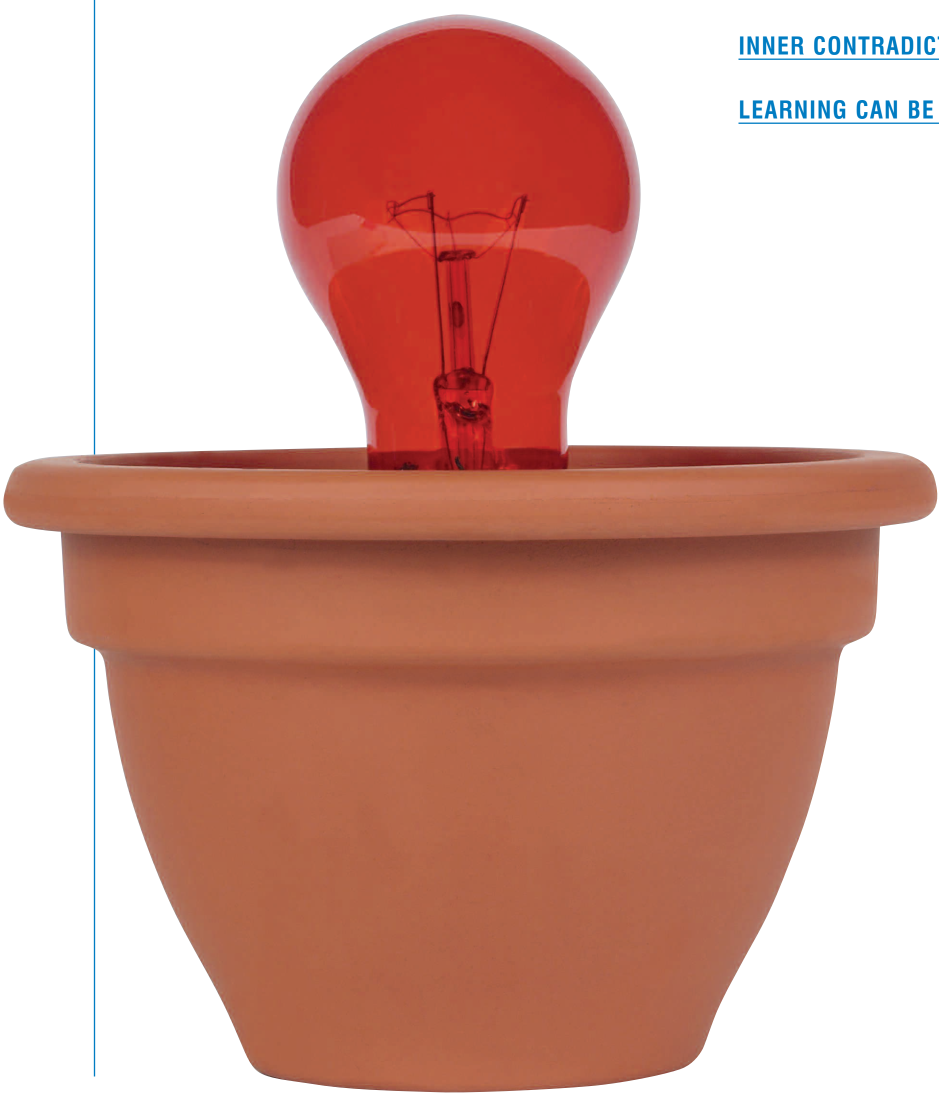
IN 2005, THE NATURAL SCIENCES AND ENGINEERING Research Council of Canada launched a pilot program, *Centres for Research in Youth, Science Teaching and Learning*, to provide a forum for those individuals and organizations interested in developing and enhancing the skills of, and the resources available to, science and mathematics teachers. It attempts to address a decades-old, recurrent problem: Despite the tremendous efforts that have gone into improving the teaching of science since the 1960s, in Canada and around the world, there continues to be a dearth of students who enrol in science-related careers. Many educators and policy makers argue that science literacy and numeracy are vital skills for successfully participating in the economy of this century. But how do we increase the levels of scientific literacy, let alone make science a subject for all students, when the subject matter itself has been keeping students away?

MOVING SCIENCE CLASSES TO THE COMMUNITY A Question of Social Justice

WOLFF-MICHAEL ROTH

WHILE STUDYING STUDENT LEARNING IN SCHOOL SCIENCE LABORATORIES, I CAME TO REALIZE THAT THERE IS A FUNDAMENTAL, INNER CONTRADICTION IN THE IDEA THAT THE SPECIFIC CONTENT OF LEARNING CAN BE PLANNED.



