals repeatedly exchange in the course of the conversation. Their interactions are mediated by the rules that mediate turn taking or rules of respect for one another. Finally, participants themselves are participants in the open-house event, which itself is part of Oceanside. In this activity system, scientific literacy is neither a property of the individual participants nor something a priori available in the activity system as a resource. Rather, scientific literacy is the contingently achieved outcome emerging from local organization of the different conversations. In the same way, scientific literacy is produced in conversations that take place in other situations in the community, and where individual participants bring different resources based on a variety of socio-, ethico-, and politicoscientific practices. The settlement of controversial issues, as scientific literacy, is an outcome of the dialectic and dynamic conversational processes to which the different elements in an activity system contribute in non-deterministic ways.

Scientific literacy can be thought in terms of the right use of specialists, black boxes, simple models, interdisciplinary models, metaphors, standardized knowledge, and translations and transfer of knowledge (Fourez, 1997). Right use does not imply that decisions have to be made by individuals; right use can be accomplished within collectives that work in their specific ways on the resolution of the problems at hand. That is, right use of the above entities can be made to be a characteristic of situations, such as public meetings or other democratic fora that shape policy-setting and decision-making processes in public arenas. Such a view implies that the task of educators becomes one of enabling situations characterized by a collective scientific literacy rather than thinking about the individual appropriation or construction of knowledge. In the same way, if educators were to think of science as but one fiber next to many other fibers in thread of life, we might focus more on learning as participating in solving everyday (and societally relevant) problems. In our approach, we do not break individuals out of the societal contexts and material settings in which they normally conduct their activities. We do not sever the mediating relations of tools, community, division of labor, and situated rules then forms of activity are observed that are not possible in currently normal circumstances. Thus, learning problems and learning disabilities, made visible when students such as Davie and Steve work in regular (traditional) classrooms, do not exist in settings such as those that we featured here.

Our activity theoretical perspective also allows us to rethink the notion of "zone of proximal development" (Cole, 1985; Vygotsky, 1978) as it relates to conversation as activity and scientific literacy. In activity theory, subject-object relations understood as being, among others, mediated by society. Individual (restricted) actions are only a subset of all (generalized) actions within society (Holzkamp, 1991b). The zone of proximal development, then, describes the difference between the everyday actions of individuals and the historically new form of the societal activity that can be collectively generated" (Engeström, 1987, p. 174). That is, conversations (e.g., during open-house event, public meeting) constitutes zones of proximal development that allow collective bodies to produce and further develop scientific literacy. Students, whether they attend middle or high school, or work in the community as part of their summer jobs, can already participate in these conversations. Such participation could continue, without experienced discontinuities, when they move on to different levels of schooling, take on jobs in the community, or participate as lay persons in a variety of environmental issues at the local, national, or global level (e.g., as members of Greenpeace or Doctors without Frontiers).

Activity theory addresses another problem. Traditional educators are concerned that unless individuals carry knowledge around, it cannot be found in the situations in which they take part. However, from the perspective of activity theory, it does not matter whether some tool (e.g., a graph) is available on a computer or has been internalized by the individual subject. Once the tool is available in the system, it contributes to the activity. The only difference is that, internalized, the use of tools can shift to the level of automatic (tacit), routine operations, whereas as knowledge residing in tools may remain at the level of conscious actions.

Toward science education as lived and life-long curriculum

Current efforts in rethinking scientific literacy have many shortcomings, which impede with the development of achieving their goals of broad participation (e.g., Science for All Americans). Ways of enacting the reform agenda also fail to sufficiently address the wide gap between school and everyday knowledge, and therefore fail to set up a continuity of life-long learning. The reform documents pay insufficient heed to the fact that students constitute a heterogeneous clientele; furthermore it makes little sense to treat citizens as though they were a homogenous group (Jenkins, 1999; Rodriguez, 1998). In the present study, students pursued investigations of their interest, drawing on those tools that best responded to their (intellectual, motivational) needs, and produced a large variety of representations of stream and watershed health.

