Learning Science in/for the Community°

Wolff-Michael Roth

University of Victoria

For some time now, I have argued that science education needs to be deinstitutionalized to overcome the deep crisis in which it currently finds itself. In the present paper, I outline ways in which such deinstitutionalization may be thought and enacted in science teaching and science curriculum design practice. Activity theory is proposed as a framework to conceptualize different activity systems and their contradictions. Practical examples from my own teaching of an environmental activist unit and designing a curriculum appropriate for indigenous peoples are provided to show a science education that situates itself in the everyday world of the community.

> The philosophers have only interpreted the world, in various ways; the point is to change it. (Marx, 1969, p. 15)

Science education (as other aspects of schooling) is in a deep crisis. Despite the rhetoric that knowing science (the scientists' way) is a prerequisite in an increasingly technological world (e.g., Hazen & Trefil, 1991), people not only make a good living without knowing science but also often proudly proclaim their ignorance. That is, in everyday experience, scientific knowledge, at least the one prized by science educators and science teachers, is not as necessary as this is portrayed in the literature of the discipline. In contrast to the traditional rhetoric, science education can be seen

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° Prepared for the congreso Enseñanza de las Ciencias, Barcelona, Spain. All correspondence concerning this paper should be addressed to Wolff-Michael Roth, Lansdowne Professor, Applied Cognitive Science, MacLaurin Building A548, University of Victoria, PO Box 3100 STN CSC, Victoria, BC, Canada V8W 3N4. E-mail: mroth@uvic.ca. Tel: 1-250-721-7885. FAX: 1-250-721-7767.

as but one of the tools of a bourgeois society to reproduce itself by shaking students, often of specific backgrounds (females, minorities, or economically disadvantaged), out of learning trajectories that could lead to scientific and technology-oriented careers (Roth & McGinn, 1998). Knowing the Krebs cycle, the difference between meiosis and mitosis, or Newton's three laws, in most cases, contributes very little to the successes and failures that make our everyday lives. Even most scientists are not experts to the extent sometimes claimed; asked questions about concepts or graphs slightly out of their immediate research interests, cannot provide the standard answers (Roth & Bowen, 2001).

Schools fail to foster the development of but a small number of individuals who become scientists, engineers, or technicians. Nevertheless, one can find an increasing number of instances where everyday folk band together because of their common interest in some controversial issue and to assert the value of their (local) knowledge against often hegemonic scientific discourse (e.g., Epstein, 1995; Lee & Roth, 2001b; Rabeharisoa & Callon, 1999). Thus, individuals and groups without scientific background engage in environmental-, AIDS-, or health-related activism and, in the process, come to establish themselves as obligatory passage points for other, often more powerful actors in the community[1].

Increasingly, a few science educators call for different ways in thinking about the scientific literacy and, in particular, about what and how we ought to teach school science (Hodson, 1999; Jenkins, 1999). From my perspective, many of the new proposals change little because, despite the changes proposed, students continue to focus on learning for school rather than on participating in meaningful activity and learning in the process of doing so. For example, one curriculum innovation allows students to reenact consensus making in the classroom (Kolstoe, 2000). The problem is that consensus making in the classroom is not for real, it is an ersatz activity that has no consequences other than assisting teachers in constructing grades, subsequently used for determining whether students can continue their studies in the career of their choice (Roth & McGinn, 1998). School science is problematic in that it

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[1] "Obligatory passage points" are sites of power or pressure points in societal processes (Latour, 1987). Those located at these sites or points wield considerable power.

focuses on learning concepts and theories independent of situations in which they are useful. In contrast, learning is almost never the focus in everyday activity outside schools; rather, we learn incidentally, while engaging in relevant, meaningful, purposive, and responsible action.

In his eleventh thesis on Feuerbach, Karl Marx made the now famous comment that opened this article: the purpose of activity is to make changes in the world that we inhabit. Furthermore, these changes require that we understand the world, which is possible only if we encounter it in daily praxis (Bourdieu, 1980; Mao Ze Dong, 1967). I also prefer action to withdrawn ("fly-on-the-wall") understanding. My own predilection lies therefore with science education that not only prepares for (e.g., Kolstoe, 2000) but also (and more importantly) engages in responsible action (e.g., Hodson, 1999). This is science education at the final (fourth) level of sophistication in an issues-based approach that involves caring for:

> A politicized ethic of care (caring for) entails becoming actively involved in a local manifestation of a particular problem, exploring the complex sociopolitical contexts in which the problem is located, and attempting to resolve conflicts of interest. (p. 789)

When students begin to care for specific situations and entities in the same way that others in the society do, they no longer do tasks that serve to sort them but to actively change (and therefore understand) the world that they (we) inhabit. Students' (incidental) learning is meaningful because their own actions are concrete realizations of the generalized, societally mediated possibilities of acting and changing the world. Students experience themselves as (decidedly human) agents who understand and shape their life situations through concrete realization of their power.

Although my thinking evolved out of a practice of teaching science in different ways, a praxis that I subsequently theorized in new terms, I begin this article with a description of a conceptual framework that explains why I do what I do. Subsequently, I work out some of the details of teaching science and designing curriculum by providing detailed description of my ongoing research. This research is concerned both with understanding everyday ac-

tivity from sociological perspectives and with articulating and trying out possible implications for school curriculum.

