ABSTRACT: In this article, I propose a radical redefinition of what it means to know science. Illustrated with data of a recent study of learning science by constructing knowledge for the purpose to enrich the community, I argue that ability and disability in science (knowing and learning) are characteristic of situations rather than attributes of individuals. Whether individuals “acquire” an ability or disability with respect to science depends on where we observe them. Framing my work in terms of activity theory, I provide descriptions of enabling and disabling situations, leading to visibility and invisibility of scientific literacy, respectively. I propose the analogy of thread and fibers to argue that science educators use an inappropriate unit of analysis for assessing knowing and learning, ability and disability. There are considerable implications of this view for science teaching, for teachers are held to promote knowledge-enabling situations rather than the construction (acquisition) of individual knowledge.

[The] deletion of students’ work and voices is daily practice in today’s schools. Their contributions to collective achievements are consistently deleted in the service of sorting individuals, by means of grading, into standard curricular trajectories. Institution-alized forms of accountability such as grades, take students out of the continuity and complexity of their activities and pass them through sorting devices that are intended to assess many things but say nothing about whether they should engage in particular career trajectories… (Roth & McGinn, 1998, p. 401)

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 (Barton & Yang, 2000). In school science, there are often differences in achievement along the lines of gender, race, and social class. Yet across many studies, there were no such differences in achievement (as shown by statistical tests) after students
participated in innovative, hands-on and discourse-focused curricula that I had
designed with resident teachers to promote an agenda of science for all students.
The tests in a recent project revealed that 5 of the 7 students in the top achieve-
ment quartile had been students who were designated by the school system as
cognitively disadvantaged (learning disabled) or socially disadvantaged indi-
viduals (Roth, McGinn, Woszczyyna, & Boutonné, 1999). When fellow science
educators asked me why the normally highest achieving students were not also
the highest achieving students, I felt embarrassed because I did not have a clear
answer. My subsequent analyses of the data showed that while normally “dis-
abled” or “lower-ability” students sometimes had problems on written tests of
their knowing and understanding, the great variety of test formats we chose al-
lowed them to achieve as well or even above other students (Roth, 1998).
Whereas these analyses provided partial answers to my colleagues’ questions, I
still did not have a model that allowed us to explain why traditional orderings
of students were altered in the curricula that we were designing. In an ongoing
study, where students learn science as they produce knowledge for the benefit of
their community, we used activity theory as a framework because it enabled us
to compare knowing and learning across the diverse settings in that community
(e.g., Lee & Roth, 2001). It turned out that activity theory also provided me with
a methodologically suitable tool to understand why, again, the “learning dis-
abled” students have done so well in my work.

Scholarly discussions of what it means to know and understand science are
almost exclusively based on the generally unstated (and perhaps unfounded)
assumption that knowing and understanding are attributes of individuals, which
can be assessed in situations where they are isolated from the resources (e.g.,
people, tools, or interests) that characterize most everyday activity. This as-
sumption leads science educators to ponder (a) how individuals can be made to
appropriate (internalize) or construct specific scientific concepts, (b) what sci-
ence content to teach, and (c) how to make students transfer science concepts
and skills to other contexts. In this article, I propose to decenter the focus of
scholarly debate by considering two alternative assumptions. First, science
knowing and learning is a property of collective situations and characterizes
interactions irreducible to characteristics of individuals. Second, students learn
by participating in activities that are meaningful because they contribute to their
community as a whole.

1 I deliberately use the expression by the school system because it takes into account how attributions
such as "learning disability" arise from the interaction of many individuals (cf., Mehan, 1993).
2 Throughout this article, I use quotation marks to signal that a term is emic, that is, used by insiders
(teachers, administrators) in the situation. I use italics to highlight important theoretical terms, which
are etic, that is, brought from the outside of the situation.
The purpose of the present study is to articulate a framework for knowing and learning that allow us to understand and explain how students are constructed as having an ability or disability with respect to learning science. After articulating activity theory and describing the context of the study, I present a detailed case study featuring Davie and Steve, labeled in their school as “learning disabled” students and therefore receiving special instruction. I show how specific situations lead to assessments of disability and ability, which could subsequently attributed to and turned into characteristics of these same students. If science knowing and understanding are conceptualized as features of situations rather than individuals, there are then considerable implications for science teaching.

ACTIVITY THEORY

In most theories of human knowing, individual action is the central unit of analysis. However, these theories have difficulties accounting for the distributed and situated nature of knowing and learning and for the nature of human activity as mediated by artifacts and culture (Engeström, 1999). These theories also fail to address the “continuous, self-reproducing, systemic, and longitudinal-historical aspects of human functioning” (p. 22). In this study, I use activity theory (Leont’ev, 1978) to frame the water- and watershed-related activities of adults and seventh-grade science students. (For another study of science learning that uses an activity-theoretic framework see Barab et al., in press.)

Theories consist of entities (categories and processes) that divide the world they attempt to explain. In activity theory, there are six such basic entities: a human subject (individual or group), objects (artifacts or motivations), tools, rules, community, and division of labor (Figure 1). The unit of analysis is not the individual or individual-with-task but activities in their entirety; because activities involve more than one person and, in fact, entire communities, they are theorized as systems. Examples of activities are “farming,” “schooling,” “health care,” or “environmental activism” all of which are carried out and motivated by communities. Those events often referred to by teachers as “activities” are, in the context of activity theory, considered as tasks that are characterized by specific goals completed by some subject.

Activity systems are defined and motivated by the relationship between an individual or group (subject) and the primary object. For example, the seventh-

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3 There is insufficient space for elaborating all of the details of activity theory here. Suffice it to say that activity theory takes a subject-centered (almost phenomenological) approach to studying human activity (e.g., Holzkamp, 1991a).
grade students in my studies decided to make Henderson Creek the object of their inquiry and to make facts and knowledge (outcomes) available to their community by contributing to an open-house event. Relations between the different activity–system-constitutive entities are never direct: all relations are mediated by other entities. For example, the tools a student research group (subject) uses mediates her relation to Henderson Creek (object), which leads to quite different knowledge facts (representations) of the creek (outcomes). Doing speed measurements and correlating these to animal species frequencies lead to different outcomes than audiotaped, journalistic descriptions accompanied by photographs. To use another example from my research: the children’s choice to focus on Henderson Creek was mediated by the community in the sense that the children responded to a call, published in a local newspaper, by an environmental activist group to contribute to the community’s existing knowledge about the creek. Two further entities that are considered by activity theory are rules and division of labor. Rules 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.

It should be evident that analyses in terms of multiple interacting mediated relations is well suited to the complexities of human activity. Missing from the
picture presented so far are the contradictions that may be inherent within entities, within mediated relations, between object/motive of dominant activity and object/motive of more advanced activity, or between activity systems. Whereas contradictions have the potential to be drivers of change, they lead to (re)production of resistance and subversive action when they are not openly addressed (e.g., Engeström & Escalante, 1996).