INTENTIONS, LEARNING, MOTIVATION

Throughout the 1980s and early 1990s, I was a science teacher in Quebec, Newfoundland, and Ontario. During these years, I learned that when students are provided with opportunities for making decisions about how to approach certain school topics – e.g., ecology, kinematics, or electricity – even those who frequently exhibit disinterest in science find something that motivates them to participate. As a consequence, even normally "recalcitrant" students learned science. It was only later that I came to understand why this might be. My studies of the learning of science and mathematics, conducted not only in schools but also in scientific research settings (laboratories, field ecology) and in the workplace (in fish hatcheries, among environmentalists and electricians), have taught me two major lessons.

First, while studying student learning in school science laboratories, I came to realize that there is a fundamental, inner contradiction in the idea that the specific content of learning can be planned. This contradiction derives from the fact that conscious human activity requires an object: we do not just have intentions; we have intentions *to do something*. We orient ourselves, both physically and mentally, toward the objects of our activity.[1] It follows, then, that if students are to learn the concept of "watershed," they have to have the intent to do so; but they cannot form this intent, because in order to do so, they need to know the concept. So, when teachers provide their science students with instructions for a practical or a reading investigation, the students do not know why they take the steps they are asked to take. They are like someone who wants to cook a dish he has never cooked (or even heard about) before, and who therefore cannot know whether he is doing the right thing. Only with some input (e.g., a photograph in the cookbook, a comment from someone who has prepared the dish before), does the cook know whether the result matches the desired dish. On the other hand, when students frame goals themselves and realize that, in the attempt to achieve their goals, they need to expand their agential room to maneuver, they inherently do what they consider necessary to increase their possibilities for acting.

Second, while researching science students, scientists, and workers, I learned of the role that participation in everyday activities such as hatching salmon, wiring houses, doing research – all of which have collective motives in that they provide for societal needs – play in framing personal goals and providing meaning to actions. By participating in societally motivated activities, we also incorporate broad societal motives into our own personal goals, so that we no longer have to be motivated externally.[2] Further, the tools and instruments we use, the hierarchical and horizontal division of labour, and the rules we follow, all mediate work and products that are destined to be used or consumed in some community. For example, my research among scientists shows that many of them have trouble interpreting graphs from first-year courses in their own field when they are unfamiliar with the purposes for which the graphs were constructed, the instruments used, and the particular conventions employed in their construction.[3] We find similar situations among those working as fish culturists, electricians, or environmentalists. Yet all of these individuals are highly competent in their fields, including in the use and construction of graphs. These studies show that what we know and do is not so much determined by what we can produce on some test – which always disconnects us from the tools and social relations that make us successful in everyday life – as it is determined by the forms of collective activity in which we participate.

Based on these two lessons, it is most useful to think of knowing in terms of knowledgeability and knowledgeable participation. But how can we design curriculum that uses knowledgeability and knowledgeable participation as its goal rather than the image of "stocks of knowledge" that reside somewhere in the head, to be recalled on demand?

CONSEQUENCES FOR SCIENCE CURRICULUM

After researching the knowing and the learning of science, in and out of schools, it was time for me to try my hand at teaching again, this time based on years of research. The two major findings articulated above led me to the idea that school students may learn science, for example, if they are given opportunities to participate in collectively motivated activities that others in their community already pursue, such as gardening, hatching salmon, or stream stewardship. The question of meaning then no longer presents itself, since it is answered by the fact that sections of society engage in such activities. Teachers already have their students participate in such activities, of course, as when an elementary teacher plants and harvests a garden with her children, or when a secondary teacher assists his students in operating a small salmon hatchery to enhance or bring back salmon stocks in a Vancouver creek.

EN BREF De nombreux éducateurs et responsables de politiques soutiennent que la littératie scientifique et la numératie sont des compétences essentielles pour participer à l'économie de ce siècle. Comment peut-on accroître la littératie scientifique, voire même faire que les sciences soient une matière étudiée par tous les élèves, alors que le contenu même de la matière les rebute ? Un programme scientifique fondé sur la collaboration avec des activistes communautaires et visant à nettoyer et à protéger un ruisseau local et son bassin hydrologique a permis aux élèves de concevoir et d'effectuer leurs propres enquêtes et de faire rapport à la collectivité lors de portes ouvertes. Comme les élèves pouvaient choisir l'aspect à approfondir, les outils et instruments à utiliser et la façon de présenter leur rapport de recherche, ils maîtrisaient le processus et pouvaient s'identifier aux résultats de leur travail.

