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Science Education as/for Participation in the Community

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Abstract

In this article, we take up and advance the project of rethinking "scientific literacy" by Eisenhart, Finkel, and Marion (1996). As part of a project of rethinking science education, we advance three propositions. First, because society is built on division of labor, not everybody needs to know the same basic sets of concepts; it is more important to allow the emergence of scientific literacy as a collective property. Second, scientific knowledge ought not to be privileged in democratic collective decision making but ought to be one of many resources. Third, rethinking science education as and for participation in community life sets up the potential for lifelong participation in and learning of science-related issues. To show the viability of these propositions, we provide a case study based on a three-year, multi-site ethnographic research project as part of which we investigated science in the community. Framing our work in terms of activity theory, we provide descriptions of science in a local middle 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 presently existing boundary separating formal schooling from everyday life outside schools.

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 science education reform efforts (AAAS, 1989; NRC, 1996). Educators 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 stipulated 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, p. 409). For many, this has meant using scientists’ definitions as a template for what “science” is, independent of the epistemological paradigm brought to science education reform and independent of the fact that science as it plays out in the community is very different from science when it is isolated in a laboratory (Epstein, 1996; Latour, 1988). Yet science courses continue to be means of pushing students into the world of scientists rather than a way of helping them cope with their own lifeworlds (Fourez, 1997). Eisenhart et al. (1996) therefore point out (see opening quote) that 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 expended, 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 among many possibilities to select and teach in the limited amount of time available, and (c) how to make students transfer science to out-of-school situations. In this paper, we want to push the rethinking of "scientific literacy" further than Eisenhart et al. (1996) had done. We propose to decenter the scholarly debate and to consider 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, it makes more sense to organize learning environments that allow students to become knowledgeable by participating in and contributing to the life of their community, which has the potential to lead to lifelong participation and learning.

We begin our argument by articulating some of the core issues involving the concept of scientific literacy and by introducing a theoretical framework (cultural-historical activity theory) that is well suited to conceptualize, study, and compare human activities across a diversity of settings. We then use school-science-related data from a three-year ethnographic study (also involving environmental activists and the watershed-related activities and practices of various related groups) to provide a case study of one model effort that moved children's science and scientific literacy into the life of one community. We conclude this paper by reflecting on the implications for science education that arise from our work.

Background

We frame our rethinking of science education in terms of the debate about scientific literacy. Scientific literacy is, in our approach, a social practice. In a practice approach, the focus is on levels of participation, division of labor, and knowledgeability rather than on decontextualized procedural and declarative knowledge (Lave & Wenger, 1991). In the same way, we think of science and scientific knowledge in terms of social practice rather than as something that exists in human minds as concepts, skills, representations, and so on (e.g., Roth & McGinn, 1998a). Cultural-historical activity theory is most appropriate for theorizing human activities because it is centrally concerned with the primacy of lived praxis (the structures of which are theorized as “practices”). In the following, we briefly review scientific literacy and activity theory, and then articulate the former in terms of the latter.

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 (e.g., AAAS, 1989). Despite the rhetoric of scientific literacy for *all* students, school science 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 (Fusco & Barton, 2001), 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 (as well as others) may fail in school science exactly because of the nature of science and forms of knowing that are stressed in teaching (Rodriguez, 1998); many students (especially women) who leave science are discouraged by the organizational structure of science including its competitive and individualistic nature and its claims to objectivity, value-free inquiry, and being an isolated enterprise (AAUW, 2002). Unsurprisingly, minorities (e.g., African Americans, First Nations) and women often feel discouraged from studying science because its ways of knowing and everyday practices privilege White middle-class and male standpoints and interactional patterns (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 whom have been squeezed out of science in traditional approaches.

Not everyone agrees that science could or should be for all. 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). The scientific community, facing the potential to be continuously questioned in the public debate (e.g., anti-GMO demonstrations, AIDS activists), might therefore not be interested in a general scientific literacy. In this article, we not only subscribe to the ideal that science is for all and practiced by collectives, but we also propose that “science,” “scientific literacy,” and their roles 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. While most science educators will accept that not every student needs to know how to build a house, how to repair a car, lawnmower, or washer, or how to grow one’s own food in a small garden, they will insist that *all* students need to appropriate (via information transfer or construction, depending on the theory of learning) knowledge of the atomic model, Newton's laws, and other "basic facts" and "basic principles." Thus, the debate over scientific literacy focuses on knowledge, facts, and theories that individuals are expected to posses and exhibit:

> 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)
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> To acquire information necessary for scientific literacy, individuals must comprehend, interpret, and evaluate information and conclusions based on scientific research. (Korpan, Bisanz, Bisanz, & Henderson, 1997, p. 516)

The notion of scientific literacy as the content of individual minds (episodic and semantic memory) is further illustrated, for example, in research that tests how much information visitors remember from a museum visit (Medved & Oatley, 2000). Rather than studying how scientific literacy emerges in practical situations, these researchers attempt to peek into the individuals' minds. Eisenhart et al. (1996) decentered the debate by taking up three metaphors for literacy previously proposed by 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 suggest 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 (Roth & Lee, 2002b). 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; the former is adapted to the complexities of everyday life in the community, whereas the latter only works under the highly-constrained conditions of a laboratory isolated from much of the world (Latour, 1988).

It therefore makes sense to conceive 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 own research, citizen science is 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 (Roth & Lee, 2002b). In the community, however, citizen knowledge is collective and distributed: our lives in society are fundamentally based on the division of labor. If we need advice for a backache, most of us go to the doctor or chiropractor; if our cars or bicycles do not work, most of us go to the car or bicycle shop. In the same way, we can think of science in the community as distributed, making the social organization rather than the individual the seat of knowing and learning (Hutchins, 1995). Thus, although many Brazilian child street vendors do not read numbers (e.g., on the currency bills) or do not perform well on school mathematics tasks, they make profits from buying and selling candy (Saxe, 1991); the phenomenon is better understood by considering knowledge to be distributed across the different social organizations in which these children take part. Likewise, scientific literacy in everyday community life then means to be competent in finding whatever one needs to know at the moment one needs to know it. Our research in one community showed that it is exactly in this way that an environmentalist group concerned about the health of the watershed in which their community lies draw on resources distributed across this community to bring about changes (while avoiding conflict) to attitudes and practices (Lee & Roth, 2003).

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. In such a context,

> [t]he term *learning* simply glosses that some persons have achieved a particular relationship with each other, and it is in terms of these relations that information necessary to everyone's participation gets made available in ways that give people enough time on task to get good at what they do. (McDermott, 1993, p. 277, emphasis in the original)

This implies that science educators no longer seek to stack educational environments to coax *individuals* into certain performances, but that they 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. If we wish science education to be relevant to people's citizenship and their everyday lives, we do well to allow the learners to participate in a diversity of these relations: expecting one set of relations (institutional school) to prepare students for a world of many relations does not make sense. Furthermore, the literature on communities of practice (Lave & Wenger, 1991), which focuses on legitimate peripheral participation and the trajectories people consequently take within such communities, suggests to us that students participating in some community-relevant practice can continue to do so even after they have left formal schooling. Such an approach therefore sets people up for life-long participation, and because of the close association of participation and learning (Lave, 1993), sets them up for lifelong learning. Cultural-historical activity theory is particularly appropriate for theorizing participation and learning in and across multiple, heterogeneous settings (e.g., Chaiklin & Lave, 1993; Engeström, Miettinen, & Punamäki, 1999).

Cultural-Historical Activity Theory

At the outset of this review, let us emphasize that activity theorists use the term "activity" differently than it is often used in education. Consistent with cultural-historical activity theory, we conceive of activity as something that is motivated both at the societal and individual level; activity is a collective system that has a complex mediational structure and often takes the form of an institution. What students engage in at school are tasks, motivated by tangible teacher-set goals to which students often do not subscribe, over which they have no or little control, and which require relatively short-lived actions. 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 studying science in the community, we have successfully used activity theory to frame the water- and watershed-related activities of adults and seventh-grade science students (Lee & Roth, 2002; Roth & Lee, 2002a).

Theories are based on basic ontologies, that is, sets of fundamental entities and processes that define the domain. In cultural-historical activity theory, there are six such basic entities: human subjects (individuals or groups), objects (artifacts and motivations), tools, rules, community, and division of labor. 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, which exists as concrete object and as vision of the forthcoming product, the material conditions (tools, materials), and knowledge of extant material and social conditions (Saari & Miettinen, 2001). For example, an environmental group that attempts, while avoiding conflict, to bring about changes in the attitude and practices of the Oceanside municipality published a call in a local newspaper for community participation in protecting and finding out more about the Henderson Creek watershed.[1] The seventh-grade students taught by one of us decided to follow the call. They chose Henderson creek as the *object* of their inquiry and thereby to construct facts and knowledge (*outcomes*), which they subsequently wanted to make available to their community during an open-house event of the environmental group.