A central fallacy of the traditional approach appears to be its focus on laboratory science as the touchstone against which science teaching and learning should be compared. Our own early approach was characterized by the idea of science teaching as a form of cognitive apprenticeship to the laboratory sciences that we had previously practiced ourselves (e.g., Roth, 1995). Such approaches teaches students to see the world with the eyes of science rather than to build their own view of the world; it favors students to become conformist rather than autonomous (Holzkamp, 1992). Research among community and health activists overwhelmingly shows that other forms of knowing and relating to the world can contribute to the resolution of urgent problems (e.g., Rabeharisoa & Callon, 1999; Lee & Roth, in press). Thus, it was through the interactions with and contributions by AIDS activists that the traditional scientific protocols for testing new drugs, double-blind treatment control studies, were changed into new, previously unacceptable forms of testing drugs (Epstein, 1998).

In this study, knowing and learning were taken as aspects of culturally and historically situated activity. Learning is discernable by noticing self and others' changing participation in changing social practices. Because interaction and participation cannot be understood as the sum total of an individual acting toward a stable environment, learning cannot be understood in terms of what happens to individuals. Rather, if learning is situated and distributed, educators must focus on enabling changing participation, that is, enabling new forms of societal activity that is collectively generated. We are therefore particularly interested in forms of participation that are continuous with out-of-school experiences and therefore have the potential to lead to life-long learning rather than to discontinuities between formal and informal learning settings.

Science and scientific literacy for the students in this study constituted the outcome of a lived curriculum. Rather than studying to be admitted to higher levels of learning (science as propaedeutic) students actively participated in the social life of their community by contributing to the available database on the health of one local stream. For these students, science was a lived curriculum, in which students "have a feeling that they are involved in their own development and recognize that they can use what they learn. This venture in science curriculum development recognizes the socialization of science and its relevance to how science impacts our culture, our lives, and the course of our democracy" (Hurd, 1998, p. 411). A lived science (technology) curriculum requires a collective endeavor involving not only science but also disciplinary knowledge in the social sciences, humanities, ethics, law, and political science. However, an interdisciplinary approach, which gives science an epistemologically equal place among rather than an epistemologically exceptional status, does not necessarily lead to a different science education. Thus, Hurd continued by listing specific social, cognitive, and personal concepts that each individual has to acquire. We disagree with this approach because it goes against our commitment to truly democratic forms of education (not in the sense of serving capitalist interests) that allow individual members to develop their own representations of salient issues.

Redefining scientific literacy in such ways that students begin to participate in the community may come with considerable political consequences. Thus, when students construct facts not only about environmental pollution but also begin naming and publishing the names of individuals, groups, and companies that perpetrate, communities will begin to change. For example, one middle school student researched the amount of coliform bacteria, a biological contaminant, in various parts of the stream. He presented his results not only at the school and regional science fairs but also during the open-house event organized by the Henderson Creek Project. His report specifies particular sites of pollution and names the farms where the contributed significantly to the contaminant levels.

There is the chicken farm. It [375 coliform count] shows that because of agricultural use right above the test site, there is a lot of coliform in the water. But you are not allowed to do a test. But at the Geoffrey farm, I found 500 coliform per mil, which was way above what it should have been, compared to what happened at the mouth of Graham. So what I am guessing is that somewhere between the mouth of Graham and the farm of the Geoffreys, there is a lot of extra coliform that gets into the waters that causes the high numbers. (Graeme)

