Diversity in Environmental Education Research

David B. Zandvliet (Ed.)

Simon Fraser University

Research in environmental education (EE) is a growing field of inquiry and should be seen as respondent to a variety of program developments around the world. These diverse programs are the context for this body of educational research. Diversity in EE research is also compounded when one considers the various cultures, epistemologies and research traditions that may inform the field. This complexity accounts for the range of forms for environmental learning in formal, informal or non-formal contexts.

There is a good deal of evidence that, in order to be more responsive to the needs of diverse populations, program developments around the world are now beginning to reflect the variation in our society. However, the same cannot always be said in terms of research methodologies within mainstream environmental education research. Outside of a few examples, there seems to have been very little in the way of development of research genres aimed at understanding, characterizing and supporting cultural diversity within much of mainstream environmental education. Diversity of method may also be important for the overall quality (or health) of environmental education research. To locate many of the new ideas and approaches in this area, one needs to look outside environmental education, towards general educational research, or to other fields such as environmental justice, indigenous education, science education and health education to name only a few examples.

This volume of original research reports from around the globe begins to richly describe aspects of diversity in environmental education research. It does so in two ways: first, it mirrors the diversity of voices and cultures that are conducting research in this ever-broadening and increasingly global and international field of inquiry, second: it illuminates a potential diversity of research methods by highlighting a range of methodologies salient in other fields which have emerging promise for the practice of research in environmental education.
Diversity in Environmental Education Research
There continues to be growing concern about the state of the environment, yet we are often confused by the complexities of economic, ethical, political, and social issues related to it. Daily, there are references in the news media to environmental issues such as global climate change, ozone depletion, dwindling resources, famine, disease, loss of biodiversity, pollution, and continuing job losses in many BC communities. The problems we face both as individuals and within our broader society are now so pervasive and ingrained within our cultural ways of being that we can no longer look to education about science and technology alone to solve these problems. Resultantly, environmental learning can and should include a sustained critique on dominant societal and industrial practices that often contribute to widespread and localized environmental problems.

We must also turn to ourselves as individuals, as researchers and as educational professionals to make change and develop a new ethic - a responsible attitude toward caring for the earth. Working to integrate environmental learning within all subject areas promotes this change in attitude by providing students with opportunities to experience and investigate the relationships linking individuals, societies, and natural surroundings. Education ‘about’, ‘in’ and ‘for’ the environment provides students with opportunities to learn about the functioning of natural systems, to identify their beliefs and opinions, consider a range of views, and ultimately make informed and responsible choices for themselves, their families and communities. This book series aims to look at environmental learning and the associated educational research related to these practices from a broad and international perspective.
Diversity in Environmental Education Research

Edited by:
David B. Zandvliet
Simon Fraser University
## CONTENTS

1. Diversity in Environmental Education................................................................1  
   *David Zandvliet, Carlos Ormond, Susan Teed, Veronica Hotton, Melanie Young and Quirien Mulder Ten Kate*

2. Towards Epistemologically Sound Approaches in Environmental Education.............................................................................................................9  
   *Michiel Van Eijck and Wolff-Michael Roth*

3. Three Perspectives of Environmental Education in Israel: Ideologies, National Conflicts and the Environmental Movement ............................................25  
   *Tali Tal*

4. The Impact of Methodological Practices in Research and Evaluation in Environmental Learning .................................................................................................43  
   *Bruce Johnson and Constantinos C. Manoli*

   *Joanna Kidman*

6. Using Chat to Identify Barriers to Education for Sustainable Development ........................................................................................................77  
   *Ahmad Qablan, Sherry Southerland and Yavuz Saka*

7. Unpacking the Complex Influence of Schooling, Sense of Place and Culture on the Motivation of Taiwanese Elementary Students to Learn Science in School: Using A Socio-Cultural Approach With Phenomenological Research Methodologies ..................................................103  
   *Eleanor Abrams, Chiung-Fen Yen, Erica Blatt, And Lihua Ho*

8. Critical Discourse Analysis: A Research Methodology for the Analysis of Environmental Education Materials .................................................................131  
   *Joan M. Chambers*

9. Globalization and Education for Sustainable Development in Teaching Science: Perspectives from Chile, China and Canada ........................................147  
   *Susan Barker, Pat Rowell, Pilar Reyes, Jianzhong Zhou, Frank Jenkins, Zhaoning Ye, Min Wang, and Evelyn Leyton Fuentes*

10. Living in and off the Environment: Educating for Sustainable Development in an Unequal World..............................................................................159  
    *Bob Manteaw*

11. Place-Based Learning Environments in India, Mauritius and Australia........177  
    *Rekha B. Koul and David Zandvliet*
DIVERSITY IN ENVIRONMENTAL EDUCATION

In this new collection of work, we aim to describe research with/in environmental education as a diverse and growing field of inquiry, respondent to a variety of international program developments and contexts. This research might be labeled under various genres: environmental education, global education, indigenous education, health education, eco-justice education, education for sustainable development, environmental learning, etc., however in our opinion, what truly matters is that there are a broad range of perspectives and paradigms described that may critically inform our work as educators and as researchers. This work then begins to describe a range of possibilities that exist around the various contexts for research in environmental education.