An important aspect of this theory is its endeavor to understand activity systems, such as those that focus on knowing and doing science (Fusco & Barton, 2001) as historically constituted systems. That is, activity systems require an understanding of their historically contingent nature and of the cultural context that allowed it to emerge. Similarly, the identity of the subject (individual or group) is a function of all mediated relations that operate in the activity system (Lave, 1993). Thus, the problem of environmental health that motivates the activities described in my study cannot really be understood without studying the historical changes that turned the area from tribal hunting and gathering grounds to a farming community, increasingly under pressure from the expansion of the urban communities. Correspondingly, agency, knowing, and learning are not thought in terms of properties of individuals but in terms of situated and distributed “engagement in changing processes of human activity” (p. 12). Furthermore, individual agency, knowing, and learning are subsets of generalized agency, knowing, and learning available to society at large (Holzkamp, 1991b). Human activities, such as conversing, farming, or engaging environmental activism are therefore irreducibly social phenomena that cannot be understood as the sum of the contributions of individuals; they are analogous to threads made of a variety of fibers (McDermott, 1993).

In the thread of society, each human being is but a fiber. Although made up of fibers, the properties of the thread cannot be derived from the properties of an individual fiber. Furthermore, the properties of a fiber cannot be derived from the thread. There is therefore a dialectic tension between the natures of fiber and thread—and by analogy, between individual human beings and the society of which they are part. In my analyses I understand (necessarily collective) activities and interactions, such as a public meeting, in terms of fibers and threads. A collective activity is analogous to the thread and individual contributions are no more than the individual fibers. Thus, scientific literacy is something *achieved collectively* rather than a property of individuals. It makes no less sense to think of a thread independently of the fibers (individuals, tools, etc.) that constitute it than it makes sense to think the fibers independent of the thread that sustains them and gives them direction and shape.
RESEARCH DESIGN

My 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 northern 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 twenty-five kilometers from the center of a mid-sized city that continues to expand, pushing suburbia into the rural and agricultural landscapes. Together with my graduate students, I have now conducted three years of ethnographic research in Oceanside. Our research was generally focused on the role of science in a variety of settings within the community. Specifically, we were interested in science as it related to the actions of the Henderson Creek Project, an environmental activist group, and to the actions of seventh-grade students whose aim was to contribute to the existing knowledge about Henderson Creek. To properly understand the subsequent case studies (and consistent with the non-reductive framework underlying this work), I provide “thick descriptions” (Geertz, 1973) of the context in which my work is situated.

Water Problems in Oceanside

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 residents of the area. During many summers, insufficient water supply requires the community to limit the amount available. Other residents, with individual wells that draw on the local aquifers, have found their water biologically and chemically contaminated and sometimes (especially at the end of a long dry summer) have to get their water from a gas station about 5 kilometers away.

Recent developments have exacerbated the issue by altering the water’s flow over and through the ground. 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. 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.

4 Pseudonyms are used throughout this article.
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. The farmers in the area are in continuous search of water during the summer, depleting groundwater levels and Henderson Creek, and cannot get the water-storm waters sufficiently fast of their fields in late winter and early spring. (In the past, farmers had damaged the health of Henderson Creek by straightening it to carry the water away faster.) The farmers also use fertilizers, some of which are washed into the creek, and cattle graze so close to Henderson Creek both damaging the shore and polluting the water.

The Henderson Creek Project, an environmental activist group, has the objective to bring about changes in Oceanside (shaping policy documents) and to residents’ water-related practices (e.g., unhooking downspouts). They also actively modify Henderson Creek (by building water-oxygenating riffles or strengthening and planting riparian areas) to improve the health of the watershed. A First Nations community is also located in the watershed, but to date, its inhabitants have shown little interest in participating with the activists in restoring the creek, which historically had been a source of food and a spiritual resource.

Science in the Community

As we researched a variety of events involving different members of the community, we came to understand that science is but a fiber in the thread of social life in the community. Even when scientists participated in some event, their contributions were interacting with those made from different epistemological positions, and therefore were but an aspect of the work by means of which groups and the entire community entered into conflict over its problems (e.g., Lee & Roth, 2001). An activity theoretic framework makes it quite clear that Henderson Creek shows up in different activity systems (farming, activism, or industrial production), which involve different individuals or groups (subject) and their tools; yet the representations, which are the results (outcomes) of these activities, are quite different. Depending on the particular instances of mediating entities (tools, community, division of labor, and rules), different discursive and inscriptions (visual representations) are produced and subsequently contributed to a variety of interactional forums. Furthermore, the same individuals participate in different activity systems or take different roles in the respective division of labor. Some of instruments (tools), such as the dissolved-oxygen meter and colorimeter, are used in different activity systems perhaps aspiring to the same standard uses (rules), but mediated by different intentions.
Curriculum

It has been suggested that students ought to be involved in school science in ways that allow them to develop a keen appreciation of the places where science and technology articulate smoothly with their experience of life (McGinn & Roth, 1999). In this study, I attempted to follow this suggestion. Given the water-related problems in Oceanside, it was not difficult to convince teachers to participate in a study where students would learn science by investigating the Henderson Creek watershed. Over the past two years, my graduate students and I have assisted in the teaching of science to three seventh-grade classes over two- to four-month periods. In these classes, students design and conduct their own research in and along Henderson Creek with the intent to report their findings at an open-house event organized each year by the Henderson Creek Project (i.e., the activists). The idea underlying these science classes is to provide students with opportunities to become active citizens and to contribute to the knowledge available in and to the community. Other students at the middle and high school also conduct research in the watershed as part of their involvement in regionally funded “Streamkeepers” program or in science fair competitions. In this way, students already participate in creating knowledge available to the their community and the activists. Members of the Henderson Creek Project, my research team, parents, and aboriginal elders contribute in various ways to the “teaching” of the children by providing workshops and talks and by assisting students in framing research and collecting data.

When this project began in 1997, I still believed that all students ought to engage in their activities in ways that would foster “scientific” practices. That is, my model for school science was influenced by the science of scientists. However, I soon realized that requiring all (in the sense of the AAAS [1989] rhetoric) students to measure series of variables and to represent correlations in the form of Cartesian graphs or histograms excluded some (notably female and aboriginal) students. While these students still participated in the data collection, the subsequent data analyses and activities that focused on mathematical representations generally turned them off. Taking my lead from other activities in the community, where different representational forms are legitimately used, I (as coteacher) began to encourage students to conduct investigations on their own terms, to choose and take control over their data collection and representational tools to 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 traditional conceptions of science and science education in the community had to be abandoned. Ultimately, the children pre-
sented the results of their work at an annual open-house event (organized by the environmental activists) whose principal focus was the health of the Henderson Creek watershed.