To better understand student learning in such a context, I conducted longitudinal studies of students who participate in environmentalism in their community and in the process learn science. In all studies, I taught the science unit together with resident teachers.

An important consideration in our collaborative planning of these innovative science curricula was how to allow students to interact with others and how to start up the science unit in such a way that they had some control over how they participated and what they researched. In one instance, I came to know about the Hagan Creek-Kennes Watershed Stewardship Project, which, operating in Central Saanich north of the city of Victoria, has as its main goal the stewardship and restoration of the watershed. Its director, Misty MacDuffee, was interested in working with schools, and we began a collaboration that lasted until her departure. We approached scientists and First Nations elders to participate in the unit and encouraged parents to become involved, not only by driving children every other week to the field sites, but also by supervising and teaching. To begin the units, we read, with the students, newspaper articles articulating concerns about the health of the local watershed and featuring the work of the environmentalists. In one of these articles, MacDuffee calls for community participation in dealing with the pollution of Hagan Creek and in generating knowledge about the creek and its surroundings. Underlying these lessons was the idea of putting students in a situation where they are active citizens contributing to community life.

SCIENCE IN THE COMMUNITY

The newspaper articles – and particularly the environmentalists' invitation to the community – sparked the children's interest and their desire to help. This desire was further fueled when the leader of the environmentalists came to class to talk about the issues. Students immediately volunteered to clean up the creek and to investigate its various facets. The environmentalists introduced the students to a variety of tools and techniques, and the students designed and conducted their own investigations at different parts of Hagan Creek, which they ultimately reported on to the community during the annual open house event organized by the environmentalists.

Parents, activists, aboriginal elders, scientists, graduate students, and other Oceanside residents were an integral part of the science units – they constituted the relevant community in the context of which our Grade 7 students learned. This community was constituted by an interpenetration of school and village life more generally. For

example, every other week the classes I co-taught spent one entire afternoon in and around the creek. Parents assisted, driving children to the different sites along the creek and teaching by asking productive questions, scaffolding, and supervising children. Members of the Hagan Creek Project also contributed by giving presentations, and by teaching students how to use particular tools, do research in the creek, and analyze 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 other classes that were just beginning and assisted their peers during fieldwork and data analysis.

In designing the unit, we took our cues from the activities of others in the community concerned with the health of the local watershed and its main water-carrying body, Hagan Creek, and we allowed students to pursue investigations of their own interests. Because people in the community created and used various representations of the watershed, creek and the pressing issues, we changed from an initial focus on "scientific representations" (e.g., graphs) and encouraged students to create representations that best met their personal styles of expression. That is, students had considerable control over their objects of inquiry and the means used for producing the outcomes of their engagement (e.g., the representations). Because students were free to choose what they wanted to research, which tools and instruments they wanted to use, and how they wanted to report their research, they had control over the process and a personal identification with the products of their labour.

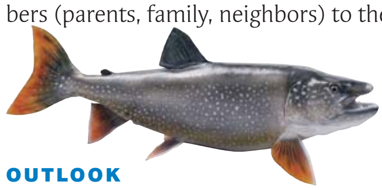
Although the activity–system defining object was the same for all student groups – Hagan Creek and the watershed it drains – different tools and rules mediated the relations in different ways, leading to very different outcomes. Nevertheless, the various outcomes ultimately contributed to the totality of the findings. We understand the students' activities to be authentic in the sense that their goals were motivated in the same way and by the same concerns that other goals in the community were motivated. Different members of the community in general, and the activist group in particular, participated in the same activity system that describes the students' activity, using many of the same tools. Not surprisingly, then, some of the outcomes of the student-centered activity system were similar to those created elsewhere in Central Saanich by adults or university students. For example, the use of colorimeter, pH meter, or dissolved-oxygen meter all led to numeric representations of stream health.[4] Similarly, middle school students and college students working for the Hagan Creek Project as a summer job produced very similar graphical representations, all of which entered a collectively established database. Likewise, forms designed by scientists (water quality assessment, physical assessment) assisted older students in their summer jobs and middle-school students in producing representations (outcomes) that could be used by the Hagan Creek Project members to pursue other goals (e.g., getting grants, proposing restoration work). That is, the students produced more than assignments that would be discarded after receiving grades: they contributed knowledge and representations to a collective cause and a greater good.