This collection of original research, drawn from around the globe begins to richly describe aspects of diversity in environmental education research. It attempts to do so in two ways: first, it begins to mirror a diversity of voices and cultures that are conducting research in this ever-broadening and increasingly global field of inquiry; second: it illuminates further potential for diversity in research by highlighting a range of methodologies salient in other fields which may also have promise for the practice of research in environmental education.

WHY DO WE NEED DIVERSITY IN RESEARCH?

Diversity in environmental education research is compounded when one considers the various cultures, epistemologies and research traditions that often inform the field of environmental education. This complexity also accounts for a range of forms for environmental learning whether it occurs in formal, informal or non-formal contexts. Still, published research accounts do not always mirror the complexity inherent in the broader field. For any research, it is important to consider two important and linked aspects of diversity: 1) diversity of voice and 2) diversity of method.

Cultural diversity is often talked about in educational circles, and it is assumed that great benefits are to be gained by educators through careful attention to the range of perspectives that the world has to offer us. According to Agyeman (2002; 2003) the dominant idea here is that if there are variations according to race and/or culture within the fields we study, then as environmental educators, our practice, pedagogies, and research methodologies should reflect this. He asks us to reflect on the question: “if racial and cultural variation is happening, are we as educators reflecting these variations?”
In terms of curriculum content, pedagogy, and practice, there is a good deal of evidence that, in order to be more responsive to the needs of diverse populations, program developments around the world are beginning to reflect the variation in our society (Bowers, 2001; Cajete, 1994; Lewis & James, 1995; Marouli, 2002; Rixecker, 1999; Russell, Bell, & Fawcett, 2000; Taylor, 1996). However, the same cannot be said in terms of research methodologies within mainstream environmental education (Agyeman, 2003). Outside of a few examples, there seems to have been very little in the way of development of research genres aimed at understanding, characterizing and supporting cultural diversity within much of mainstream environmental education.

Following from this, we feel that a diversity of method is also important for the overall quality (or health) of environmental education research. To locate many of the new ideas and approaches in this area, one needs to look outside environmental education, towards general educational research, or to other fields such as environmental justice, indigenous education, science education and health education to name only a few examples. Diversity of method speaks also to the question of “what counts as research?”

In response to this question we propose that a range of strategies (rather than a limited subset) would be more desirable. For example: in an environmental or ecological curriculum, educators often work diligently to facilitate students’ understandings of the concept of biodiversity and a range of associated scientific and ecological benefits linked to the planet’s overall wellbeing. We believe that the same should be said for the practice of educational research. In this chapter, we will use a biodiversity metaphor to describe the pluralism of method we feel needs to become more commonplace in environmental education research publications.

A METAPHOR FOR DIVERSITY

The word ‘biodiversity’ was coined by biologist E.O. Wilson in 1986 as a contraction of the phrase ‘biological diversity’ and came into widespread use after the United Nations’ Rio de Janeiro ‘Earth Summit’ Conference in 1992. Biodiversity is described as the variety of living things, including diversity within species, diversity between species and diversity of ecosystems. An ecosystem is any interacting system of living organisms including their relationships with each other and their surroundings. In a properly functioning ecosystem the components are inseparable and act upon each other.

If we view the educational system with this lens, we may see it as a complex ecological system in which practitioners, researchers, specific places and endemic cultures are part of an interrelated whole. It follows naturally then, that diversity in research is desirable both for the health and survival of the entire system. In this metaphor, various research methods and epistemologies would arise (as they do) from unique, situated contexts and would have special relevance for that specific ecology.

When diversity characteristics are assessed for any location or region, three attributes can be considered as contributing to this metaphor. The first theme, composition would describe the parts of each diversity component in an area (for
example, the unique social context of the setting, programmatic elements, pedagogical approach, demographics, etc.). This aspect refers essentially to the habitat of students. Next, the structure of the diversity theme could refer to physical characteristics supporting that composition (for example, class size, type of school, grade level and all the inherent systematic functions related to these). Finally, the last aspect of our metaphor refers to the function for the diversity. This could serve to describe a characterization of the processes affecting educational life within that structure (for example, teacher’s intent, links to the curriculum, and values and ethics imbued in all of these complex processes) all of these impact the learning environment of students.

In summary, in proposing this metaphor for research, we believe that a healthy and diverse research community should be congruent in these ways with the diversity of programs now emerging on the global scene. This diversity in cultural perspectives, methods and contexts can encourage an energetic, vibrant research community that responds to a changing world with continued and fresh perspectives. This volume of research begins to tell that story.

CHAPTER SUMMARIES

In the next chapter (Chapter two), a case is made for what Van Eick and Roth term: ‘epistemologically sound approaches to environmental education’. The authors present a holistic framework they describe as grounded in human evolution and the notion of collective human activity as the pivotal unit of individuals’ transaction with the natural world. Drawing on data from a study of a project-based learning environment, Van Eijck and Roth’s research is consistent with our diversity metaphor in that the study relates how multiple stakeholders come together around a local watershed. Initially they describe how their project began as a way to engage students in the science curriculum through active participation in an authentic study of a local stream. However, they relate that the composition of study participants soon expanded to include parents, elders, scientists, politicians, environmentalists, and the local community. Further, the structure of their watershed studies were conceived of and designed by the students themselves, and carried out with the support of these same key stakeholders. Consequently, the project’s function grew to include imbedded conversations with water technicians and environmentalists revealing a rich history of the watershed through audio interviews with local politicians and elders from the community, and scientific studies of water sampling and testing conducted at a university microbiology lab.