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

This involvement of community members therefore integrated the children’s work with activities in the community in two ways. First, the community came to the school, assisting students and teachers in their activities. Second, the student activities were concerned with a pressing issue of the community; the science lessons took children out of the school and into the community. That is, the children’s activity system was motivated by the same concerns that impelled other activities in the community. In terms of my activity theoretic model (Figure 1), there is therefore legitimate (peripheral) participation because the motivation that drives the activity system share many elements. It is this overlap with the activity system characterizing everyday life in the community (motivation, subjects [community], and tools) that makes the children’s work “authentic.” Rather than preparing for a life after school or for future science courses, children participated in and contributed to social life in the community. It is in the process that learning—belonging to the various conversations of which individual persons are part (McDermott, 1993)—was occurring.

Students

The students come from working- and middle-class backgrounds; about 10% of the students are from aboriginal families who chose to attend public rather than the tribal school.6 A substantial number of students in this school are designated

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5 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.

6 Aboriginal students have a choice to attend a local tribal school or to attend the public middle school. About 10% of the middle school student population have aboriginal status.
as having “special needs” (the school receives funds for special instruction). For example, in one of the classes we taught there were 27 students (15 male, 12 female), five of whom designated as “special needs students” (LD) and four were from the local First Nations band. In the course of our three-year study, we observed that a considerable number of aboriginal students appeared uninvolved, resigned, and often achieved low grades. We had been invited to conduct a workshop in a summer science camp for aboriginal children normally taught by aboriginal people, we were able to see a drastic difference in the involvement of the same children when activities were framed in their native context. At the grade-7 level, the students were often far apart developmentally, some boys and girls having more the appearance of young adults (about 6 feet tall), others looking more like grade 5 students.

"Measures" of "success"

Enacting science in the community presents severe problems for assessment (Jenkins, 2002). 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. In this study, I took the impact of the children’s work on the community as a measure of participation and learning. The interactions at the open-house event involving students, activists, and community members not only led to the emergence of scientific literacy but also to the emergence of the legitimacy of the children’s activities. From the perspective of the environmental activists, the children had contributed in a significant way to the success of the open house by contributing to its content and by being a drawing factor—the children’s presence encouraged the participation of many parents and relatives alike. That is, the activists recognized the contributions of the grade-7 students as the outcome of a legitimate activity of the type that they had called for in the (earlier featured) newspaper article. The results of the students’ investigations were reported in the local newspaper and on the website of the environmental activists. Thus, one article reported:

When it comes to the [Henderson Creek] watershed Project, [Meagan McDonald] says, it’s the people who will have to make the difference.... The open houses will have numerous exhibits including... a display by [Oceanside] Middle School Grade 7s on their invertebrae work done in [Henderson Creek].... “What we want to see happen is that the community embraces the concept of a healthy watershed and takes it on themselves,” she said Sunday from the banks of [Henderson Creek], adding that water quality decline and habitat loss in local streams has severely influenced the range, numbers, and size of trout over the past several years.... For the past two months, [McDonald] has been working with students at [Oceanside Middle School] in an ambitious attempt to identify and count invertebrae—another barometer of water quality—at various sites on the Peninsula. Early
Such publications, which emphasized the contribution of the children’s work to the overall project of environmental health in the Henderson Creek watershed, further underscored the legitimacy of the children’s work. When considered in terms of the notion of “legitimate peripheral participation” (Lave & Wenger, 1991), the children contributed in more than marginal ways to knowing and learning available in their community about environmental health.

Data Sources

The data sources include extensive field notes, publications produced and appropriated by the students and 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. Two cameras were used to videotape all science lessons—having obtained the equivalent of one entire school year of science instruction, spread over three classes. A range of participants in the Henderson Creek Project, students, and local residents responded to questions in audio- or videotaped interviews. On several occasions, videotapes were recorded of groups of activists and other interested local residents who walked sections of Henderson Creek with different consultants. The activists drew on these consultants for advice on how to improve the creek, find the best trout habitat, and how to expand the healthier sections of the creek.

Interpretation

My analyses, grounded in reflexive hermeneutic phenomenology (Changeux & Ricœur, 2000), are based on the assumption that reasoning is observable in the form of socially structured and embodied activity. In my analyses, videotapes, transcripts, and artifacts produced by the observed individuals are natural protocols of their efforts in making sense of, and imposing structure on, their activities. Following those who treat culture, particularly local knowledge and action as texts, these protocols constituted my “texts” were elaborated in these analyses.

An analysis begins with reading transcripts and viewing videotaped lessons, public events, and interviews before meeting for collaborative analysis. I sometimes involve colleagues and graduate students to conduct collaborative analy-

7 Original names in this quote have been replaced by pseudonyms in square brackets. Meagan McDonald is the pseudonym of the coordinator of the Henderson Creek Project.
ses, in my Interaction Analysis Laboratory (Jordan & Henderson, 1995). For example, in the analysis of videotapes, replay is stopped whenever one of us thought a significant event had occurred. This person then stated an assertion before the event was reviewed as often as necessary for a full exploration by both researchers. I then review other episodes to check the degree to which they confirmed or disconfirmed the assertion. On the basis of these checks, I reformulate initial assertions until they are representative of the data. I subsequently discuss personal constructions with others, subject them to critique and analysis, and test them in the entire data set to evaluate fit and plausibility. In a similar way, I conduct the analyses of transcripts. The understandings reported here emerged from many such iterative processes of engagement with the data sources. In the analyses, I follow conversation analysts who take conversations as irreducibly social phenomena that cannot be understood as the sum-total of individual contributions (ten Have, 1999). Thus, I analyze conversations by thinking of them, consistent with my theoretical framework, as threads that cannot be understood by adding up the properties of individual fibers.

PRODUCING LEARNING DISABILITY

There are suggestions that “learning disabilities” are the result of situations rather than attributes of individuals across situations (Mehan, 1993); assessments of science ability is socially constructed and therefore value laden (Fusco & Barton, 2001). There is strong evidence that this is also the case in the school where I do my research. Children who are labeled as learning disabled or as having special needs (e.g., LD, aboriginal) often do not exhibit learning problems or learning disabilities when their activities are integrated into the larger concerns of their community.

As in previous studies where I had designed innovative, hands-on curricula focused on participation in practices rather than on getting knowledge into the head, there were no statistically detectable differences ($t = 0.44, p = .65$) between male ($X = 30.0, SD = 5.8$) and female students ($X = 30.9, SD = 4.5$) on the criterion variable of achievement. Furthermore, two “learning disabled” students, Steve and Davie achieved the highest scores on a unit test designed by the resident teacher in the class, more than 1.5 and 1.1 standard deviations above the mean (which, at 79.9%, was exactly at the mark usually used to establish “mastery”), respectively. Davie in particular had become such an expert that he assisted in teaching the class of grade-7 students to conduct research in and alongside the creek. He also participated with others in the open-house event organized by the environmental activist group in the community. At the same time, excerpts from Steve’s and Davie’s answers on a unit test (Figure 2) both exhibit their understandings but also, particularly in Davie’s case, “spelling and
writing problems." That is, the very format of traditional assessments, conducted in settings that isolate students from the social and material resources characteristic of the other settings in which we observed them being highly literate, turns up and thereby constructs their disabilities. The production of “learning disability” became clear when we observed Davie in his mathematics class.