Graeme concluded that the chicken farm and Geoffrey's farm were major contributor to coliform counts. Whereas we have no indication that the farmers objected (we do not know what Graeme meant by "you are not allowed to test"), the contribution of children to a community's knowledge resources, and the potential implications for political pressure on farmers and industrialists to change their current practices is evident. Rather than direct participation, some science educators propose school-based mock activities, such as the consensus project model designed to empower student to deal with science and scientific experts on emerging socio-scientific issues by providing them students with relevant experiences, knowledge, skills, and attitudes (Kolstoe, 2000). This project is laudable because the point of departure is not a scientific topic but some controversial real-world socio-scientific issue. Furthermore, the consensus project model highlights the search for collectively achieved solutions and the potential contributions of science in the face of controversial problems. However, we see two major problems with Kolstoe's approach. First, enacting consensus projects in school classrooms reproduces existing separations between school and everyday society; the processes and outcomes of the consensus projects are evaluated in terms of school objectives rather than in terms of their contribution to community life. The students have to play the roles of scientists, environmental activists, or local residents in a pretend activity rather than taking a place in community life more generally. Second, Kolstoe assumes that what is learned during school-oriented pretend activity is somehow transferred to everyday knowing.

Based on our research of science in and for the community, we propose a different way of approaching science and science education, a way that acknowledges the limitations of science—which does not mean that scientific efforts become undervalued. Acknowledging the nature of science as it is and can be practiced in the community opens the door to richer understandings of science as a "profoundly creative and imaginative activity tempered by a scrupulous honesty in the face of experimental evidence" (Jenkins, 1999, p. 708). Such an approach permits groups and communities to enact different relations between scientific and other forms of knowledge, including various forms of situated knowing (e.g., traditional, relational). Rather than privileging disciplinary science we ought to foster situations that allow the negotiation of different forms of knowledge geared to particular (controversial) problems as these arise in the daily life of a community.

Teachers are often held to connect or to assist students in connecting school science to their everyday lives. But teachers experience difficulties in assisting students to make such connections, which has been attributed in part to lacking pedagogical content knowledge (Cajas, 1999). In this very framing of goals and problems for achieving them, the difference between school knowing and acting and everyday activities is acknowledged. The solution to build bridges between formal academic discourse and everyday life remains fraught by the presence of the gap between in- and after-school experiences. Of course, there would not be a gap if the students' activities already constituted an aspect of everyday out-of-school activity. That is, science education transcends traditional propaedeutic approaches that attempted to *prepare* students for subsequent levels of schooling and life after school, and provides students with opportunities to engage in everyday (relevant) activities that shape community and their own identities alike. The issue is one of going about engaging in and contributing to the solutions of everyday-life contentious issues rather than making connections to bridge an artificial divide.

Coda

In our approach, science education moves outside the school and thereby becomes, at least partially, deinstitutionalized (Roth & McGinn, 1997). Conceptually, this deinstitutionalization shares some similarity with the institution of halfway houses or with the group homes that replaced mental hospitals in some countries. In both situations, the members are no longer locked up in institutions (prison, psychiatric clinic) but participate in (limited ways, sometimes under supervision) the everyday affairs of their community. In our situation, students' activities take their place in the community more broadly rather than being something relegated to particular locations (schools) with local and temporal effects. The outcomes of students' work has relevance and contributes to the broader lifeworld that they inhabit together with their parents, siblings, elders, town council members, and others in the community. If science is to be for all, then there have to be opportunities to participate in ways that emphasize students' strengths, address their interests… Rather than setting up situations that bring out inability, disability, and problems and thereby contribute to the reproduction of society, we may conceive of education as one that focuses on the achievements of collectivities, and consider "best teaching strategies" to be those that lead to new forms of collective activity.

When educators focus on creating situations with the potential for scientific literacy to emerge and for life-long learning along trajectories not marked by currently prevailing discontinuities when school boundaries are crossed, new instructional possibilities and difficulties are likely to emerge in non-deterministic ways. Documenting these possibilities and difficulties, as well as knowing and learning that emerge from them, remains virtually uncharted terrain. Much research remains to be done to study the forms distributed and situated cognition take in the approach we propose. Before policy recommendations can be validly made, such research has to show that our proposal can be implemented more widely in a number of different domains and with more diverse student populations than that participating in this research.

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