Activity Theory

In my work, which is concerned with knowing and learning science and mathematics in everyday settings (of which school is but one), activity theory has shown to be an important tool for thinking about similarities and differences between contexts. Activity theory is non-reductionist in that it uses whole activities as the basic unit of analysis (Leont'ev, 1978). Here, "activities" does not refer to the tasks characteristic of schooling, motivated by goals to be accomplished by individuals or groups of students; rather, activities are characterized by motivations at the societal level. Farming, schooling, and selling goods all are typical activities organized as activity systems.

At one level, activity theory is concerned with the *production*, *consumption*, *distribution*, and *exchange* of goods, knowledge, etc. (Figure 1). To analyze these processes, activity theorists identify six basic entities: *subject*, *object*, *tools*, *community*, *rules*, and division of *labor* (Engeström, 1987). However, activities are not analyzed in terms of individual entities, or even in terms of pairs of entities. Rather, activity theory recognizes that the relationship of each pair of entities is mediated by a third entity. Thus, when a group of seventh-grade student takes on the task of representing a creek in their community, the *outcome* of their actions will depend on the *tools* (i.e., means of production) that they have at their free disposition. Thus, when three boys use an orange, a stop watch, and a yardstick (*tools*) to determine stream speed (*object*) and a D-net (*tool*) to collect invertebrates (*object*), they may (perhaps with a little help) eventually present a graph that shows correlations between the occurrence of different organisms and stream speed (*outcome*). When a group of four girls decides to use a taperecorder, a camera, and a bird guide (*tools*), they may (perhaps with a little help) produce an illustrated classification of birds that inhabit the area near the creek (*outcome*). I advocate that students have free choice over the *objects*, means of production (*tools*), and division of *labor*. In my observations, if teachers exercise too much

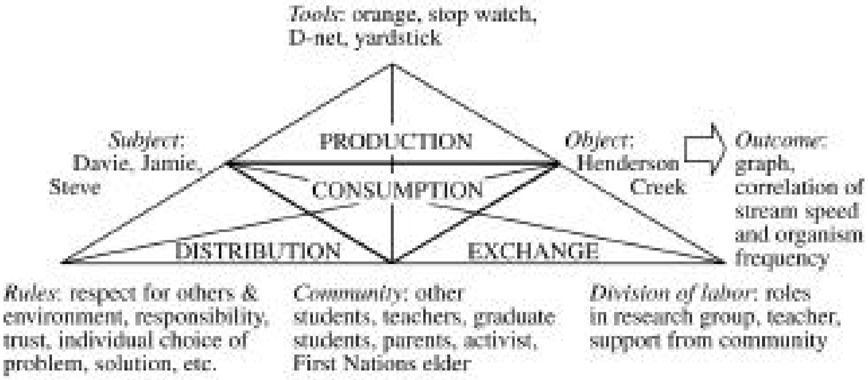

Figure 1. Activity theoretic representation of children's environment-related research.

control over the means of production, students often become disinterested in pursuing investigations.

In contrast to other theories of knowing and learning, activity theory conceptualizes activities as unfolding from the dialectical relations between (mediated) pairs of basic entities. Activity theory recognizes that a change in one or more of the basic entities changes existing relations and, therefore, knowing and learning as they are assessed by the observer. For example, Lave (1988) showed that the same individuals who exhibit near error-free performance on best-buy problems in the supermarket exhibited lower performance on simulated problems just outside the supermarket. Performance decreased even further on best-buy problems that were presented in paper-and-pencil format. I do not have the space here for conducting a full analysis of this study here, but readers can easily reconstruct the differences by looking at the three situations in terms of activity theory (Figure 1).

To visualize knowing and learning that will be attributed to an individual (subject), I use the analogy of thread and fiber (McDermott, 1993). Thus, an activity can be thought of as a thread made up of many different fibers, including the six basic entities; when the fibers are twisted or woven together, they form a thread much stronger and with different properties than any individual fiber alone or in combination. What I find interesting about this analogy is that the properties of the individual fibers cannot be derived from the properties of the thread; conversely, the properties of the thread cannot be derived from any individual fiber or the sum of all properties. However, current educational practices often use the outcomes of particular testing situations (thread) and attribute them to the individual (subject), disregarding that the same individual in a different context may show significantly different levels of performance (McGinn & Roth, 1998; Welzel & Roth, 1998). Adding or providing choices over tools, assigning tasks to groups (division of labor), or allowing choice over the object all will change the thread (activity) and therefore the levels of knowing and learning subsequently re-attributed to the individual subject (Roth, 1998).

The analogy of the thread and its fibers allows us to understand why individualistic knowledge, in the way science educators currently think about it, is not necessary to do well in the world. As fibers, we contribute to the thread; the actions of all individuals in an activity system are concrete realizations of a generalized action potential. Division of labor and material world (object, tools) enable actions that go far beyond what individuals do on their own in the isolation of a psychological laboratory. The thread of everyday activity, in fact, stabilizes each fiber even if it does not have the properties of the thread or other fibers. In this way, for example, Brazilian street vendors of candy return each day having made a profit buying and selling candy even though they cannot read numbers (including the denomination of the bills they use) or do school-like calculations (Saxe, 1991).