The mathematics teacher, Cam, had agreed to cooperate with the science teacher Nadine to “teach” students a variety of graphing techniques. By cooper-
ating with Nadine, Cam saw an opportunity that her science unit could “reinforce” those “skills” that students were supposed to learn in mathematics. On this day, Cam had prepared a sheet containing several columns with data, which would allow students to have some choice in selecting the data set that they wanted to work with. He explained the task as one of finding relationships. He reminded the students of the lessons where he had taught them a variety of graphing techniques, including pie charts, bar graphs, and scatterplots. Cam distributed the sheet containing task description and data and a sheet of graphing paper. He encouraged students to use pencils so that they could easily correct any errors that they might make.

As the students begin settling down, reaching for their pencils, rulers, and erasers, the camera focuses on Davie and Jamie. Jamie was a quiet student, always task oriented and doing what the teachers asked him to. He was classified as “one of the better students,” not the best, but “always producing reliable results.” Davie does not seem to know what they had been asked to do and queries the teacher who is passing his desk.

Davie: What are we supposed to do? Like when is, ahm, ahm, like a bar graph? (Points to an example of a bar graph in the book in front of him)
Cam: A scatterplot graph and choose the speed and one of these other categories.
Davie: We are comparing this (He points to one column on the task sheet) and this (points to a second column) and this (points to a third column).
Cam: So make a scatterplot that compares two things.
Davie: But how do I make a scatterplot? (He restlessly gets out of his seat and appears to move away from it.)
Cam: You are not going to do it? (He gently pushes Davie back into his seat.)
Davie: Jamie is going to do it.
Cam: And you are going to do the rest of it? OK!

Despite the teacher’s encouragement, Davie gets up again after the teacher has moved on to another pair of students. He returns about one minute later. Jamie, though usually a “good” student, does not know what to do.

Jamie: What do we have to do?
Davie: I thought you knew what to do.

As Jamie begins to draw axes on his graph paper, Davie orients himself toward another group and throws some paper. He gets up and walks around, goes first to one group, then another, talking about the lemonade in the bottle from which he is constantly sipping. He returns and watches Jamie for a while, then talks to the students to the left of him, then to those on the right. Jamie does not take his head up but sedulously works on the task assigned by his math teacher. During one of the brief moments when Davie is watching, Jamie asks him to look for the largest number in the data table, which Davie finds and reads out. Davie then turns his attention to other things and people, and at one point, even whistles.
When Cam passes nearby, Davie says “We don’t get this,” but the teacher continues moving toward another group. Davie watches the students on his left and begins to talk but turns his attention to Jamie when the teacher comes back to their table.

Cam: (to Davie) Are you contributing?
Davie: Some.
Brad: What kind of graph are you using?
Davie: I don’t know how to do it.

By answering “some” to the teacher’s request, Davie keeps himself out of trouble. But it is clear that he does not know what to do when his neighbor Brad asks him about the kind of graph that he and Jamie are using. Davie does not focus anymore on the task for the remainder of the dedicated time. He walks about the classroom, shares his drink with other students, and sometimes watches what his peers in other groups are doing. He does not attend to the task or listen to the teacher who returned once more to his desk.

In the end, Davie had spent less than 8% of the 26 minutes in task-related activities, interacting with Jamie, talking to the teacher, or engaging in other ways. When I talked about this and other videotapes with the science and mathematics teachers of this class, they suggested that Davie always behaved in this way, that he had attention deficit disorder, severe writing problems. For all of these reasons in addition to the test results from the school psychologist, he had been classified as “learning disabled.” Davie was regularly pulled out of the classroom to receive the special services to which a student in these categories “has a right.”

Activity theory is a tool for understanding and explaining the production of failure to do school mathematics (Williams, Wake, & Boreham, in press). Figure 3 outlines the form such an analysis takes. Davie faces a task that he has not chosen; the object of this task is different for him then for the teacher so that there is a contradiction inherent in the task (see flash in Figure 3). Furthermore, the teacher also controls the means of production (tools). Rather than allowing students to use the 6 computers in the classroom or the 24 computers in the neighboring, connected computer room, Davie has to use paper and pencil. There is therefore a contradiction between the tools allowed and the more advanced tools actually available in the setting, and therefore also between the this activity and a cultural-historically more advanced activity (see flash in Figure 3). The teacher allowed students to work with a partner, so that, drawing on the division of labor, “weaker students” could partake in successfully completing the task. However, Davie let Jamie do all the work. That is, there is a contradiction in the teacher’s intention for the group work and the way in which Davie contributes (see flash in Figure 3).
In the context of these contradictions, Davie does not produce the graph or contribute to producing it in the way that the teacher had intended. There was no outcome. In activity theory, associated with production is consumption in and by the community; however, consumption also means production of the individual subject within the community (Marx, 1973). That is, because Davie failed to produce something on the task, the failure is reattributed to him and becomes an attribute. Davie not only fails to produce the graph but also is produced (constructed) as a failure in the process. As I show in the next section, this image of Davie as a failure and “learning disabled” student stands in stark contrast to other situations that produced a highly literate individual. I will use this contrast as a ground for suggesting that teachers (psychologists, tests) evaluate situations (characterized by all the entities that enter an activity-theoretic framework) rather than individuals.

PRODUCING KNOWLEDGEABILITY

In their regular curriculum, both Steve and Davie experience learning problems. Davie was labeled “LD” and received special services, for which he was often pulled out of the class. Throughout this unit, Davie and Steve participated in knowledgeable ways, not only learning about science but also assisting peers and adults alike in learning science. Or, in terms more consistent with activity theory, Davie and Steve participated (as subjects) in an activity system and produced knowledgeability in such a way that, if one wanted to retain focusing on
CONSTRUCTING DISABILITY

individuals, (science) “ability” would have become an appropriate characteristic attributed to these students. Four situations are described to show how it was possible for Davie and/or Steve to emerge from this unit as experts rather than as learning disabled students. That is, this science unit, which essentially existed of contributing knowledge to the community by working on a community-relevant problem, set up situations in which Davie and Steve turn out to be functional and scientifically literate individuals. In the resulting activity system, the community mediated the relation between the subject (Davie and Steve) and the object of the activity in such a way that they were able to move along a trajectory of legitimate peripheral participation.