In Chapter three, Tali Tal describes an environmental education that is set in the backdrop of social conflict that historically exists and continues to challenge the Middle East. This perspective is enabled by Tal as she recounts the development of Environmental Education in Israel. The uniqueness of this context for environmental education is described in this chapter with reference to various influences such as the national emergence of a proud Israeli Arab (Palestinian) community that became empowered to integrate itself and become a part of Israeli society, and also by that of the global environmental movement. The research that Tal conducts in Israel speaks to the diversity of method in that her work not only aims...
to bring about a connection and an ethos towards the environment but researches environmental education as a means to confront the social conflict between Jews and Arabs in Israel. In addition to observing differences between how Jewish and Arab children perceive the environment and the benefits that come with bringing these two communities together using the environment as a bridge, Tal also discusses the differences and issues in environmental projects that have been and are being conducted by both the Israeli government and non-governmental organizations in that country.

In Chapter four, Johnson and Manoli compare and contrast an earlier study with two studies of their own. Their study assessed significant changes in the affective domain of participants in the Earth Education program: Sunship Earth. While Keen’s study attributed no changes resulting from the program, Johnson and Manoli, attribute significant affective changes. Even though multiple explanations are available for this apparent difference in results, the authors carefully examine the design of the pre-test and post-tests employed in these respective studies, as key to accounting for their opposing conclusions. This chapter challenges the reader to consider the importance of a theoretical framework that supports their methodology used to gain insight into this important affective component of environmental learning. The authors suggest that differences in research methodologies and conceptual frameworks can result in different conclusions about affective change in students. This supports our suggestion that research methodologies must reflect cultural diversity, and acknowledges how the nature of the participants will change how an environmental education program might be received and perceived. In other words, the research method must lend a voice to all aspects of an environmental education program, and it must be congruent with its many variables that it tries to expose, understand, interrelate and act on.

Chapter five explores the ways in which visual methodologies can be used in environmental education to map the intersecting cultural and physical territories of indigenous groups. Joanna Kidman’s research is premised on the idea that some indigenous peoples, in this case groups of Maori teenagers in Aotearoa/New Zealand, construct cultural identities which are closely linked to their tribal and physical landscapes and these in turn influence the way they learn about the world and ultimately, how they act upon it. Kidman’s discussion focuses on data gathering methods which involve the creation of visual representations of tribal landscapes by research participants, using digital media. To this end, a study aimed at exploring the ways that young people ‘see’ the world they live in (literally through a camera lens) and how their perceptions of their physical environments influence their sense of cultural identity, is discussed. Kidman’s research speaks to the diversity lens in both senses here: first she brings the unique perspectives of Maori culture to environmental research; and second, she utilizes an arts-based research methodology that incorporates digital media to assist students in their representations of their landscapes.

In Chapter six, Qablan, Southerland and Saka describe a situation within the U.S. academy, where two professors’ experiences and ability to incorporate Education for Sustainable Development (ESD) into the classroom, are examined using the methodological lens of Cultural Historical Activity Theory (CHAT). The
qualitative data included: interviews of both professors and students; examination of university materials; course materials (syllabi, assignments, readings); and classroom observations. The results highlight the personal and institutional contradictions that often influence post-secondary educators ability to implement ESD into curricula. The contradictions described serve as both barriers and opportunities for change, including such factors as university priority on research at the expense of teaching and service, a demanding workload, a fear of indoctrinating students with biased facts and non-objective views, a lack of an ESD community within and outside academia, and finally, professors’ conceptions of teaching and learning. Through personal and institutional transformations, the authors suggest these challenges can be addressed in substantive ways. The use of CHAT as the study’s methodology is also seen as a unique in describing the complexity of factors influencing the post-secondary teaching environment.

Chapter seven invites the reader into a discussion on the importance of using rigorous qualitative research techniques to examine complex sets of concepts in environmental education. Abrahms, Yen and Blatt elaborate on the use of socio-cultural theory with phenomenology as a way to collect data to understand the motivation of Indigenous children to learn in school. The foundation of the chapter is based upon research conducted with Taiwanese Indigenous children. To understand the motivation of the children to learn science, the authors needed a theoretical framework and a methodology that allowed for the emergence of new themes, which stemmed from the participants’ unique perspectives. In this chapter, they describe how the intersection of schooling, sense of place and culture, are significant to Indigenous science education in Taiwan. Abrahms et. al. use a socio-cultural theoretical framework in this research and apply it to the study and a phenomenological interview technique used as the main data collection technique. The chapter also describes through a step-by-step process how these approaches were implemented including site selection, data collection, and triangulation. The qualitative approach allowed for new themes and associated concepts to emerge; furthering our insight into the best practices for serving the needs of Taiwanese Indigenous children in learning school science.

In Chapter eight, Joan Chambers uses critical discourse analysis as her research methodology in the analysis of environmental education materials in Canada. The context of Chambers’ study – the composition of her methodology – is the Alberta education system, and more specifically elementary school classrooms in that province. The structure of her work is built upon two theoretical frameworks. She uses critical discourse analysis to bring to light the assumptions underlying the message, and the values and biases represented in the selected environmental education resources. Then, drawing upon eco-social theory (which acknowledges our embedded and embodied relationship with the environment), she uncovers how these resources create and are created by social and material worlds. Through such indicators as the language chosen, its position in text or on the page, the placement and colour of images, and what is omitted from text and image, Chambers highlights the tacit messages in the learning resources; in particular the relationship between humans and other living beings (the more-than-human). The claim of neutrality made by the producers of such resources is challenged, and Chambers research also
asks us to consider whether such a position is even possible. Chambers closes by challenging us to become aware of biased or hegemonic discourses embedded in all resources intended for the school classroom.