These considerations make it quite clear that there are problems with thinking about school as true preparation for life. If knowing does not easily move across activity systems, then critical educators have to think about setting up contexts that are continuous with everyday activities. For example, participating in environmental activism, contributing to a community knowledge base about environmental health, or running a hatchery are all activities with considerable importance to everyday life, at least here in British Columbia where I live (Roth, in press). Once students participate in everyday activities, many possibilities for the involvement of adults (parents, aboriginal elders, activists, or scientists) with students. At the same time, students can participate with these other people outside the school, for example, by exhibiting during open-house events in their community, contributing to websites of environmental activists, or by writing newspaper articles (Lee & Roth, 2001; Roth & Lee, 2001). Through this participation in everyday activities, young people (subject) contribute to, and thereby change their community while they are students. They both reproduce their community and produce it in new ways. They participate in legitimate peripheral ways in shaping the conditions of life in their community[2]. Students' actions are authentic not because they resemble everyday practice but because they are part of everyday practice.

As a critical educator, I am interested not so much in individual adaptation to existing conditions but in collective efforts of changing our condition (e.g., society). Therefore, it makes sense to think about creating situations, activity systems, in which knowing and learning are enacted collectively rather than about creating learning opportunities for individuals (an approach that favors middle-class students). That is, I am interested in fostering collective development, which provides opportunities for individual development, rather than in reproducing an inequitable society where opportunities are limited to a few, usually of white middle-class and bourgeois background. For example, as a critical educator I am interested in creating the conditions for scientifically literate conversations, which I understand and analyze as activities. As other activities, conversations are like threads, whose properties cannot be derived from the properties of individual fibers (i.e., individual student utterances). I can therefore no longer be concerned (if I ever was) with transferring knowledge to individual heads. Rather, I allow scientifically literate conversations by supporting the emergence of appropriate combinations of subject (individuals or groups), objects, tools, community, division of labor, and rules and the mediated interactions involving triplets of these items.

In the following two sections, I want to flesh out how these ideas look like in educational practice. The first example comes from a research project in which I taught science for several years in a middle school in my community, which experiences severe

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[2] Lave and Wenger (1991) point out that "peripherality" is a positive term, to be used as an antonym to unrelatedness and irrelevance to ongoing activity. When peripherality is enabled, it is associated with a way of gaining access to knowledge resources through growing participation in relevant activities.

problems with the quantity and quality of water it has available. The second example comes from an ongoing project where my fellow researchers and I are thinking of ways in which traditional (indigenous) ways of knowing can become starting points and anchors for possibly useful formal scientific knowledge (tools). In both projects, our focus is on issues-oriented education where the usefulness of science has to be established on a case-by-case basis, by students as much as by teachers.

Activism for Environmental and Community Health

Context

One of my projects is concerned with science and science learning in the community, primarily focusing on environmental activism both as everyday activity and as context for school science. My doctoral student Stuart Lee, a trained biochemist, has become a practicing member of an activist group that attempts to change policy and people's practices pertaining to the environmental health of Henderson Creek within the community of Oceanside, where I am also a resident (e.g., Lee & Roth, 2001b). As part of my contribution to the project, I have taught science to several seventh-grade classes at Oceanside Middle School, where students generated knowledge that they contributed to the community through their exhibits at an open-house event organized by the activists (e.g., Roth & Lee, 2001a). The environmental activists and students learn science by focusing on stream and watershed health and its sometimes-severe problems with quantity and quality of water that is threatening Oceanside.

Oceanside is located in the Henderson Creek watershed. In Oceanside and the watershed as a whole, water has been a problem for many years. Despite being located on the West Coast, Oceanside has a relatively dry climate (about 850 millimeters of precipitation per year) with hot dry summers and moderately wet winters. Concomitant with the climate, recent developments have exacerbated the water problem. Farmers have straightened the local creeks thereby decreasing the amount of water retained in the soil available for filtering into and supplying the aquifer. At the same time, the farmers draw on the creek and groundwater during the dry summer months, further increasing the pressure on the valuable resource. Other residents have individual wells that draw on the aquifers. Their water isbiologically and chemically contaminated during the dry period of the year so that they drive 5 kilometers to the next gas stations to get useable water. Urbanization and the related increase in impervious surfaces (pavement), loss of forest cover throughout the watershed and along the stream banks, loss of wetlands and recharge areas, and the loss of natural stream conditions further worsen the water problem.

In addition to the decreasing amounts, the water has been affected by human activity in qualitative ways as well. 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 community 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.

An environmental group arose from the concerns about water quality. The actions of the group include monitoring water quantity and quality or contributing the rewriting of community policies related to Henderson Creek, the watershed, and the quality and quantity of water. The activists also created and actively promote a stewardship program, build riffle structures in the stream to increase cutthroat trout habitat, build fences designed to protect the riparian areas, and monitor the number of cutthroat trout in different parts of the creek. Other activities include replanting riparian areas for increased shading to result in a lowering of water temperature more suitable for fish. The activists are also engaged in educational activities, which includes giving presentations throughout the community or assisting children in their Henderson Creek-related investigations. Every now and then, a newspaper article features the work of this group. It is with these newspaper articles that I have been beginning the science units at Oceanside Middle School, particularly an article that calls for the community to contribute to the currently available knowledge and direct actions to understand and change the health of the Henderson Creek watershed.