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 birdcalls and journalistic impressions accompanied by photographs. To use another example from our research: the children's choice to focus on Henderson Creek was motivated 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. All entities are constitutive of a culture (or community of practice) and are understood as continuously undergoing historical change.

To think about human activities we propose the analogy of a rope made of threads, which in turn are made of fibers. Thus, communities of practice and society are like ropes

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[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 W̲SÁNEC', consisting of several communities, has been maintained.

and each human being is but a thread, each constituted by sets of fibers (knowledge, skills). Although made up of threads, the properties of the rope cannot be derived from the properties of each thread and even less from the properties of the fibers. Furthermore, the properties of the fibers cannot be derived from the thread or the rope. In fact, although the fibers are discontinuous, threads are extended and the rope (collective, society) is virtually infinite (on the scale of the individual human life). We can then understand a scientific community as a rope, made from a collection of threads, each containing a "science" as a dominant fiber. There is dialectic tension between the nature of thread and rope—and by analogy, between individual human beings and the society of which they are part. To think science, scientist, scientific community, and scientific literacy one always has to think the interplay of the rope (community), thread (scientist), and fibers (science knowledge, skills). Even if an individual thread does not have a mathematics or scientific literacy fiber, he or she is still supported and contributes to the stability of the rope (community): the Brazilian street vendors make profit although they do not read numbers or do school mathematics when examined in isolation of the context within which they normally function.

We understand (necessarily collective) activities and interactions, such as a public meeting, in terms of fibers, threads, and ropes. A collective practical activity is analogous to the rope and individual contributions are no more than the individual threads and fibers. Thus, scientific literacy can be thought of as something achieved at the level of the rope (collective) rather than as a property of the threads (individuals). What is more important is that (a) scientific literacy exists within the collective and (b) scientific knowledge is related in democratic ways to other forms of knowledge. For us, this implies that individual students learn to engage in collective endeavors, even though they bring very different dispositions, interests, skills, and so forth and even in the absence of the "basics."

Rethinking Scientific Literacy

We announced as the purpose of this article the reframing of scientific literacy along three proposals: (a) scientific literacy as a characteristic of collective social situations; (b) scientific knowledge as one among many forms of knowledge; and (c) lifelong participation and learning in and about collective community-relevant issues. We briefly present the three issues in terms of the framework articulated thus far.

In cultural-historical activity theory, agency, knowing, and learning are not properties of individuals but are understood in terms of situated and distributed “engagement in changing processes of human activity” (Lave, 1993, p. 12). Individual agency, knowing, and learning are understood to be subsets of generalized agency, knowing, and learning available to society. That is, human activities (including conversations) are irreducibly social phenomena that are more than the sum of the contributions of individuals. That is, because division of labor and the associated uneven distribution of knowledge and skill across communities are fundamental to the emergence and development of human society (Holzkamp, 1983), we propose, firstly, to think about scientific literacy as a collective rather than individual practice.

Our second point concerns scientific knowledge, which, in a truly democratic context, we view as one resource among many that may be relevant to the issues at hand. Based on previous work relating to (democratic) science in the community (Lee & Roth, 2001), we extend the analogy of rope, thread, and fibers in a second way. In everyday collective endeavors over contentious issues, science is but a collection of fibers along other collections of fibers such as politics, economics, aesthetics, sociology, philosophy, or everyday know-how. Scientific practice and knowledge is but one strand, but a strand that must not attempt to make the rope in its image. 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).

The third point in our proposal concerns life-long participation in collective endeavors, the rope and its strands. If students (threads) learn to participate in a particular strand of collective life, such as environmental campaigning, environmental stewardship, or hatching and raising endangered fish (e.g., Roth, 2002b), their participation can continue beyond the spatial and temporal markers of school life. Participation in, and therefore learning about, issues where science can make relevant contributions can become life-long endeavors.

Over a three-year period, we studied science in one community and, at the same time, cotaught a science unit to three seventh-grade classes. In the course of our work, these science units were explicitly planned to allow participation in a community-relevant issue. In the following two sections, we provide a thick description of this work to articulate our perspective on scientific literacy.

Community Water Problems as Curricular Topic

Eisenhart et al. (1996) suggested that educators need to find and build 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. The emergence of such broader visions is supported when school children focus on issues and problems that are of immediate concern to their own lives and community, because of the coincidence of individual and collective motives (Roth, 2002b). Over the past three years, we recorded and documented many events featuring adult citizens and school students who deal with the water-related problems of one community.