THE GRADE 7 STUDENTS PARTICIPATING IN THIS SCIENCE UNIT LEARNED SCIENCE BY CONTRIBUTING TO A COLLECTIVELY MOTIVATED ACTIVITY – ENVIRONMENTALISM, CONCERN FOR THE ENVIRONMENT, AND STEWARDSHIP. IN SO DOING, THEY CONTRIBUTED TO SOCIETY AS A WHOLE.

SCIENCE FOR THE COMMUNITY

Ultimately, the children presented the results of their work at the yearly open house events organized by the activist group that focuses on the environmental health of the Hagan Creek watershed. They mounted posters that engaged adults and other children alike, who had come because of the exhibit generally rather than the students' work in particular. Our classes presented, for example, descriptions and photographs in the form of a website, which the visitors could peruse at the event. After the units came to an official end with the open-house event, the result of the students' work was published in the local newspaper and on the website of the environmental activists. Thus, through both their exhibits during the open-house event and the subsequent publication of their findings, the outcomes of the students' production reentered the community in a process of knowledge distribution and consumption. The children noted, for example, that many adults who had never known about the existence of Hagan Creek now knew not only that it was there but also about its blight (e.g., farm- and industry-generated pollution).

The open house event and the subsequent publications were key points in the unit because students' work came to be legitimated and legitimate as the village community members accepted what they had done. To the children, the science units were 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 the impacts of the collective actions on the environment – e.g., the protective barriers along the creek in one park or the artificial riffles that oxygenated the water to make it suitable for trout habitat. 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.



OUTLOOK

The Grade 7 students participating in this science unit learned science by contributing to a collectively motivated activity – environmentalism, concern for the environment, and stewardship. In so doing, they contributed to society as a whole. A large part of my book *Rethinking Scientific Literacy*[5] deals with knowing and learning science in the Central Saanich community, among the environmentalists, ordinary village folk, and the students who participated in our science unit. It received an award from the American Educational Research Association for its decided focus on issues of social and environmental justice. That is, these students not only learned something for the purpose of getting a grade but also contributed in a valuable and valued way in the affairs of their village community.

I do not suggest that all students should participate in environmentalist activity, but there is much to do in our society where children and older students can contribute in inestimable ways – stewardship, fish hatching, understanding chemical, physical, and biological pollution, organic backyard city gardening, and so forth. By participating in these activities, which already exist and contribute to making this a better world, children not only learn science but also adopt the ethico-moral stance that characterizes them. This, as I have seen in my own work, leads to an increased awareness for the human-environment relationship that is becoming increasingly precarious, as can be gauged from ongoing public concerns about genetically modified organisms, environmental pollution, global warning, and so on. Learning science by contributing to society likely has a double benefit: children learn in a meaningful way, contribute to the societal needs, and develop the kinds of orientations that future generations will need to make the survival of the human species possible.

In 2005, the *Natural Sciences and Engineering Research Council of Canada* funded the proposal for the *Pacific Center for Scientific and Technological Literacy*, which I had submitted as the principal investigator on behalf of a consortium of educational researchers, scientists, and non-governmental environmentalist organizations who partner with local school boards and the BC Ministry of Education. The goals of the Center include better understanding of student learning in a variety of out-of-school contexts and increasing interest in science, even among those who will not pursue science-related careers. These future citizens need to be able to keep checks on those who, with great fervor, produce things and conditions that turn out to be harmful to humanity: things like thalidomide, atomic bombs, terminator (suicidal) seeds, and agent orange.

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Notes

1 M. Merleau-Ponty, *Phenomenology of Perception* (London: Routledge, 1992).

2 K. Holzkamp, "Societal and Individual Life Processes in *Critical psychology: Contributions to an Historical Science of the Subject*, eds. C. W. Tolman & W. Maiers (Cambridge: Cambridge University Press, 1991), 50-64.

3 W.-M. Roth, *Toward an Anthropology of Graphing* (Dordrecht, The Netherlands: Kluwer Academic Publishing, 2003).

4 S. Lee and W-M. Roth, "How Ditch and Drain Become a Healthy Creek: Representations, Translations and Agency During the Re/design of a Watershed," *Social Studies of Science, 31* (2001): 315–356.

5 W.-M. Roth and A.C. Barton, *Rethinking Scientific Literacy* (New York: Routledge, 2004).