In chapter nine, the authors aim to share their understandings about how teachers, science educators and scientists in three culturally contrasting countries perceive the globalized phenomenon of education for sustainable development. Barker et al. report out on some of the cultural understandings of education for sustainable development in China, Chile and Canada. The basis for the chapter is research from a large project tracking the implementation of science inquiry as a process of science and a teaching approach in schools in each of these countries. The goals of the project were to determine how stakeholders in each of the countries perceived the implementation of a pedagogy developed in North America, that models the practice of western science yet is utilized in culturally distinct ways in each of the different countries. As part of the study’s interview protocol, the authors asked stakeholders (scientists, science educators and science teachers) for their views on sustainable development and whether science teaching was an appropriate context for exploring it. This research shows how culture can influence environmental pedagogy and also allows for a diversity of perspectives in the interpretation of the research data.

Chapter ten focuses on what the author, Manteaw, terms the 'educational imperatives of sustainable development.' Manteaw begins on the premise that current discourses on sustainable development ignore issues of critical geography, as well as the spatial, cultural and situational differences of different people in their different places. Invariably, these are issues which are easily dismissed as serious considerations in the sustainability debate. The chapter, therefore, foregrounds sustainable development as a global quest that requires concerted local and global actions for attitudinal and behavioral changes. In doing so, Manteaw also calls for culturally-specific educational approaches that respond to the unique cultural and situational needs of local people. To illustrate his point Manteaw draws on his experiences growing up in Ghana. The Ghanaian understanding and perception of the concept of sustainable development becomes instructive here as they provide insights into how such understandings inform educational approaches for sustainable development in different cultures. In foregrounding the concept of sustainable development, Manteaw’s desire is to stress on the place of the natural environment and the role of education in the global sustainability quest. Thus, the chapter affirms sustainable development as an educational issue, and one that needs to be guided by conscious educational philosophies and approaches.

In the final chapter (Chapter 11), Koul and Zandvliet consider the development of a quantitative tool to measure place-based learning environments in three countries (namely Australia, India and Mauritius). In applying the theory of learning environment research to the new context of place based and environmental education, they first acknowledge the premise that all learning takes place within the social realm and that social conditions contribute to the quality of both learning and experience. They then recount the development of a robust instrument for measuring perceptions of environmental education settings termed the Place-based Learning and Constructivist Environment Survey (PLACES). The chapter reports on focus
DIVERSITY IN ENVIRONMENTAL EDUCATION

groups with environmental educators which explored, from the teachers’ perspective, the factors viewed most important to environmental learning and most likely to influence the unique learning environments in place-based or community-based education programs. Analysis of this qualitative work resulted in the inclusion of eight scales developed or adapted from previous learning environment surveys for inclusion in the new instrument. After field-testing the new instrument in three countries, validity and reliability data for the new instrument are presented and the implications of these data for future research in environmental education programs are discussed.

REFERENCES


David B. Zandvliet
Carlos Ormond
Susan Teed
Veronica Hotton
Melanie Young
Quirien Mulder ten Kate

Simon Fraser University, Vancouver Canada
MICHEIL VAN EIJK AND WOLFF-MICHAEL ROTH

TOWARDS EPISTEMOLOGICALLY SOUND APPROACHES IN ENVIRONMENTAL EDUCATION

The increasing awareness that the quality of education is critical for sustainable development has led authors in high quality science and science education journals to call for the improvement of environmental education. Yet, the different, often simultaneously proposed approaches that can be found in science journals are commonly grounded in epistemologies that mitigate the very attitudes that are to be propagated. To overcome such epistemological contradictions, we present a holistic framework that is grounded in human evolution and the notion of collective human activity as the pivotal unit of individuals’ transaction with the natural world. Drawing on data from one environmental education project, we exemplify how this framework allows a dual contribution to both the improvement of education and sustainable development.

INTRODUCTION

In recent issues of PLoS Biology, Science, and Nature, natural scientists argued for the improvement of science education to increase the number of new researchers “in the pipeline” and the throughput of students through scientific programs. Such pleas reflect the growing awareness that the quality of science education not only is required for sustaining a lively scientific community that is able to address global problems like global warming and pandemics but also to bring about and maintain a high level of scientific literacy in the general population. In the chain from the current environmental problems towards solutions that contribute to a sustainable future of life on earth, including humanity as a whole, science education is increasingly recognized as a critical and vital link. Yet, the solution of global environmental problems does not automatically follow from the ideology-laden big issues that scientists bring forward and which find their way in a trickle-down fashion into school science classrooms. The issue here is not only what is being taught—the amount of scientific knowledge currently available to be taught is too large to teach even a fraction of it—but also how science education curricula are developed and evaluated.