Learning Science by Producing Knowledge for the Community

Given the urgency and importance of the water problems in Oceanside, it was easy to convince the principal and a few teachers at Oceanside Middle School to participate in a study where students would learn science by investigating the Henderson Creek watershed. I offer interested teachers to coteach[3] a unit with them, which means that we take collective responsibility for planning, enacting, and evaluating the curriculum.

Sparked by their desire to help the activists and the community, students volunteer to clean up the creek and to investigate its various facets. They design and conduct their own investigations at different parts of Henderson Creek, which they ultimately report, upon my suggestion, to the community during the annual open-house event organized by the environmental activists. The idea underlying these lessons is putting students in a situation where they become active citizens who contribute to community life.

This way of organizing the science lesson makes it interesting for other members of the community to participate in various ways. That is, students produce knowledge in the context of a community (Figure 1) that is much larger than “classroom community” characteristic of most educational practice and theory. For example, members of the activist group give talks, participate

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[3] I have written extensively on coteaching, a way of learning to teach by teaching at the elbow of another (Roth & Tobin, 2001). Coteaching is, as the present work, grounded in activity theory.

with students in collecting and interpreting data and, in the process, assist them in learning to use such instruments (i.e., tools in Figure 1) as dissolved-oxygen meters or Serber samplers. Some parents assist by driving children to their research sites and others provide assistance to student investigators. Aboriginal elders give presentations, middle and high school students who already have already gained research experience assist in teaching, and several graduate students of mine assist the children in framing research and collecting data. This participation of community members also changes the traditional division of labor (Figure 1), which leaves schooling to teachers and school administrators and excludes others who validly and competently could contribute to such an enterprise.

Consistent with my belief that emancipation comes with control over the means of production, the students in my classes frame their own investigations and choose the tools (e.g., instruments, computers, or camera). It comes hardly as a surprise that within each class, students produce different representations of Henderson Creek and its surroundings, all legitimate, but contributing in different ways to understanding the creek and its problems. Table 1 features some of the student groups (subject), the tools they used, others who participated with them in the activity (division of labor), and the outcomes that they produced. Because they were in control of much of the activity system, including the objective for a particular investigation and the means of production (tools), they are generally motivated by their work (rather than by the teacher) and designed an increasing number of investigations. In the following, I provide a few examples from the work of the children in my class.

When students pursue investigations of their own design, their eyes and minds are fully engaged, productive, and absorbed by their interest—which is not unlike what can be observed everyday in factories when workers have the opportunity to contribute to the shaping of their workplace. Table 2 provides a glimpse (here in the form of an excerpt from Shannon’s notes) that the unit provides students with rich experiences during one afternoon in the field. These excerpts document questions, observations, and future directions that opened up and outlines completed actions.

Table 1: *Differences in tools, division of labor, and community lead to different outcomes*

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 (timer, releaser, measurer)	correlation between speed and profile
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	Role Davie and teacher in scaffolding investigation	Classification and frequency of organisms; stream speed
Michelle et al., Kathy et al.; Chris	Henderson Creek, shore	Cassette recorder, tape, camera [photo]	Teacher, Michael, graduate student, Oceanside	Accurate verbal descriptions,	Roles in research team	radio-like reportage, slides, web site
Gabe	Other students	Video camera, tape	Class, Oceanside	Fairness in representation, use of camera	Role as reporter of process	Processes of investigating environmental health
Jodie et al.	Henderson Creek	Dissolved oxygen meter, Serber sampler	Teacher, Michael, Meagan, Oceanside	repeated measuring and averaging, sampling consistency	Roles in research team	Dissolved-oxygen levels, organism-type/oxygen-

Some of the students are interested in producing scientific representations in the forms of graphs, bar graphs, charts, and tables. We support these students by allowing them to learn the use of new tools on a just-in-time and as-needed basis—we found that this is the best and highly motivating way for students to conduct very interesting and very competent investigations (Roth & Bowen, 1995). Thus, when the students in a group decide that they want to look at the relationship between the frequency of different invertebrates and stream speed, I make sure that they use the stop watches in an appropriate way. I also ask students how they new tools on a just-in-time and as-needed basis—we found that this is the best and highly motivating way for students to conduct very interesting and very competent investigations (Roth & Bowen, 1995). Thus, when the students in a group decide that they want to look at the relationship between the frequency of different invertebrates and stream speed, I make sure that they use the stop watches in an appropriate way. I also ask students how they want to measure stream speed. want to measure stream speed. When they suggest measuring how long it takes for a floating object to move a certain distance, I ask them whether they think that

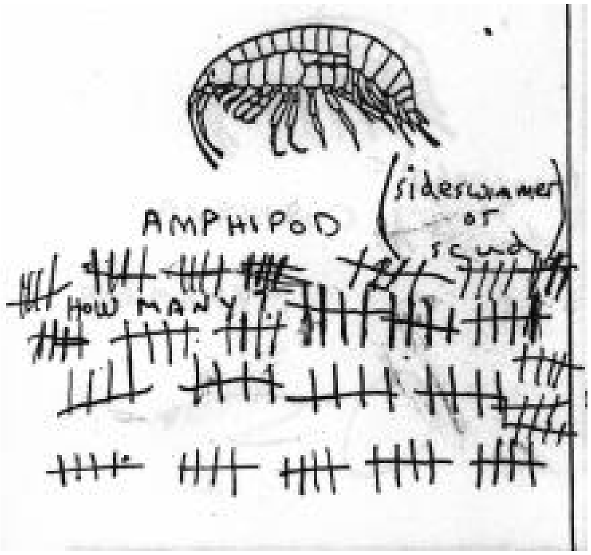

Figure 2. Drawing of organism and tallies used to count the number of organisms seventh-grade students captured in their Serber sampler.