Davie and Steve in the Field

This is the second day out in the field for the seventh-grade class. The teacher has asked the students to familiarize themselves with the different instruments and tools available for collecting data. Davie, Steve, and Jamie form a group. The video shows them deciding to investigate whether soil temperature changes with differences in the surroundings. In contrast to the previous day, they have obtained a regular alcohol-based thermometer mounted in a rigid casing so that they can measure soil temperatures. Jamie has a note pad to record observations, the type of setting where they measure the temperature.

Steve: Usually it goes down, that is what I observed last time. The ground is usually colder when it is outside.

Davie: (Closely observes thermometer and falling temperature). It’s going down.

Steve: Observe the spot. Like, write down where it is.

Jamie: High stump and grass.

Steve: Let’s pull it out.

Davie: No, because it hasn’t gone completely down.

Steve: 13. Well, I am going to stick it back in. (Jamie is still writing.) It doesn’t take very long. Yesterday we measured about 5 or 6 or 7, all of them. (Closely observes thermometer.) It’s gone to about… Do you want to see how sensitive it is? (Pulls out thermometer.) Watch!

Davie: But we want to measure...

Steve: Watch! (Holds thermometer tip in hand. Liquid column doesn’t seem to move.) May be because of all the dirt. Maybe it takes a bit longer.

Davie: It is not as sensitive...

Steve: The other one, when we just touched it. Whoop. (Gestures an up-down movement along the thermometer.)

Davie: It is probably not as sensitive as the other is.

Steve: Yeah, it doesn’t look as sensitive. I guess, this is all that we have to do here.

Davie: We still didn’t finish it.

Steve: Yeah we did.

Davie: It was still going down when you took it out, because it’s going slow.

Steve: See, it went up past 15. Jamie, it’s your turn.

Davie: I think it will be lower. (Looks up at canopy.) That one (points toward the opening in the canopy) wasn’t covered; it will make a difference.
Steve and Davie construct sensitivity differences between soil thermometers. Arising from their observation that the indicator column had fallen only slowly, Steve pulls the thermometer from the ground to show Davie, who argues that the temperature “hasn’t gone completely down,” how sensitive the thermometer was. Steve holds the measuring tip in his hands but the liquid column does not seem to move. Steve uses this information to argue that the thermometer is not as sensitive as the one they had used on the previous day; Davie supports this conclusion by reiterating the statement about the lower sensitivity. Based on this conclusion, Davie subsequently argues that they needed to measure the temperature again, for Steve had pulled it before they “finished it.” He suggests that the temperature should be lower than in the previous spot, which was not covered by the canopy and therefore was more exposed to the sun.

In this situation, Steve and Davie did not just use the tool in a rote manner to read the temperature. From the differences in responsiveness to warming, they constructed the thermometer as less sensitive than the one used on the previous day. Therefore, as is evident from Davie’s statement, they needed to measure for a longer time to get the temperature. He used the previous measurement, taken in a presumably warmer spot, as an additional referent in making his point. This moment therefore shows considerable knowledgeability rather than the rote collection of data that students in “cookbook activities” often seem to engage in (Tobin, 1990).

Davie and Steve were very much invested in this unit. They had many ideas as for different investigations that they could conduct and found that the teacher did not plan sufficient time for going to Henderson Creek. Davie and Steve, in the same way as their classmates, collected data and constructed representations of the creek that ultimately made it into the community, through the community newspaper and the website of the environmental activist group. In some instances, the visual representations constructed by the children were not unlike those constructed by the environmental activists and their volunteers. As Figure 4 shows, Davie and Steve constructed a creek profile that had striking resemblance with that produced within the environmental activist group—there are differences, of course, arising from the fact that different tools were employed to produce the respective diagrams (pencil, computer software).

Davie and Steve eagerly participated throughout the unit and developed considerable expertise. Working, among others, with Jamie, an environmental activist, or some parent who accompanied the class into the field, Davie and Steve could not be perceived as “learning disabled” students. To the contrary, the teachers who observed the videotape were taken by the tremendous level of knowledgeability that both exhibited and the “leadership roles” that they had taken with respect to peers. Viewing both students through the disability lens, the teachers had not seen either student in this light. When the science teacher
asked students for volunteers to present their research and results in another seventh-grade class, which was slated to do a similar unit, both Davie and Steve volunteered.

Presenting Research in other Science Classes

Davie and Steve behaved as central participants whatever the role they were taking in the project. Thus, when they accompanied their teacher (Nadine) and four peers (including Danielle and Niels who appear in the transcript below) to another class to talk about their research and results, they did not simply tag along and thereby get out of their responsibility toward another course. Rather, they were active and knowledgeable participants throughout the presentation.

Figure 4. a. Cross section of Henderson Creek produced by Davie and Steve as part of their investigations. b. Cross section in a different part of Henderson Creek produced by individuals from the environmental activist group.
The following is an excerpt from the presentation, during which the students and science teacher (Laura) of the other class asked questions in an ongoing way.

After other students and Nadine finished talking about the invertebrate study they had conducted, Steve comments that they completed other investigations as well.

Steve: We didn’t just look at the invertebrates, we did like, everything, temperature and D-O stuff.

Danielle: Also, we’ve been … the water temperatures, because, well if there are trees covering over top of the creek, then the water would be colder, because of the shade over the creek. So if there is less oxygen at higher temperature, it is very difficult for the critters in the water to survive.

Laura: So they survive more in colder water than in warmer water?

Niels: Yep, because the dissolved oxygen level or D-O is way higher.

Laura: So colder water has more oxygen?

Steve: Yeah. We also found that the different parts of the creek are at different temperatures and all that.

Davie: We were also measuring, like Danielle was saying. She was talking about the overhang about how the bushes came over. We measured that. And we also measured, as they were saying the D-O or dissolved oxygen and how much oxygen is in the water, and it was higher in the shade … because the oxygen affects the organisms.

Nadine: It is important to have high levels of oxygen, because the fish need the oxygen to breathe and if there is not enough in there, there is probably not a whole lot of fish in there.

Danielle links the lower temperatures in covered areas of Henderson Creek with the levels of oxygen, which were lower when the temperature was higher. When Laura asks about the relationship between survival and water temperature, Niels provided an explanation for it. When Laura expands her question about the relationship between temperature and oxygen, Steve and then Davie provide an elaborate answer in which they relate the levels of dissolved oxygen (which they had measured with a dissolved-oxygen meter obtained from the environmental activists) with temperature. They also mention tree and bush coverage as affecting the temperature, an issue that had already emerged early in the unit (see previous episode). Nadine links the levels of oxygen to respiration and low survival if there is not sufficient oxygen.

In this situation, the students and Nadine speak about their work without any prompts or props. The discourse is highly informative and scientifically literate. The students had not just obtained dissolved-oxygen levels from someone else, but actually measured it on their own. They learned to competently operate a variety of instruments (i.e., tools) and use them for their purposes. More importantly, the students did not just collect data that they assemble in some required way but they construct meaningful relations between different types of observations (variables). When asked, they spoke about these relations...
CONSTRUCTING DIS/ABILITY

in a knowledgeable way, appropriately responding to questions from Laura who learned, as subsequent debriefings and interviews showed, from these exchanges with the students from another class. Here, a teacher (Laura) learns science, among other things, from Davie and Steve, who supposedly are "learning disabled" students.