There is no doubt about the good intentions of calls for more effective education as a vehicle for solving global problems. Good intentions are not enough as the U.S. experience has shown, where despite the involvement of natural scientists in science education, “effective ‘pipelines’ and ‘pathways’ from early science and math education to successful science and math-related careers” do not exist (Frantz, DeHaan, Demetrikopoulos & Carruth, 2006). Yet, despite this
recognized role as a critical link, there appears to be a poor understanding of what makes science education effective in this respect. This is revealed by a closer look at the different, often-simultaneously proposed approaches that accompany pleas for the improvement of science education. Such approaches are commonly grounded in epistemologies that work against the very attitudes that are simultaneously propagated. For instance, in one of the featured contributions to noteworthy journals, it has been proposed to “design environmental education programs that can be properly evaluated, for example, with before-after, treatment-control designs” (Blumstein & Saylan, 2007, p. 975). The point we wish to make here does not concern the necessity of proper evaluation of educational programs. Rather, we are concerned with the ramifications for the design of educational programs following from particular epistemologies that are simultaneously adopted with “proper” evaluations.

The treatment-control design, for example, assumes that individuals can be subjected to a particular educational “treatment” which triggers a particular reliably measurable response that allows valid comparison with a “control” group. This assumption is grounded in behaviorism, which attempts to reduce behavior to its environmental causations. Although behaviorism still dominates formal education (Greeno, Collins & Resnick, 1996), cognitive scientists and learning scientists no longer consider it to be an appropriate framework for educational design (Ertmer & Newby, 1993). Indeed, educational design is concerned with human beings and therefore requires a framework that appropriately explains human behavior. Contemporary ethology has shown that this requirement is not met by behaviorism—it cannot explain the more complex behavior of animals, such as social behavior of primates (including humans) and language (De Waal & Tyack, 2003). Rather, for the design of education to effectively contribute to a sustainable future, we must adopt the notion that humans are a self-determined yet integral part of their environment (Bonnet, 2002). According to such a perspective, humans collectively produce and reproduce their environment through their actions and are hence capable of acting responsibly for and toward a sustainable future. Behaviorism, in contrast, departs from a subject-environment dichotomy and assumes behavior to be the result of stimuli from the environment (Baum, 2005). It ignores the capability of humans to collectively produce, both reproduce and change their social and natural environment through their actions—humans are not playthings of their environment that can be either validly controlled or reliably subjected to treatments (like guinea pigs) but are capable of responsibly acting for a sustainable future. Unwittingly, the proposed requirement of treatment-control designs works against the very attitudes of sustainable development that are simultaneously propagated.

To overcome the inner epistemological contradictions in the design and evaluation of educational programs proposed in various scientific journals, we argue for an epistemology that is congruent with acceptable frameworks in contemporary ethology and accounts of human beings as self-determined, environment modifying and controlling beings, but yet integral subjects of the environments that they co-create (see current debate on the human contributions to global warming). Such an epistemology is more holistic and draws on the central paradigm of the life
sciences—evolution. More so, it approaches collective human activity as the pivotal unit of analysis in which individuals transact with the social and natural world. Drawing on data from an environmental education project, we exemplify this epistemology that allows us to understand how we can both contribute to the improvement of education and a sustainable future of life on earth for humanity as a whole. We herewith contribute to a consistent and coherent understanding of both the macro-educational aspects of a sustainable future and the micro-educational aspects of science education.

A FRAMEWORK FOR ENVIRONMENTAL EDUCATION

Nothing in biology makes sense except in the light of evolution.
–Dobzhansky, 1973, p. 125

In the 1920s, Soviet psychologists—including Lev Vygotsky and his colleagues Alexander Luria and Aleksei Nikolaevich Leont’ev—were discontent with the then-current dominating frameworks in psychology—psychoanalysis and behaviorism—for the very same reasons we outlined above. In response to these frameworks they recognized that “cognition does not exist outside the life process that in its very nature is a material, practical process. The reflection of reality arises and develops in the process of the development of real ties of cognitive people with the human world surrounding them; it is defined by these ties and, in its turn, has an effect on their development” (Leont’ev, 1978, p. 13). For these psychologists, therefore, consciousness accompanies and is a (non-linear) reflection of reality that humans create and inhabit.

To understand human cognition as a result of both evolutionary (historical) and cultural development integrated with its natural material environment, Vygotsky and his collaborators formulated a completely new psychological framework: cultural-historical activity theory. The core concept of this framework is that of artifact-mediated and object-oriented action (Vygotsky, 1978). A human individual never directly acts in or reacts to (with inborn reflexes) the environment; tools mediate the relationship between the human subject and objects of environment. Tool use is not limited to humans but rather a critical evolutionary step associated with higher-order cognitive processes common in animal species such as chimpanzees and crows (McGrew, 1992; Hunt, 1996). The most important tool of all is language, which constitutes the very possibility of and for consciousness.