The Community and its Problem

We are, as a small number of other science educators (e.g., Barton, 1998; Barton & Yang, 2000), interested in transgressing the boundaries between school science and science in the community and in allowing both to interpenetrate and support one another (McGinn & Roth, 1999). Our research is therefore conducted both in schools and in the community, where we attempt to identify, as part of an ongoing ethnography, different ways in which science-related issues arise. One study takes place in the Henderson Creek watershed and in Oceanside, the community that lies within this small coastal watershed in the Pacific Northwest. Henderson Creek drains the north end of the watershed, Gordon Creek the south, and they meet in a valley, forming the main stem of Henderson Creek, which then flows west, into the Pacific Ocean. The watershed is located about 25 kilometers from the center of a mid-sized city that continues to expand, pushing suburbia into the rural and agricultural landscapes.

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 non-aboriginal residents, who, with their recent developments, have exacerbated the issue. 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.

As a consequence of these developments, water is shed much more quickly and the water quality declines and water levels become extreme, high in the winter (more than 8,000 liters/second) and low in the summer (less than 10 liters/second). 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 gas stations about five kilometers away.

The Henderson Creek Project (HCP) arose from the concerns about water quality of three watershed residents, a farmer, a professor of environmental law and 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 is an environmental group that attempts to bring about change of attitudes and practices regarding water and the watershed, but without engaging in confrontation as can often be observed with other local but especially national and international groups (e.g., Greenpeace). The Henderson Creek Project is headed by a coordinator and a 5 to 7 member steering committee, and enlists the support of many other people (e.g., hired high school and university students doing summer jobs) and institutions within the region. The group members believe that they work in and against an adverse political climate. The interests of farmers, industry, and other landowners are often opposed to those that motivated the founding of HCP. Since most of the land in the municipality is private, the HCP members feel that building and maintaining good relationships with as many stakeholders as possible is paramount to their success in bringing about desired changes. They attempt to work with farmers, community officials, school and university students, and other residents to work towards change. They also formed a training and support group for watershed stewards with the intend to build continuity of their ideas into the community so that these can persist even if individual members left or if the entire HCP was to disappear.

As we researched a variety of events involving different members and groups of the village community, we came to understand that science is but a strand in the rope of collective community life (Roth & Lee, 2002b). Even when scientists participated in an event, their contributions were always 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 village community entered into conflict over its problems (e.g., Roth et al., 2004). Our cultural-historic activity theory 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; the representations these groups make of the creek, which are the results (*outcomes*) of the activities, are quite different (Roth & Lee, 2002b). Depending on the particular instances of mediating entities (tools, community, division of labor, rules), different discursive and inscribed representations were produced and subsequently contributed to a variety of interactional forums including public hearings, council meetings, and open-house events. Furthermore, the same individuals could participate in different activity systems or take different roles in the respective division of labor—a person might participate both in farming and in environmental stewardship and another person might both be practicing university chemistry and undermining the validity of official chemical analyses of the well water.

Science Education: As/for Participation in the Community

Science educators have been encouraged 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 (Hodson, 1999). Given the water-related problems in Oceanside, it was not difficult to enroll teachers in a project where students would learn science by contributing to the activities initiated by the Henderson Creek Project—investigating the Henderson Creek watershed and contributing the results to the community at large. Over a two-year period, we cotaught with regular teachers science to three seventh-grade classes each lasting two- to four-month. In these classes, students designed and conducted their own projects 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. Fundamentally, we wanted to provide students with the opportunity to participate as active citizens in community-relevant affairs by contributing to the knowledge and representations available in and to the community. Other students at the middle and high school also conducted research in the watershed as part of their involvement in a regionally funded “Streamkeepers” program or in science fair competitions. In this way, students already participated in creating knowledge available to the their community and the Henderson Creek Project. Members of HCP, the authors, parents, and First Nations elders have contributed in various ways to the teaching of the children by providing workshops, talks, and assistance in framing research and collecting data.

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 safe. 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, our emphasis)

The teachers read the article with the students and asked questions about the need for revitalizing the ocean—children had no difficulties in answering given that some parents fished as a hobby or for a livelihood. First Nations students were able to contribute to understand the need for action by comparing their oral history about the abundance of fish in the creek and ocean inlet with their current virtual absence. At the end, teachers and students discussed how to respond to the call by the environmental group and 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 (because of parent involvement, we had six to eight cars and vans available each field day and in each class), the students began framing initial investigations and even entire programs of research.