Presenting their work to another class was not the only way in which Davie and Steve contributed to the learning of others. They were among the first volunteers when I asked whether there was someone interested in helping Laura and myself to introduce this other class to doing research in and along Henderson Creek on their own. By participating in scaffolding the activities of their peers from another class, Davie and Steve both expanded the learning opportunities of others and the possibilities for their own participation in and learning of science. By scaffolding others, they increased their own knowledge-ability of the subject.

Expanding the Learning Opportunities of Others

As peer teachers and coaches, Davie and Steve contributed in varied ways to the successful science unit in Laura’s class. Both students participated in whole-class presentations, where they illustrated, for example, the use of instruments, and led small groups of students in and along the creek. In the following excerpt, Davie and the teachers (Laura and I) introduce Laura’s class to some fundamentals of working with Serber samplers and D-nets, used for capturing invertebrates.

Davie: See, and you only do it in there [within metal square of Serber sampler] to find out in that one area how much bugs there are. And you have to do it really good when you use this one, because you want to find out exactly how many bugs there are. This one [D-net] you can just try and estimate the area in front, but because it is not accurate, you are just trying to get much bugs in there.

Laura: Davie, how long do you get your hands in there and rub?

Davie: I don’t know exactly. I just move around in there, about a minute or two, just to get everything.

Michael: With the D-net, you should take about one square foot, because otherwise we won’t be able to compare the counts across sites.

In this episode, Davie demonstrates to his peers how to use the Serber sampler and the D-net, the two tools students used for sampling the invertebrates. But students are not the only ones to learn from this situation. Laura, who had not used these tools before, finds out about the procedure for collecting samples. This situation, as many others involving Davie that are recorded on video, does not produce the public appearance of a "learning disability." Being both an individual subject and an aspect of the context for others, he contributes to the
learning in the situation involving students and adults (e.g., teacher, parents) alike. In this, Davie is one of several fibers that make science knowing and learning possible for the students in Laura’s class.

Later during the same lesson, the video shows Davie simultaneously assisting two groups of students. One group of three boys previously had decided to measure the speed of the stream. A group of girls working next to them collected invertebrate samples.

Davie: OK, you guys [boys group] choose a spot. Maybe go along there [shore]. Then you have to measure how deep it is. And then make a breakdown [into up-stream and down-stream].

John: Is this (strong?) exactly five meters?

Davie: Yes, it is. You guys, put this [Styrofoam] in the middle of the stream, where the water is flowing a bit. And then you just throw it in there and measure how long it takes. (Moves to Lisa’s group.) And you put the net in like this, and you move around like this (washes rocks with his in front of Serber sampler) and you will get lots of bugs in there.

Lisa: And they will go into the net?

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

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

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

John: I do.

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

Len: Will we check for the bugs?

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

In this situation, Davie “multi-tasks.” He organizes John and his male group mates into setting up their investigation, getting their tools, and he shows and explains how to sample a spot in the creek for invertebrate organisms. In stark contrast to the mathematics lesson described earlier, Davie is not only “on task” but also and simultaneously manages to knowledgeably assist two groups of students, who are engaged in and accomplish different investigations. He provides directions how to note the results of measurements (an outcome [Figure 1]), for example, how John and his group ought to use tables for recording stream speed and stream width (Figure 5, left). He subsequently helps them, finding additional assistance from a teacher, to produce a visual representation of the data. (Figure 5 shows the circles drawn by a teacher who assisted students in interpreting the plot.) Davie is frequently so eager that he often takes over from the students he is supposed to assist. The teachers have to remind him that he was to scaffold the inquiries of his peers rather than taking the inquiry away from them.

Even if one attributes knowing and learning to individual students, the present episode supports the contention that Davie is “scientifically literate” rather than “learning disabled.” Again, the situation supported the emergence of scien-
tific literacy and did not create and make visible any learning disability. All we can see are children in the pursuit of their investigations, scaffolded by the participation of another child who has had more experience participating in such investigations than the others.

Exhibiting at the Open-House Event

Steve and Davie also participated in the open-house event. Here, they talked about their project to visitors of all ages, adults and children who were younger than they were. Again, the situation did not contribute to bring disability and learning problems to the foreground. Rather, both students were experts in their own right duly recognized by their peers and by visitors to the open-house event. That is, the analysis of Davie-in-the-open-house-event-among-visitors-and-artifacts reveals high levels of expertise that, in the tradition of cognitive and folk psychology, is attributed to Davie.

For example, the video shows Steve tending to a poster featuring a map and photographs of his research sites (outcome [see Figure 1]), a list of tools, drawings of different invertebrates, and a bar graph of the frequencies of different organisms. An adult approaches the poster and asks what he is presenting. As Steve began to talk about the project, Davie joins into the interaction between Steve and the adult visitor.
Steve: We have gone out to three different sites, Centennial Park, Malcolm Road, which is right by [NAME] School, and [Oceanside] Farms. You know where this is at?

Adult: (Nods) Yeah.

Steve: And we counted them. (Points to histogram they had constructed, Figure 6.) Like we collected all these samples (points to invertebrate drawings) and counted them and we plotted them (points to graph). And we found these sorts of bugs. (Adult looks at drawings of organisms.)

Adult: Are those (points to stone fly larva drawing) around now? Or those fly larva?

Davie: We might have one of those right now. I am not sure. But I know that we have lots of these, lots of mayflies, and amphipods.

Steve: And worms…

Davie: And we also got crayfish…

Steve: And the ones that are called blood worms…

Davie: These are very common in some spots. Some spots there are like lots of worms, and at other spots there are none. Usually, we don’t get very many mayflies at that time of the year.

Adult: How did you catch all of them?
Steve: Like that (points to photograph showing student with Serber sampler) or with D-nets. Like see, we have tools there (points to displayed list of tools), and a D-net is a net that looks like a D. It has a flat side that sits on the bottom. And we just brush the rocks in front of it (waves with hand), and the bugs fall in. And then we just pick up the net (points to photo) and throw it into the bucket. Then we take it back to school and look at it.

Davie: (to adult) Come over here, I put one under [the microscope], so you can take a look at it. (Goes to microscope, puts it into focus for the adult.)