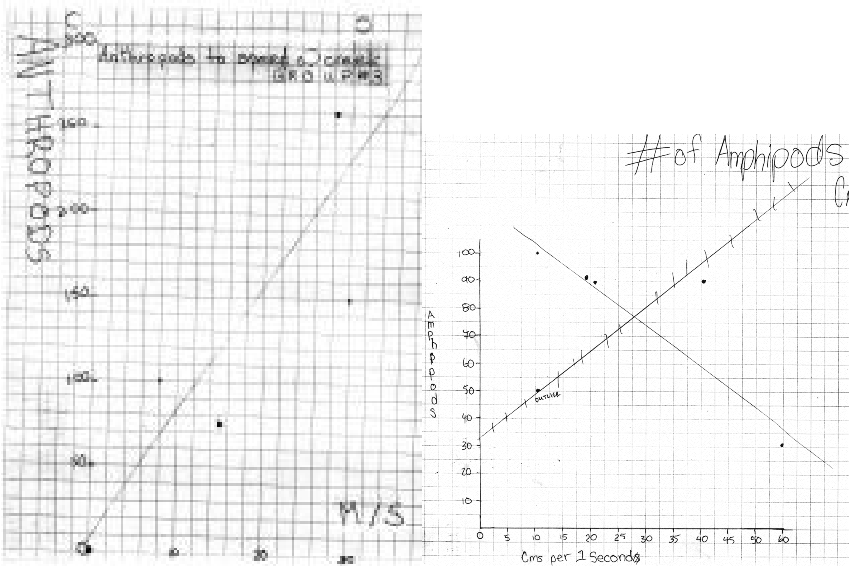

Figure 3. Graphs constructed by seventh-grade students to see whether there are correlations between stream speed and the number of particular organisms caught in the Serber samplers.

there are differences between floating objects of different materials (e.g., a stick, a piece of Styrofoam, or an orange). Although they may begin with wild guesses, they learn in the course of their investigations that a piece of styrofoam may be pushed by the wind, or an orange may get stuck in shallow parts of the creek. That is, in the process of their inquiry, my students learn a great deal about how to make an investigation work despite the continuous and unforeseen problems that arise in the process. In the end, one group recorded time and distances, sampled the creek in different spots for invertebrates, calculated speeds, grouped and counted the microorganisms (Figure 2), and produced line graphs for different organisms (Figure 3).

Figure 2 shows a side-view drawing of an amphipod; this and other drawings assisted students in classifying and sorting the invertebrates and, as shown, to count each incidence. These were later entered in data tables and subsequently plotted. I assisted students in interpreting their results, sometimes by helping them to think of their data points in terms of trends, and asking them to

Table 2: One student's list of activities and things she learned during the field trip on April 16, 1998

What I Did and Learned
– Researched three different sites, pollution
– What sites look like (grass, trees)
– fish population decreased 100 years
– Testing to see which bugs like what water
– Working with university and Institute of Ocean Sciences
– Interviewed the mayor and ocean sciences rep
– Used to be spawning creek for salmon, only one fish found now
– Different places on sites: sandy or grassy or shallow site
– Used D-nets, microscopes, water sampler, buckets, nets
– Measuring speed of creek
– Measuring width of creek
– Testing water temperatures in different places
– Fish survived in cooler water
– Measure overhang
– Measure dissolved oxygen
– Seen what center of stream was made of
– Riffles get water flowing faster
– Farms use water in spring and summer
– Found dragon flies, sun fish, crayfish, leeches, damsel flies, dragon fly larva
– Mostly found anthropods
– Animals have to be placed in ice overnight; always return them back to the creek

draw trend lines. Sometimes (Figure 3b), they make interpretations that differ from those that one of the adult scientists may have made. These scientists then engaged students in an exchange, often involving the concept of "outlier." Students ended by drawing conclusions such as "There are more anthropods where the water runs faster" or "There are fewer amphipods when the creek goes faster."

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. They presented descriptions and photographs in the form of a website, which the visitors could peruse at the event because the children had brought a computer. Other children presented posters, con-

Table 3: Excerpt from the report of one group of students

Henderson Creek

Every second Tuesday, our class has been going to Henderson Creek in three different spots—Community Park, Molson Road, and Oceanside Farm. In the different parts of the creek we looked at the bugs because certain bugs only live in a high pH level, low pH level or a perfect pH level. We're trying to find out what the pH level is in Henderson Creek. With these tests we can find out how many bugs are in the water and how healthy the creek is.