We should think of human activity as a complex evolutionary achievement of which the emergence may be conceptualized in three steps (Engeström, 1987). First, animal activity can be thought of as an immediately collective and populational “methodology of survival” of a species (Figure 1). This type of activity is not just passive—we should speak of construction of the environment rather than adaptation to the environment (Lewontin, 1978).
Second, in animal evolution, each of the three sides of the triangle depicted in Figure 1 thus exhibits evolutionary development. The emerging utilization of tools therefore evolves at the uppermost side of “individual survival.” Collective traditions, rituals and rules, originating at the crossing of adaptation and mating are emerging as part of “social life” on the left hand side; in meta-analytic studies, primatologists have reported such collective, cultural traditions among chimpanzees and orangutans (Whiten et al., 1999) and orangutans (van Schaik et al., 2003). On the right hand side, the “collective survival” exhibits an evolving division of labor, influenced by the practices of breeding, upbringing and mating, and appearing first as the division of labor between the sexes (see Figure 2).
Third, the emerging mediators on each side of the triangle depicted in Figure 2 become unified, determining factors that mediate human activity. The ecological and natural become the economic and historical. In cultural-historical activity theory, then, activity is understood as some macrolevel formation that serves the survival of the collective—such as farming, education, or environmentalism (Roth & Lee, 2007). The model of human activity thus allows us to understand such activities as a set of relations (see Figure 3). Such an activity system is the smallest unit that allows us to understand cognition in its orientations and achievements. Any smaller unit only yields one-sided, partial representations and understanding of knowing and learning that can be observed. Yet, in accordance with an evolutionary paradigm, the task is always to holistically grasp the systemic whole, not just to reduce human activity to its separate connections.

Central to the model is the concept of object-oriented and artifact-mediated activity: Artifacts are any tool, sign, or other means required for the mediation between the subject, a human agent, and the object, the thing or change in the environment to which a human simultaneously acts and reacts to and interacts with. This means, when we study any form of human activity, we must take the mutual constitution of subject and object of activity into account lest we misunderstand the motivated ways in which human beings orient toward motives, goals, and the outcomes of their productive activity. This relation between subject and object is mediated further by the other moments characteristic of human activity: rules, division of labor, and community (culture). The community entails multiple individuals or sub-groups who share the same general object and who distinguish themselves from other communities. The division of labor refers to both the horizontal division of tasks between the members of the community and to the vertical division of power and status. Finally, the rules refer to the explicit and implicit regulations, norms, and conventions that constrain actions and interactions within the activity system. In groups of humans, knowledge is a dynamic set of artifacts that simultaneously mediate activity and are produced by activity.

Cultural-historical activity theory allows us to better understand knowledge, which is so central in education. Knowledge is in and spread throughout the activity, not merely in the heads of individuals: thus, for example, tools embody knowledge in a crystallized form so that their users do not have to mobilize it themselves, which means in tool-use, part of the knowledge-in-action resides in the tool. Humans today can do so much more than their forefathers precisely because much of the knowledge and practices required then now are packaged into tools and unconscious operations so that they no longer need to be attended to consciously and no longer need explicit teaching. Knowledge is inferable from patterned actions, and actions leave traces in human bodies, which subsequently mediate actions in the future. Such traces can be conceptualized as artifacts. Accordingly, knowledge can be seen as part of object-oriented and artifact-mediated activity (Vygotsky, 1978). Importantly, sense and meaning are characteristic of activities as a whole rather than of actions in themselves. Whereas tacit operations that compose actions are embodied in individuals, they have their origin in mimetically copied or routinized culturally meaningful action and therefore constitute a crystallized form of social action.
Cultural-historical activity theory allows us to think and rethink science education in such a way that its effectiveness is conceived in terms of contributions to a sustainable future. We exemplify this with a case study from the practice of environmentalism. Currently, schooling does not give students opportunities to participate in setting the goals and objectives of their activities, choose tools, determine the division of labor, or participate in the constructing the going rules that shape how people interrelate among themselves and with their environment. The result is that students are more in the situation of lab rats that perform to reap benefits in the form of grades, points, stars and so on rather than in really trying to understand—they engage in defensive learning, a form of learning that has the function to avoid punishment, as one of Leont’ev’s intellectual students put it (Holzkamp, 1993). As the following description shows, there are other ways to organize school science that provide students precisely with the kind of learning opportunities that characterize other everyday, science-related activities, including laboratory and field sciences or environmentalism. As they pursue their goals, students engage in whatever they deem necessary to expand their action possibilities, which, when it has happened, is a sign that they have learned.

**EFFECTIVE EDUCATION FOR SUSTAINABLE DEVELOPMENT: AN EXAMPLE**

In three iterations, we have assisted local middle school teachers to implement a curriculum focusing on the watershed of one community in Western Canada, allowing students to learn whatever science they needed (biology, environmental science, chemistry, physics) while studying the main creek draining the watershed. This curriculum embodied the best we had learned about teaching science over more than a decade, including the involvement of scientists, environmentalists, water technicians, farmers, aboriginal elders, community politicians, and parents.

We began the curriculum with a lesson in which the students read several articles from the local, two-issue per week newspaper concerning (a) the health of

![Figure 3. The structure of human activity (after Engeström, 1987)](image_url)
the local watershed, (b) the watershed- and creek-focused actions of an environmentalist group, (c) the struggle of one citizen group to be connected to the water main that supplies water to all other residents, and (d) other water-related activities in the community (meetings, water advisory task force, etc.). In one of the articles, the director of the environmentalist group was interviewed: she not only told about the sorry environmental health of the watershed and creek (Figure 4) but also invited all community members to contribute to better understanding the watershed and to revitalizing parts of the creek and watershed.