In the first part of this situation, Steve and Davie knowledgeably talk about their research, where it had been conducted, the type and frequency of the organisms that they had found. Davie points out that some of the organisms cannot be found at the particular time of the year during which they had sampled. Subsequently, the adult asks the two students how they had caught the organisms. In an extended fashion, Davie and Steve provide they explanation drawing on resources immediately available in the situation. They point to photographs or describe tools in words. They articulate key features of the procedure by means of which the specimens were detached from the bottom of the creek, how these enter the net, and how to empty the net into a bucket, subsequently used to transport the organisms back to school. Steve’s final statement segues Davie into an explanation of the microscope work he had done with the invertebrates. He places a tray under the microscope and allows the adult to observe it. Together, Davie and the adult then attempt to classify the organism engage in a comparison of the specimen under the microscope and a set of drawings that they always used for classification purposes.

In the context of this open-house event, where community activists presented posters from their own work, and where visitors of all ages moved from exhibition to exhibition, Steve and Davie were legitimate contributors to a public event. Whereas the videotape that features Davie in his mathematics class and his written statements on the unit test (Figure 2.b) lend themselves to make traditional assessments of a “learning disabled student,” the present data show Davie-in-the-open-house-event as highly knowledgeable. Evidently, the conditions that produced learning problems and disability become visible in the regular school contexts did not exist here. Rather, Steve and Davie’s participation contributed in important ways to the very emergence of the phenomenon in which we are interested here—scientific literacy.

Knowledgeability in Everyday Activity

In the preceding parts of this section, I provide descriptions of several situations, transcripts from videotapes, and examples of the visual representations Davie and Steve produced or helped others to produce (outcomes). Davie and Steve came out of this unit feeling very successful. Every part of their involvement, as
investigators, presenters to others, peer tutors, and open-house exhibitors had provided them with opportunities to participate in legitimate ways not only at school but also, and more importantly, in the community. They interacted with environment, peers, activists, parent helpers, teachers, and open-house visitors about Henderson Creek and the environmental health of the associated watershed (object of their inquiry). The outcomes of the interactions included visual scientific representations (inscriptions) of and scientific discourse about Henderson Creek. But, as a result of these productions, Davie and Steve were themselves produced (“consumption,” Figure 1) as able, legitimate peripheral participants in community science. That is, based on these situations (and my videotapes), one is tempted to constructed and re-attributed scientific literacy to both students, as something that they carry around in their heads. Here, then, we have a contradiction: How do Davie and Steve come to be both “learning disabled” and “highly literate” students at the same time? How is it possible that Davie fails to contribute to the construction of a data analysis in his mathematics class and yet be so astute in assisting his peers to construct a graph from their data? How is it possible that Davie (frequently) and Steve (sometimes) are jerked out of their regular classes to “fix” their “learning disability” when it is possible to design situations where they turn out to be highly able?

In the context of this science unit, Davie and Steve chose, together with their classmates, to conduct investigations in the creek and they chose the particular investigations that they wanted to conduct. Thus, there is no contradiction between the teacher’s and the students’ goal for individual investigations. Furthermore, the students chose the tools and instruments with which to conduct their inquiry, that is, they owned the means of production. Again, the corresponding contradiction that appeared in Figure 3 did no longer exist. In ordinary schooling, teachers represent the community; students produce tasks for teachers who are the sole evaluators of learning outcomes, and who assign grades that become attributes of students’ qualities as learners and human beings. In the present situation, the community included students in other classes, their teacher, and the community at large. The representations of Henderson Creek produced by Steve and Davie became part of the knowledge in this community (consumption [Figure 1]) by being communicated (exchange [Figure 1]) during the open-house event, in a newspaper article, and on the website of the activists. The visual and verbal representations that they had produced were distributed across the community (distribution [Figure 1]).

I do not claim that schools are the only setting that produce failure. Rather, failures and successes are produced in everyday activity in an ongoing way—though, in different amounts and of different quality than they are produced in schools (Lave, 1988). The production of failure is not my contention. Rather, the problem with school tasks is that they lead many students to fail.
This failure, as shown in Figure 2, subsequently becomes an attribute of students noted in qualitative (anecdotal) form ("good student," "poor student," etc.) or in the form of grades, which in turn bias the (career) trajectories of the labeled individual (Roth & McGinn, 1998). Thus, for Davie and Steve, the contradictions continued even as this science unit was under way. In other classes, they still failed to produce the teacher-determined standards, which added to the reification of the "learning disabled" label and further jerking out of the regular classroom settings to "fix" the "learning disability."

DISCUSSION

Science educators need to find and build alternative activity systems in which the mediational entities that influence learning in and of diverse student populations (Eisenhart, Finkel, & Marion, 1996). These authors recommend activity systems that would sustain a broader vision of scientific literacy than the narrow view currently enacted in schools and policy alike. I presented evidence from a three-year ethnographic project within a middle school where we (students, teachers, parents, activists, and researcher) enacted a curriculum consistent with the motivation of other activities in their community. In the process, learning was made possible as students exchanged knowledge and tools with others and produced knowledge for the community, where this knowledge was distributed and which consumed the knowledge (Figure 1). My 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 (e.g., Lee & Roth, 2001). Thus, in everyday water- and watershed-related activities, adults defined purposes, goals, tools, division of labor, rules of interaction, and so forth. Similarly, we found that the motivation for the children’s actions integrated well to other immediate lifeworld aspects; this, as critical educators have repeatedly pointed out (e.g., Giroux, 1992) are indications of an empowered citizenship. I showed that this focus eliminated many contradictions characterizing ordinary schooling.

The considerations and findings presented here now allow us to view “ability” and “disability” in a different way. Because the unit of analysis in this study is the whole activity, the subject of activity never exists outside of its relation to the other elements in the activity system and the mediated relations that they give rise to. What we ought to consider (taking into account something that is already embodied in evaluative practices) are situations such as Davie-in-the-mathematics-class-required-to-do-data-analysis or Davie-in-another-seventh-grade-class-scaffolding-inquiry-in-and-about-the-creek. These hybrid entities involve all those entities and mediated relations that are made salient in activity theory (Figure 1). It is these situations that are scientifically literate or mathe-
matically illiterate; “good,” “learning disabled,” or “obnoxious” students are always good, learning-disabled, or obnoxious situations rather than properties of the students. (I take it for a given that attributions such as “poor,” “highly able,” or “lambs” may be used for the same students in different situations.) As an activity system (here schooling) develops in time, so does the subject, whose lived experience and biography arises from activity as a thread woven from the fibers of the elements. Whether the resulting thread (i.e., the individual student who is the subject) is best characterized by the terms “learning disability” or “ability” is a function of the varied situations (constituted by object, tools, rules, community, and division of labor) in which students find themselves.

Readers may have noticed that a subject both participates in producing and is itself the outcome of activity. This is an aspect of the dialectical constitution of subject: we are always participating in activity, but who we “are” is determined from the outcomes of activity including interactions with others (Harré & Gillett, 1994).