Molson Road

Molson Road has a 75% overhang of trees and plants. In the summer there is a 100% overhang in some spots. There are lots of side swimmers and worms in the creek. There is a 50% deciduous and 50% coniferous vegetation. Molson is one of the most natural and healthiest sites. On half of the creek there are trees and on the other half there is nothing. In the creek at Molson road, there were fish eggs when we were there. We laid out a fish trap but didn't catch any fish. Molson also has a good habitat because it has all of the things that the fish, animals, and bugs need to live are there: riffles and pools and calm current.

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From interview with the mayor

Question: Did you know that there are a lot less fish living in Henderson Creek?
Mayor: Yes, I am aware there are less less because I used to go fishing in Henderson Creek when I was a kid and there used to be a lot of fish. It would be nice to have that many fish again, so you kids could go fishing.

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taining the results of their observations or interviews with community members (e.g., Table 3).

After the unit came to an official end with the open-house event, the result of their work was published in the local newspaper and on the website of the environmental activists (Table 4). Thus, both through their exhibits during the open house and the subsequent publication of their findings, the outcomes of the students' production entered the distribution and consumption process (Figure 1).

The open-house event and the subsequent publications were key points in the unit because students' work became legitimated and legitimate as the community members accepted what they had done. The following comment by a student was rather typical.

Table 4: Excerpt from the environmentalists' website describing the work of students

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.

> I worked hard in helping my group members out with the model, the home page, and presenting the picture board. In this project I learned that there are invertebrates in the creek, I also learned where Henderson Creek is located. I never knew that the creek through Community Park was connected to Henderson Creek. I noticed that since the Henderson Creek article was published in the Peninsula News Review that the public has noticed the creek. (Brandon)

To the children, the science unit was successful not because they received high grades but because the unit was useful and contributed to community life. They began to notice the creek and its problems; they also remarked that the community (their parents and relatives) began to notice it. Students' actions had further impact in the community, as the environmental activists told me, because their presence in and contributions to the open house brought a greater proportion of community members (parents, family, neighbors) to the events.

In concluding this section, it has to be remarked that in activity theory, "consumption" does not only refer to consumption (absorption) of the products of labor but also to the production of individual subjectivity (Engeström, 1987; Holzkamp, 1991). That is, while they produce knowledge in and for the community, the students become legitimate peripheral participants in the life of the community. Whereas in traditional schooling, test outcomes are used to construct hierarchies of students (subsequently used to attribute various types of merits) my environmental activist unit leads to the construction of student citizens through participation in community-relevant activity. That is, my unit contributes both to the reproduction of society and to its renewal (i.e., production). In the collective production of new representations and knowledge, students form identities from the intertwining of the different entities of their activity system into a thread. The outcomes of this thread are often reattributed to the children, who see them as their productions, their achievements. The fibers thereby reattribute properties of the thread that they helped construct back to themselves.

(Ethno-)botany and the Economic Revival of Aboriginal Communities: An Example of Curricular Reflection

Some readers may suggest that environmental activism would not work in their context. I do not want to suggest that it would work everywhere. But environmental activism is not the only activity system of which children can become part and, as they pursue goals, learn science. There are many other contexts that allow students to participate in societally relevant activities (see, e.g., McGinn & Roth, 1999; Roth & McGinn, 1997). My readers may wonder how to select such situations. Ultimately, it will always be up to the teachers and their students to identify contexts suitable for the needs of all those involved. Because particulars are highly contingent, a general recipe is almost if not entirely impossible. However, I provide the following example from my recent work to illustrate the curricular thinking in which I engage before actually teaching a unit.

Context

As a sociologist of science, I am currently part of a large research project, Coasts Under Stress, involving more than 60 researchers, mainly from the University of Victoria and Memorial University (St. John’s, Newfoundland). The project involves scholars from the areas of natural and social sciences, humanities, business, law, and education attempting to work with coastal communities that are under stress largely because their traditional single-resource economies have been disrupted in recent years. Among others, we work with different First Nations to understand their situations (historical and social analysis) and to both work towards new economic solutions and assist young people in learning and making appropriate career choices.

In one community, I work with my colleague Nancy Turner, an ethnobotanist who has been collaborating extensively with different Northwest Coast Nations to identify and record their traditional knowledge pertaining to plants (e.g., Turner, 1995). Together with Nancy Turner and the elders and teachers of the aboriginal community, I am interested in articulating ways that allow indigenous students to draw on their heritage, local knowledge about plants, and provide a context in which Western science might be useful. (Whether it is or can be has to be worked out in the process of our research with the people of the village.) We view Western science as but one tool in the activity system of the aboriginal people. That is, we view Western science as but one fiber whose contribution to the thread of aboriginal life has to be evaluated in the concrete conditions of this First Nation. Here, I want to engage in curricular reflections (from the perspective of activity theory) that prepare us to work in and with our aboriginal community.