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 conceived in a traditional way—designing experiments, graphing results, and so forth. That is, our model for school science was influenced by laboratory rather than community science. However, we soon realized that a considerable number of students were attracted by the project but had little interest in measuring series of variables and representing results in the form of correlations. While these students still participated in the data collection, the subsequent data analyses and activities that focused on mathematical representations generally turned them off. Particularly girls and indigenous students felt disenfranchised by such an approach and preferred to generate different forms of knowledge such as film, narratives, photographs, and interviews. 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. (We find this approach more democratic than forcing every student to engage in the same activity in the same way and at the same time.) A large variety of very different representations of the creek and the adjoining areas began to proliferate: there were audio-recorded descriptions, videotaped records of the watershed and student activities, photographs, drawings, and other representations. That is, because we made it possible for students to create representations of their interest and that met their needs, the total representations actually increased and provided a richer image of Henderson Creek and its problems. Furthermore, this change provided forms of knowing and learning that led to an increasing participation of students who traditionally have felt alienated and excluded because science lessons emphasized ways of knowing foreign to them. (For example, science education generally is a form of colonialism to First Nations students [Aikenhead, 2002].) 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.

Parents, activists, aboriginal elders, scientists, graduate students, and other Oceanside residents were an integral part of the science units—they constituted the relevant *community* in the context of which our seventh-graders learned. This community was constituted by an interpenetration of school and village life more generally. 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 of the Henderson Creek Project also contributed by giving presentations, and by assisting in teaching students 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 residents therefore integrated the children's activities with activities in Oceanside 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 model, there is therefore legitimate (peripheral) participation because the motives that drive the activity system share many elements.[2] It is this overlap with the everyday activity in Oceanside (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 already participated in and contributed to social life in the community. It is in the process that learning was occurring.

Because the very organization of traditional science and science education has diminished the resilience of girls, First Nations, and other under-represented groups (Aikenhead, 2001; Hammrich, 2002), we explicitly avoided the reproduction of internal relations and discourses of laboratory (professional) science. Instead, we emphasized "coming to knowing" (Aikenhead, 2001) that validates cultural knowledge and designed the units to emphasize personal relevance, cooperation, interdependence, and observation, verbal expression, and writing skills. Consistent with Aikenhead's recommendations, our students had opportunities for talking within their own personally relevant framework without sanctions for being unscientific and for immersing themselves in their everyday (gendered, Aboriginal) culture as they engaged in their investigations. Thus, students chose their investigations, partners, and ways in which they wanted to represent the results of their activities. They did not have to debate or critique other's representations and interpretations but we assisted them to reflect why others might come to different conclusions. Although we asked students to interpret the data of their peers, we emphasized the value of multiple interpretations rather than

[2] 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.

argumentation, formation of alliances to defeat alternative interpretations, and disagreement. Thus, in the classrooms involved in our studies, students characteristically helped one another in gathering data, understanding details of their collections, interpreting the data, and in formulating future plans of actions.

Student Participants

In this school, 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), nine of whom designated as "special needs students," five because they were "learning disabled" and four of them because of their aboriginal status. In the course of our three-year study in the school, we observed that the majority of aboriginal students were uninvolved and resigned, and generally achieved low grades. A special First Nations resource and help center was created to assist these students. Having been invited by the local band to conduct a workshop in a summer science camp for aboriginal children normally taught by aboriginal people, we were able to see dramatic differences in the involvement of the same children when activities were framed in their native context.[3] That is, the middle school practices appeared to truncate the agency of these students. Teachers also found it difficult to teach at the seventh-grade level because students were often far apart developmentally, some boys and girls having more the appearance of young adults, others looking and behaving more like fifth-grade students.

Researcher Participants

Each in our own way, we believe that our participation in community issues can make a difference and we believe in our fundamentally human capacity that we can shape our lifeworld rather than being determined by it. We believe that we cannot stand on the

[3] 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 has First Nation status.

political sidelines and pretend to write our object through an impartial narrative. 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 (S. 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 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 (W.-M. 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.

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 HCP members and other interested local residents who walked sections of Henderson Creek with different consultants. The Henderson Creek Project 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.

School Science in 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 (e.g., Lave, 1988), science educators have yet to 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.

In this section, we present evidence from our three-year research within school science classes that enacted a curriculum consistent with the same motive that characterizes 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. 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 motive of children's activity integrated well to other immediate lifeworld aspects; this, as critical psychologists and critical educators have repeatedly pointed out (e.g., Giroux, 1992; Holzkamp, 1993) is an indication of empowered citizenship.