In all iterations, the seventh-grade students involved felt connected: Some of their parents were fishermen affected by the toxic run-offs from the creek around the inlet in which the community is located (the salmon species include chum [Oncorhynchus keta], coho [O. kisutch], and chinook [O. tshawytscha]) and others were from the local aboriginal band, which still drew sustenance from the oysters [Ostrea lurida, Crassostrea gigas], mussels, clams [Saxidomus giganteus, Tapes japonica, Clinocardium nuttalli], crabs [Cancer sp.], sea urchins [Strongylocentrotus sp.], and barnacles [Balunus sp.] that they found on the beaches near their village. At the time, 12 of 15 shellfish beaches were closed due to fecal contamination. Recognizing the effect that creek pollution has on their and their community’s life, students began a discussion concerning their involvement: how to help, what to study, where to report their findings, and so forth.
The following week—drawing on parent volunteers as drivers, environmentalists as experts, university biology students and scientists as experts—the students first visited the creek at various places. They discovered, for example, pristine parts of the valley (Figure 4) that are not unlike how it has been just after Europeans settled here in the 19th century, a reminder of which is tiny church from 1868 (within the line of sight of Figure 4 but occluded by trees). The students found from the elders, water technicians, or environmentalist, that this watershed provides rich habitat and therefore food for the local aboriginals and initial settlers, including 24-inch cutthroat trout (*O. clarki*). But the students also discovered those large parts of the creek that have been straightened and dredged to function as ditches for the rapid discharge of water from what before settlement was a wetland habitat that the local aboriginal tribes used as their hunting ground (Figure 5).

![Figure 5](image_url)

*Figure 5. Many parts of the creek have been straightened to produce ditches that lead to faster run off; an industrial area behind the tall trees to the right spills heavy metals and other pollutants into this part of the creek affectionately called “stinky ditch”*
They discovered the small industrial area at the end of the photograph (covered by the tall fir trees), where several companies discharge their effluents into the creek side arm leading to its high load in heavy metals, organic compounds, and other pollutants. The students also learned that because that in most reaches, the creek no longer is a viable habitat because of slow moving water, the lack of oxygen, the lack of riparian vegetation that would prevent the heating up of the creek, and so forth. During their visit to the mouth of the creek, the students found that the contaminants (including sewage effluents, storm drainage, agricultural runoff) from the creek, as reported in a water quality study, pollute the inlet and lead to “marine habitat disturbances,” “disturbances of the sensitive coastal ecology,” and “environmental degradation.”

This visit really got the students excited: in the health of the creek and watershed, they have found an object (Figure 3) for their involvement in a local community issue, and, working in groups of three or four students, began to decide what they wanted to do to produce as outcome (Figure 3). Because the students decided upon what they wanted to produce, they felt in control; and in the course of pursuing their research over the subsequent 3–4 months, they identified those parts of their knowledge that they needed to expand on to achieve their objectives. They decided upon the division of labor (Figure 3) within their groups, drawing among others on equity as a rule to ensure that they all had opportunities for learning.

As students engaged in a variety of research projects, they changed their understandings and, correspondingly, evolved their research programs. There are different ways in which students involved themselves to respond to the environmentalist’s call for creating an understanding of and about the creek, each way corresponding to the particular learning needs of the students within a group. For example, one group of boys decided to determine, among others, whether there is a relationship between speed and the creek profile; in another project, they determined the relationship between the frequency of occurrence of certain organisms (e.g., Arthropoda) and stream speed. A group of girls decided to document creek health by means of verbal descriptions recorded on tape on-site and by means of photographs showing the effects of pollution, pollutants (“garbage”), and the like (Figure 6). The girls also recorded—using audiotape recorders as the tools—their interviews with local politicians and community elders, which they transcribed for subsequent “publication” purposes. Another group focused on the water itself: they used a dissolved oxygen meter and a colorimeter borrowed from the environmentalists to collect samples at various sites along the creek and studied the prevalence of organisms in the different sites. Finally, one particularly interested student, after having used a more qualitative test for the prevalence of fecal coliform bacteria, became so interested that he accessed, with the help of a graduate student involved, a microbiology laboratory to produce more reliable estimates of the coliform counts. This allowed him to correlate high coliform loads with particular farms. In one instance, an aboriginal student did not feel like contributing to the creek studies at all, but, during a brainstorming session with us, decided to become the “historian” of his class’ effort, using one of our video cameras to document what his fellow students are doing, including interviewing his peers about the projects
they conducted, their aims and rationales, and the ultimate outcomes they wanted to produce. In all of these projects, the tools (Figure 3) mediated students’ actions and therefore constituted one aspect that determined the high quality of the measurements produced.

Although the different groups pursued specific projects, they learned more than what they found out through their projects alone. Because we had regular discussions with the whole class, students in any one group also came to learn about what other groups found out, which tools they used and how they used them. Sometimes the entire class got involved in analyzing the data generated by a specific group, such as when one group makes available their incidence vs. stream-speed data for 10 different species. The knowledge generated by individual groups therefore re-entered the classroom community (Figure 3), which “absorbed” or “consumed” it by drawing on it as a resource for subsequent investigations. In several instances, students from a class that had completed the unit assisted in introducing other teachers then their peers from other classes to this unit, data collection, and so forth. These students also came to the field to serve as instructors for one or more groups while they conducted their studies in and around the creek;
as instructors, they therefore participate in the division of labor (Figure 3) among the teachers and others facilitating the efforts of those currently going through the curriculum.