Activity theory as laid out in the beginning of this article provides a suitable starting point for thinking about science in the context of a curriculum that begins with and is based on traditional ecological knowledge. Because of its importance to aboriginal ways of life, seaweed, the practices of gathering, drying, and consuming it constitute an excellent context for designing curriculum and for evaluating the use of Western science in the context of an aboriginal curriculum.[4] Furthermore, these practices constitute

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[4] Different types of seaweed have been—and still are—important plants in the lifeworld of aboriginal people around the world. Here, I focus on the Pacific Northwest coast, particularly British Columbia. However, aboriginal Australians such as the Ngarrindjeri, also used seaweed for making, among others, shelters (e.g., http://www.tafe.sa.edu.au/institutes/onkaparinga/about/abhist.shtml). A good starting point for interested readers are the seaweed websites:

a context for exploring whether and how Western science can contribute at all to the thread of aboriginal life. Because seaweed also has important economic implications in the Western world—shown for example, by the deliberations about imposing limits on indigenous harvesting of this important food group in the United States and India—there exists a potential for the usefulness of Western science as well[5].

The Importance of Seaweed

Seaweed has been and still is—an important part of the life of northwest coast First Nations people (Lewallen, undated; Simonsen et al., 1997). Although told by an elder from a different community and a different Nation than the one Nancy and I are working with, the following quote testifies to the importance of seaweed to the Northwest Coast peoples.

> They [forefathers] took seaweed or ŁEKES at that time [April-May]. It grows on rock between high tide and low tide. When the tide is partly out it comes out of the water, and in some places it grows very thick, and of course our people harvested it. They would pick ŁEKES and spread it out in the sun to dry.
>
> They had to be careful it didn't get rained on, because fresh water would spoil it. It would turn bad. If it looked like it was going to rain they would have to run out and cover it or pick it up and get it out of the rain. That was another nourishing food. After it was dry, it was pressed into blocks; pressed and compacted and put away for the winter. In the winter time it would be taken out and used in cooking or just eaten the way it was. (Elliott, 1983, p. 24)

One specific seaweed, Giant kelp (macrocystis inegrifolia Bory), was important not only because it could be eaten by itself but also

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http://www.seaweed.net/ and http://seaweed.ucg.ie/. A searchable database is available at: http://www.algaebase.com/.

[5] In India, such discussions are referenced in a workshop report to be found at URL http://sdnp.delhi.nic.in/nbsap/ecoregions/eastcoast.html; in the US, the status of the bill lifting some restrictions on seaweed harvest are contained in Bill LD#053, the progress of which can be followed on the website URL: http://janus.state.me.us/legis/status/gateway.asp?LD=553. (Accessed: May 29, 2001)

because Pacific herring deposit thick layers of eggs (spawn) on both sides of the kelp, which has very large blades. The kelp is harvested from canoes and subsequently allowed to dry on rocks and then gathered into bundles. During feasting time, the blades were broken into bite-sized pieces and steamed in, for the Northwest Coast characteristic steam boxes made from cedar wood (Turner, 1995). Different Peoples along the coast of British Columbia still harvest the herring–roe-laden kelp blades, but nowadays, salting and freezing are predominantly used as methods for preserving this food staple. Another seaweed commonly used by many Northwest coastal groups is Red Laver, porphyra abbottae Krishnamurty (Turner, 1995). It too has been and still is gathered and subsequently cured in methods often specific to each People but always involving partial or complete drying. During the winter, dried bits of this seaweed are eaten as candy, added to stews made from fish (oolichan) grease, fish heads, shellfish, or used for its health or medicinal (laxative) properties.

A seaweed camp is an important aspect of the seaweed-related activity system. To harvest seaweed, aboriginal people usually establish a seaweed camp near the harvesting areas. For a three- to four-week period (usually associated with a particular moon in the aboriginal calendar), the elders of a community would go to the camp, collect the seaweed, and dry it on the beach near the camp. For example, Heiltsuk, an aboriginal community near our own, re-establish an elders' seaweed camp close to a traditional site, constructing new buildings where they can stay during the month-long harvest. This will allow the elders from the community to once again harvest and dry seaweed in a traditional site that is now quite remote from their village (Bella Bella, British Columbia). The Heiltsuk are building cabins (as they do throughout their territory near traditional food gathering areas) to provide new venues for community gatherings and significant events. Because of the central aspect of seaweed in the life of these peoples, seaweed camps have a great potential for the revival of traditional customs and practices among the First Nations:

> By encouraging our youth to re-embrace their culture and look back to traditional lands, we hope to open their eyes and hearts to their responsibility to care for it and preserve it for generations to come. We are

> dedicated to helping our youth to see themselves and their environment in a new way. (Elroy White, in *Ecotrust Canada*, 1999, p. 10)

Being able to re-embrace their cultural heritage by combining traditional and Western knowledge (*tools*) will allow these people to create cultural landscape assessments of their territories, establish conservation-based development plans that will enable *them* to manage their resources and build reliably prosperous communities (Ecotrust Canada, 2000).

Curricular Reflection

Readers will not be surprised to learn that that Nancy Turner and I believe the seaweed camp to be an ideal site for bringing together the (almost forgotten) traditional knowledge about seaweed, its uses, its harvesting and conservation practices. Because harvesting seaweed is an important activity in the lifeworld of northwest coast aboriginal peoples, legitimate peripheral participation in the associated practices also constitutes a context in which students learn by contributing to food production (rather than by focusing on learning). This food subsequently becomes part of *consumption*-, *distribution*-, and *exchange*-related activities in the community (Figure 1). The seaweed camp and the collection of seaweed are associated with rules and taboos (*rules*). The school children therefore learn such rules not in the abstract of *a* school classroom, through teacher telling or reading about them in a book, but through the practices and practical necessities of operating a seaweed camp.