Diversity of Projects and Representational Forms

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. That is, students had considerable control over their objects of inquiry and the means used for producing the outcomes of their engagement (e.g., the representations).

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 1). 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 goals were motivated in the same way and by the same concerns that other goals in the community were motivated. Table 1 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 are some of the tools (colorimeter, rules). Not surprisingly, some of the *outcomes* of the student-centered activity system were therefore similar to those created elsewhere in Oceanside by adults or university students. For example, the use of colorimeter, pH meter, or dissolved-oxygen meter all let to numeric representations of stream health (Lee & Roth, 2001). Similarly, middle school students and college students working for the Henderson Creek Project as a summer job produced very similar graphical representations. 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 Henderson Creek Project members to pursue other goals (e.g., getting grants, proposing restoration work).[4]

]]]]]]]]] Insert Table 1 about here [[[[[[[[[

It has been suggested that if the science curriculum allows 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) seldom become an issue (Holzkamp, 1993). Framing their research agendas, having control over their research questions and the form of the representations, our students articulated 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 WSÁNEC' 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.

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[4] On the role of forms in the coordination of participants with quite different backgrounds, experiences, and immediate goals see Star and Griesemer, 1989.

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 cutthroat 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 thirty to forty 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.

We propose to look at such conversation not in terms of one person (Meagan) teaching something to another (Kathy). Rather, we suggest that scientific literacy arises from the order of interaction, the relation between questions and answers. The interview provided an occasion to interact with a central member of the Henderson Creek Project, a person experienced in environmental campaigning and familiar with many technical aspects that affect the health of a watershed. In fact, Kathy had sought out Meagan to conduct the interview; Kathy and her peers owned the project of which the interview was a part. 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-related projects that allowed a scientifically literate conversation to appear—that is, from the choreography of two threads in the context of the rope—rather than chitchat about some other topic

Gabe, an aboriginal student from the local WSÁNEC' reservation, 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 but wanted to work 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.

As Kathy in the previous example, Gabe had chosen the object of his work in this classroom. He was not forced to do some routine laboratory task for the sake of doing the task but rather had chosen something that fit his interest in cognitive needs. That is, he chose not to research the creek itself but to document the research conducted by others. It is evident that he was not just doing something else but also participating in the collective activity of the group, thereby encountering science as a strand in the activities of others. In fact, his journalism contributed to self-reflexivity in this classroom, for science is not just a strand of the events but those participating are giving accounts of what they have done and were presently doing. Science talk and (reflexive) talk *about* science arose here from the interaction of students pursuing different, personally relevant and meaningful goals of their interests. As critical science educators we are interested in facilitating the emergence of such personally experienced, publicly visible, collective praxis rather than making individuals “acquire information necessary for scientific literacy” (Korpan et al., 1997, p. 516) so that they “possess a basic vocabulary of scientific concepts” (Flower, 2000, p. 38).

Some readers may argue that by allowing students such as Kathy and Gabe to pursue activities of their interest and by making the division of labor possible, we contribute to the glorification of marginalization of some groups of students, including women and aboriginals. We counter that such a description arises only in the context where a “cognitive imperialism [that] pervades school science whenever students, particularly Aboriginal students, are assimilated (some would say ‘colonized’) into thinking like a Western scientist in their science classes” (Aikenhead, 2002, p. 288) already exists. Such students are marginalized not because they are women and aboriginals in a value-free context but because they are women and aboriginals in cognitive imperialist context that uses a variety of technologies to bring out differences in the first place (Foucault, 1975; Roth & McGinn, 1998b). Failure and marginalization occur in contexts where individuals and groups have no control; expansive learning occurs where people control the object of activity and the means of production (Holzkamp, 1993). This is the case for Kathy and Gabe, who not only chose what they wanted to do but also how they wanted to do it, the tools and instruments to use, and the assessment of the extent to which they had achieved what they had set out to achieve. In this sense, neither the aboriginal Gabe nor the woman Kathy had been marginalized but rather have become central, active participants in a collective engaged in finding out more about the physical characteristics and health of Henderson Creek.

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, one day we recorded him as 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."

Mr. Goulet: Why did it float instead of sinking?
John: Like this one is too big but if it was smaller
Mr. Goulet: It would have sunk?
John: Yeah, but if it was heavier, then it would have sunk.
Mr. Goulet: Right, so how would you figure out whether that would sink or not?
Tim: We'll say, this will generally sink.
Mr. Goulet: What would be a way to find out? Why would this [hammer] sink?
Tim: Because this is more compact in weight.
Mr. 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"). Importantly, learning was made possible by a resident of Oceanside present to participate with and guide students in producing representations of Henderson Creek.