My study shows that “ability” was constructed as Davie and Steve participated, with other children, in an activity that was similarly motivated as those in which adult members of the community engaged. During the open-house event, Steve and Davie were accepted alongside the activists as legitimate participants in the community. The resulting conversations therefore broke the mold of normal modes of schooling, opening up the possibility for life-long participation in such activities and therefore the possibility for life-long learning without the discontinuities that characterize the transition from formal schooling to other aspects of life. More importantly, for students such as Davie and Steve, the unit provided a context from which they arose as able contributors to community life more generally rather than being “learning disabled” individuals.

If the motivation underlying school science and environmental activism, stewardship, or volunteerism are similar, based on the nature of tools, rules, divisions of labor, and community, we can expect individuals (subject) to move along trajectories that do not construct them as “learning disabled.” Students who participate in activities that contribute to the knowledge available in their community will develop into adolescents and adults, continuing to participate in the activities relating to environmental health. The possibility for such transitions is clearly indicated by a variety of situations that foster the participation of students and non-students alike.

Conversation as Activity

We can think of Steve and Davie as being involved in a variety of conversations—which are always irreducible, semantically and syntactically, to individual characteristics (e.g., ten Have, 1999). Conversations can be understood as
activities in which differently located individuals participate. The interacting individuals constitute the subjects focusing on some topic (object), such as Steve, Davie, and the adult talking about the students research results. In the process, the conversationalists draw on (the same or different) discursive repertoires, diagrams, drawings, and graphs (tools). Division of labor refers to the different roles of listener and speaker, which the individuals repeatedly exchange in the course of the conversation. Their interactions are mediated by the rules that mediate turn taking or the rules of respect for one another. Finally, participants themselves are participants in the open-house event, which itself is part of Oceanside. In this activity system, learning dis/ability is neither a property of the individual participants nor something a priori available in the activity system as a resource. Rather, dis/ability is the contingently achieved outcome emerging from local organization of the different conversations. In the same way, dis/ability is produced in conversations that take place in other school situations.

It is apparent that one can think of situations as setting up “zones of proximal development” (Vygotsky, 1978), that is, zones in which students achieve more than if they work on their own isolated from the resources normally accessible in out-of-school situations. The activity-theoretical perspective allows us to rethink the notion of zone of proximal development as it relates to conversation as activity and dis/ability. In activity theory, subject-object relations are mediated, among others, by society (community). Individual (restricted) actions are only a subset of all (generalized) actions within society. Therefore, the difference between the everyday actions of individuals and the collectively generated, historically new form of activity constitutes a zone of potential learning. Conversations (e.g., during open-house event, public meeting) can therefore be constituted as zones of learning and development that allow collective bodies to produce and further develop ability.

Activity theory addresses another problem. Traditional educators are concerned that unless individuals carry knowledge (internalized in one situation) around it cannot be found in other situations in which these individuals take part. Such analyses are problematic in that they break holistic situations apart into things (individual subject) and the boxes (contexts) that contain them, attributing aspects to either things or boxes. However, from the perspective of activity theory, it does not matter whether some tool (e.g., a graph) is available on a computer or has been internalized by the individual subject. Once the tool is available in the system, it contributes to the activity. The only difference is that, internalized, the use of tools can shift to the level of automatic (tacit), routine operations, whereas as knowledge residing in tools may remain at the level of conscious actions.
In this study, knowing and learning were taken as aspects of culturally and historically situated activity. Learning is discernable by noticing self and others' changing participation in changing social practices. Because interaction and participation cannot be understood as the sum total of an individual acting toward a stable environment, learning cannot be understood in terms of what happens to individuals. Rather, if learning is situated and distributed, educators must focus on enabling changing participation, that is, enabling new forms of societal activity that is collectively generated. As a critical science educator, I am 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. As a critical science educator, I am also interested in conversations that allow individual students to be successful and able participants rather than disabled, marginalized, and forgotten individuals. As the examples provided here show, this is likely to mean that I have to give up the traditional controls over means of production (tools), motivating objects of activity, and who the activity-defining community is.

CODA

In other activity systems (e.g., penal and psychiatric), it has been recognized that locking subjects up in institutions (prison, psychiatric clinic) does frequently not contribute to the solution of problems but, in fact, contributes to their reproduction. (Foucault [1975] explicitly shows the similarities in emergence, structure, and practices of schools and those of prisons and mental wards.) In some penal and psychiatric systems, structures have been elaborated that allow individuals to participate in (limited ways, sometimes under supervision) the everyday affairs of their community. In the present situation, students are no longer contained in school buildings to "keep them off the streets," to "baby sit them," or to discipline their bodies and minds. Rather, students' actions take place in the community more broadly rather than being something relegated to particular locations (schools) with local and temporal effects. The outcomes of students' work has relevance and contributes to the broader lifeworld that they inhabit together with their parents, siblings, elders, town council members, and others in

8 For example, psychiatric treatment in Italy underwent radical change in 1978 when the government passed a law that sanctioned the end of the psychiatric hospital as an institution that removed the "mentally ill" from society and segregated them under prison-like conditions (Invernizzi, 1997). The Italian society moved from a situation where it erected a protective barrier around the "mentally ill" to one in that considers the subject as a person who suffers and has a right to be treated rather than be guarded and segregated.
the community. If science is to be for all as the reform rhetoric has it, then there have to be opportunities to participate in ways that emphasize students’ strengths and address their interests. Rather than setting up situations that bring out disability or inability and thereby contribute to the reproduction of inequalities, we may conceive of science education as an activity that produces knowledgeability by focusing on achievements of collectivities.

Such a view implies that (science) educators organize enabling situations characterized by a collective ability rather than enabling situations sorting students for career-selection purposes. In the same way, science educators might think of science as but one fiber (tool) next to many other fibers in thread of life (including local, aboriginal, and common sense knowledge with all their so-called misconceptions and alternative frameworks). Science educators would then focus on learning as participating in solving everyday (and societally relevant) problems rather than on the question whether to teach “the nucleus contains protons and neutrons” before “an atom has shells filled with electrons” or the other way around. As a critical science educator, I advocate that we not break individuals out of the societal contexts and material settings in which they normally conduct their activities. I advocate not severing the mediating relations of tools, community, division of labor, and situated rules characteristic of ordinary circumstances. Thus, learning problems and learning disabilities, which are made visible when students such as Davie and Steve work in regular (traditional) classrooms, are virtually non-existent in settings such as those that we featured here. I deliberately use virtually non-existent based on the work of Lave (1988) who showed that people who had a mean of 99% of correct solutions in the supermarket dropped to a mean of 50% correct solutions on supermarket word problems.

When educators focus on creating situations that enable rather than disable students, new possibilities of participation arise. 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 that distributed and situated cognition take in the approach I propose. Before policy recommendations can be validly made, such research has to show that my proposal can be implemented more widely in a number of different domains and with more diverse student populations than that participating in this research. For example, aboriginal, female, and poverty-stricken students are still too frequently sorted out of science than fostered so that they can emerge as able individuals, perhaps in a science that is changing its face.
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