By participating in the camp, the children can experience themselves as part of a larger whole, as fibers (*subjects*) that contribute to the strength of the collective thread (their *community*). The children's primary *tools*, *objects*, *community*, *rules*, and *division of labor* and the relations mediated by these entities reside within the aboriginal context of the people. Whether and how Western science can be a fiber that contributes to the thread woven by this activity system—which already has a long, but also interrupted history—has to be worked out. We believe that it can contribute. But to do so, Western science has to follow and honor existing *rules* that mediate interactions within native *communities*. For example, the predominant mode of teaching in native communities is the telling of stories. Thus, Glen Aikenhead and his affiliated aboriginal teachers introduce Western science theories about issues to the curriculum, grounded in aboriginal life, as stories (see http://capes.usask.ca/ccstu/). As a story, Western science becomes a fiber (*tool*) among other fibers that comes in handy when there are problematic or contentious issues. At the same time, as a story among story, Western science gives up traditional hegemonic claim to be the sole authority of legitimate knowledge. In the context of an aboriginal thread of life, the Western science story becomes one story among many, one fiber among many fibers, all of which compose the thread. I believe that such an approach is more appropriate than the overzealous replacement of traditional knowledge—always associated with values—by a form of knowledge that itself is continuously under debate and often contested (e.g., current debates over genetically modified organisms). Native children continue to go about their lives, pursuing community-relevant tasks, but have the opportunity to evaluate the usefulness of the new type of stories in the contexts that are central to their way of life.

Coda

In this article, I provide a new way for thinking about science education. Fundamentally, I believe that students ought to learn science as they participate in everyday activity systems such as engaging in environmental activism, harvesting seaweed, gardening, creating green spaces, and so on. Such activities are authentic because they have not been constructed for the purpose of schooling and its filtering mechanisms and therefore are the real thing, engaged in by all sorts of ordinary people rather than disembodied knowers. Activity theory is the most appropriate and comprehensive approach for theorizing the *production*, *consumption*, *distribution*, and *exchange* of objects, knowledge, and so forth. Two examples from my own work show how I practice and plan “science education in/for the community.”

In my first example, students participated in societally motivated and relevant activities; the *objects* orienting student actions were the same as those orienting the actions of other community members. Students (subjects) use many of the same tools (dissolved-oxygen meter, hatchery) that are used by others in their community participants in environmental activism and salmon enhancement. Individuals from within and outside of schools interact with each other, thereby providing opportunities to learn. School-based actions share many, if not most, aspects with everyday actions, not only concerned with understanding but also with changing environmental health in the community. In my second example, the role of Western science relative to other knowledge-communicating stories has to be established in the context of an aboriginal activity system—lest we continue with the Western-style colonialism still rampant in many parts of the world. I believe that change has to come from within communities, in the form of a new consciousness that allows members to open up new possibilities of actions that are subsequently enacted in concrete and community relevant praxis.

School districts, schools, and teachers will have to abandon their control over the object of the tasks, means of production, and other aspects of the activity system—unless we want to reproduce an inequitable society with all its problems, including the crisis in science education. When I began my project of activism in school science, I still believed that all students should engage in their activities in ways that foster quasi-scientific practices; my image for school science was based on the science of scientists (e.g., Roth, 1995). That is, I was still subject to the illusion that truly expansive learning could be administratively legislated and planned (e.g., Holzkamp, 1992). I soon realized that requiring all students to measure series of variables, and to represent correlations in the form of Cartesian graphs or histograms excluded particular groups of students, for example, young women and indigenous students. While these latter students still participated in the data collection, the subsequent data analyses and activities that focused on mathematical representations generally turned them off. Not being in control of the means of production (tools, Figure 1) limits students. Taking my lead from other activities in the community, where different representational forms are legitimately used (Lee & Roth, 2000a), I began to encourage students to investigate on their own terms, choosing their data collection and representational tools that best fit their interests and needs. Audio-recorded descriptions, videotaped records of the watershed and student activities, photographs, drawings, and other representations began to proliferate. This change provided forms of knowing and learning that led to an increasing participation of previously excluded students. It also meant that I had to abandon my traditional conception of what science and science education in the community might look like.

Redefining scientific literacy in such ways that students begin to participate in and contribute toward 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 eight-grade student was so inspired by the investigations of my seventh-graders that he began to research the amount of coliform bacteria, a biological contaminant, in various parts of the stream. His report specifies particular sites of pollution and names the farms where the contributed significantly to the contaminant levels. He concluded that two farms in particular were major contributor to coliform counts. He presented these results not only at the school and regional science fairs but also during the open-house event organized by a group of environmental activists. I have no indication whether the farmers objected, the production of knowledge (outcome becomes tool) and its distribution in the community and the potential implications for political pressure on farmers and industrialists to change their current practices is evident. My proposal is to unleash the societal potential that lies in allowing school-age generations to legitimately participate in the everyday societal life and thereby to expand all citizens' action potential in an increasingly complex world. With Marx, I want to suggest that until now, science students have only interpreted the world, in various ways; the point is to change it As science educators we have it in our hands to contribute to making this a better world, in part enabling students of all ages to enact their right to citizenship. Let us begin to do so now.

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