Some readers may think that the division of labor assigned education to schools and that it is idealistic to expect parents and other community members to get involved in education. We respond that parents and the community cannot abrogate their part in the collective responsibility of education the next generation and thereby contribute to the production and reproduction of society. In fact, the experience of certain schools around the world shows that the involvement of parents, town officials, and community at large provides a context in which students learn even without being taught in the normal way of understanding this term (Roth, 2002a).

Reporting to the Community

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 more interested in qualitative than in quantitative representations of the creek. For example, one of their projects involved a tape recorder, used to record bird songs and verbal descriptions of several sites along the creek, and a camera for saliently depicting some issue identified by the girls. Accordingly, their exhibit contained 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 (Figure 1). The work Michelle and her classmates had conducted in the field was represented in textual rather than graphical, mathematical or other form. A table on the right panel of their exhibit lists the qualitative differences between different parts of the creek. 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, May 29, 1999)

Figure 1. Michelle presents the results of qualitative inquiries she and her peers conducted in and around Henderson Creek—there are photographs, descriptions, and a table in which qualitative differences are articulated and highlighted.

Important aspects of the open-house event were students' contacts and interactions with visitors of all ages. The seventh-grade students and children younger than themselves interacted in ways that 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 as a collective practice. It is in and through the interaction that the adult comes to use the stereomicroscope 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. We do not want to claim that Chris is more knowledgeable than the adult and that Chris' knowledge is somehow transferred or reconstructed by the adult. Rather, we want to claim that it is in the interaction, in the questions and answers that scientific literacy emerges. The adult's questions are as much a part of collective scientific literacy as the answers they solicited from the student. Questions and answers mutually solicit one another, leading to a collective phenomenon that cannot be predicted from individual characteristics. As any other conversation, the topics covered cannot be predicted in advance but emergences from the dialectical relation of individuals that constitute the conversation unit.

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 (colorimeter), the same type of instrument that the university 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 thing 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. In this way, Jodie helped many adult visitors to the open-house event to learn about colorimetry and how to measure the clarity or opacity of water.

"Measures" of "Success"

Enacting science in the community presents severe problems for assessment (Jenkins, 2001), especially when task orientation is replaced by an orientation to social and community values (Fusco & Barton, 2001). For example, one group of Austrian students regarded the formal school evaluation as a "devaluation" of the environmental work that they had done (Posch, 1993). Their own assessment criteria were based on real-life evaluation, as they had encountered it while dealing with the people in the community. 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 seventh-grade 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 invertebrate 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 invertebrates—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), these children participated in the affairs of their local village community and 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 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.

Scientific Education as Everyday Praxis

In this article, we argue for a different way of looking at scientific literacy and use a case study of lessons that provide a context where it makes sense to take such a perspective. We formulate our perspective in terms of three propositions. First, scientific literacy more broadly and scientific knowledge more narrowly are aspects that characterize social activities rather than individuals. Because the division of labor is a fundamental process that links individual life and societal processes, individuals do not need to be knowledgeable in every domain. Rather, they need to be able to participate in collective activity and to locate knowledge when and where they need it. Not everybody needs to be able to bake bread or repair lawnmowers; people simply need to know where to get the bread and where to get the lawnmower fixed. In a similar way, we suggest that not everybody needs to know about chemical concentrations or molecules in fertilizers, but they should know, for example, where to go to get advice on concentrations of nitrogen and phosphorous for the particular problem at hand (e.g., garden center). The focus on participation makes us start theorizing and planning curriculum with collective processes; these can then be interrogated in terms of the opportunities they provide for individual participation.

Second, in a democratic society, all forms of knowledge that contribute to a controversial or urgent issue are to be valued; science is but one of these different forms of knowledge. The photo reportage and interviews of community members contribute to community knowledge in just as important ways as the correlations between stream speed and the frequency of particular organisms. Third, the students participated in activities that are not only alike but also fundamentally oriented to the same goals and in the same context as those of other people in the community. These students participated in an activity system,; they could continue this participation along their entire life spans varying their level of participation according to the needs at the moment. In the following, we encourage readers to think of science education as/for participation in the community; in fact, participation in the collective praxis of a community takes precedence over individuals and science.

Our study showed that children generally participated in activities with similar motives as those of adults, and they participated in a variety of forms of conversations with adults other than the regular teachers. If the motives underlying school science and environmental 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. That is, children who participate in activities that contribute to the knowledge available in their community will develop into adolescents and adults, but they can continue to participate in the activities relating to environmental health without experiencing a discontinuity. 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 Henderson 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, undergraduate 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.

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 [AAAS, 1989]). In some situations, these reform efforts are more damaging then helpful: "colonization under the guise of 'science for all' undermines students' self-identities as Aboriginal people, identities which are fundamentally essential to the economic development, environmental responsibility, and cultural survival of Aboriginal peoples" (Aikenhead, 2002, p. 288). Aikenhead further suggests that this is also the case for other often-disenfranchised individuals and groups, including many white middle-class students. These reform agendas fail to sufficiently address the wide gap between school and everyday knowledge. They 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). In the case study we presented, 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. In this context, different strands can emerge, including those that are characterized by representations and forms of discourse typical for scientific laboratories and scientific communities. The important implication of such an approach is that the standards of argument and rules of interaction cannot privilege a single strand (e.g., science) but need to be appropriate to mediate the contributions of multiple strands. As the example of AIDS activism showed, this changes the ways the processes and products of science, including testing protocols and research finings (Epstein, 1996). Rather than a drawback, such interactions with other strands, lead to more socially appropriate forms of science.

A central fallacy of the common approach to science education is 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. Such approaches teach students to see the world with the eyes of science rather than to build and build on their own views of the world. Such approaches both favor students to become conformist rather than autonomous (Holzkamp, 1993) and constitute a new form of colonialism (Aikenhead, 2002). 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).

In our proposal, knowing and learning are taken as aspects of culturally and historically situated activity. Learning is discernable by noticing self and others' changing participation in changing social practices. It is discernable from the particular relationships that they have achieved with others in their community at large. 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 our case 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" (Hurd, 1998, p. 411). Our venture in science curriculum development recognizes the socialization of students into the community, and relegates to science a place next to other forms of knowledge relevant to culture, our lives, and the course of our democracy. 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. 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 Geoffrey's, 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 are major contributors to coliform counts. This was consistent with and added to information collected by others participating in the Henderson Creek Project and with the complaints we heard from the First Nations band members that the creek, which in the past was an important part of spiritual cleansing rituals was no longer fit to bathe in. 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.

Some readers may question whether Graeme's claims were submitted to the same critical scrutiny as would be expected in the scientific community. But such a question is inherently colonialist because it implies that all parts of society have to conform to the standards of science, which are different from the standards of other strands. We not only believe that the imposition of one set of standards is fundamentally undemocratic but also know that scientists will change their standards as a result of their interactions with an engaged public (Epstein, 1996). Instead we can consider Graeme's work as a product of activity that contributes to and will evaluated by the community more broadly. In the present case, his claims were not only consistent with other claims but also constituted a form of broader community concerns with environmental health.

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 this 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 (Cajas, 1999).[5] Even if such connections exist (e.g., in simulated problem contexts), the problem solving activity may still be unrelated (e.g., Lave, 1988). The solution to build bridges ("connect") between formal academic discourse and everyday life remains fraught by the presence of the gap between in- and after-school experiences. Rather than pursuing the making of connections, we argue that educators should involve students in the real thing. There is no gap if the students' activities already constitute 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

[5] In this very framing of goals and problems for achieving them, the difference between school knowing and acting and everyday activities is acknowledged.

solutions of everyday-life contentious issues rather than making connections to bridge an artificial divide.

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 strand of fibers next to many other strands in rope of societal 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.

Coda

When educators focus on creating situations (a) with the potential for scientific literacy to emerge from collective praxis, (b) where science is but one strand of more encompassing democratic forms of life, and (c) where students engage in everyday community-oriented activity, 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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Table 1

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	roles in research team (timer, releaser, measurer)	correlation between speed and profile
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	roles in research team, role in knowledge production of community	Classification and frequency of organisms; stream speed
Michelle et al., Kathy et al.; Chris	Henderson Creek, shore	cassette recorder, camera	Teacher, Michael, Stuart, Oceanside	aesthetics	roles in research team, role in knowledge production of community	radio-like reportage, slides, web site
Gabe	student researchers	videotape	class	Quality of informational content	Role as "historian" of knowledge constructino	Processes of investigating environmental health
Jodie et al.	Henderson Creek	Dissolved oxygen meter, Serber sampler	Teacher, Michael, Meagan, Oceanside	for use of D-O meter	roles in research team, role in knowledge production of community	Dissolved-oxygen levels, organism-type/oxygen-level correlations