In the end, students reported the outcomes (Figure 3) of their work during the open-house event that the environmentalists organized each year. The students featured their work spread throughout the room among other stations that environmentalists and other community members (e.g., a heritage group, scientists from a nearby marine research station) had mounted. The stations included, for example, one where students featured a website (using a computer installed for the purpose), had set up trays containing specimens and guides for classification to teach visitors about microorganisms, feature stations where they teach the use of dissolved oxygen meter and colorimeter, mounted posters, and so forth. Throughout the two-day event, the seventh-grade students interacted in knowledgeable ways with the visitors of all ages. For example, our videotapes showed one seventh-grade student explaining, using a physical model he had constructed, the inner workings of a watershed to a child several years younger (Figure 7a); another student explained to a university law professor how to measure the turbidity of water (Figure 7b); at a third station, a student presented the photographs, observation transcripts, and interviews with elders and politicians (Figure 7c); and at a fourth station, two students introduced several adults to the classification of arthropods, mayfly nymphs (Ephemeroptera) and how to distinguish those larva that look rather similar. All of these interactions between students and visitors are evidence of the tremendous knowledge that the students gained in and through their participation.

But there is more to this curriculum unit than the learning of individual students. The students’ products were also featured in the local newspaper, on the Website of the environmentalist group, and, where applicable measurements (e.g., oxygen, pH, and turbidity levels), are entered into their databases, to which others (university students, residents, environmentalists) have already contributed data. The students’ work, therefore, re-entered the community at large (Figure 3), which consumed and absorbed these products and underwent sustainable change toward a positive (i.e., environmentally more healthy future) for the watershed. But this re-entering of knowledge into the community also generated tensions, when, for example, students were not allowed back onto the properties of those farmers where a student had found significant and reliably measured increases in coliform bacteria levels.
In summary, this curriculum raised scientific literacy generally rather than reaching only a few (gifted) students who would have been successful however science has been taught. Moreover, these students did not merely acquire a stock of words that they can reproduce on a post-test or a standardized test used for international comparisons, they participated in changing their community. As a result of their and other’s efforts, this community today is different from what it was prior to the first curriculum—e.g., the official community plan has been changed, fences have been built to protect riparian areas (Figure 8), riffles now oxygenate parts of the creek, and the industrial pollution has decreased. The environmentalists attribute a considerable aspect of the success to the students’ involvement, both through their public work and through the sensibilization and conscientization to environmental issues within their extended families (Roth & Barton, 2004). That is, in this community, practical scientific literacy (rather than passive words in a person’s mind) has increased, in particular with respect to the environment and environmental health.

Figure 8. Due to the environmental movement, to which three classes of seventh-grade students actively contributed, the community has changed both physically and in its attitudes toward the environment

Without the different people and groups involved, this curriculum unit would not have unfolded in the ways it did during our three iterations. An important aspect was the contributions others made (parents, elders, politicians, scientists, environmentalists, graduate students). These contributions constitute a form of
division of labor at the level of the community (Figure 3), where “education” no longer is held to be the prerogative of school and teachers but an issue for the community as a whole. And through their participation, those within the school (students learned science, teachers how to teach such a unit) and those outside the school learned (about the environmental health of the watershed they inhabit).

CODA

We began this chapter with a critique of a current way of thinking about school science generally and school biology in particular. Our critique focused on the presupposed connection between assessment and effective education. We provided a case study of a very different curriculum, taught in three iterations, where, by all measures, students not only learned science but also learned more so than in normal science lessons but also contributed to changing their community toward a sustainable future. In this curriculum, rather than copying notes that are thrown away after the unit or school year, students produce something that is taken up in their community. But students did more: during the environmentalist open-house events, they also taught visitors of all ages scientific processes and contents. Most importantly, as our immediate and long-term (12 to 18 months) post-unit interviews with the students showed, they have been able to collect evidence that their participation in the environmental cause has brought about lasting changes—including the identification of heavy polluters. For example, one student notes:

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

The theoretical model we proposed here for rethinking science curricula is suited ideally for this purpose, as it has been developed to bring about, support, and understand expansive learning, which occurs when people (workers, environmentalists, teachers) group together to change their environment for a better future (Roth & Lee, 2007). Underlying expansive learning is the recognition that collectively we can achieve more and we can better control our environment and future than if we attempt to work individually. This future is better in part because the decisions and processes of change involve whole communities who, consistent with their democratic values, both envision and work toward a better life.

This model of science education, however, has some deep consequences for how we understand design and evaluation of science curricula for sustainable development. To begin with, the activity we outlined in our example is a form of place- and community based education—the local situation in which the community finds itself thusly determines the learning objectives. Accordingly, its objectives are not universally applicable because today only half of the communities worldwide are rural and—luckily—we do not find polluted creeks around every corner.
However, our example is just one of the many examples by which contemporary science educators have shown how education can be more deeply embedded in communities and therewith contribute to a sustainable future. The opportunities are infinite and may take unexpected turns. In another project, for example, students learned about human biology as they produced leaflets and conducted one-on-one campaigns around reproductive issues among working class women (Collectif Chimie Cégep Limoilou, 1998). The learning of science content was a by-product of the project’s aim to contribute to the sustainability of the local human population rather than primary aiming at sustainable development. Even urban settings exhibit a tremendous potential for place- and community based science curricula (Tobin, Elmesky & Seiler, 2005). For instance, it has been shown that the engagement of homeless children in activities like horticulture and landscaping provides them with a sense of place from which to transform themselves and their lifeworlds (Calabrese Barton, 2002).

Local and plural objectives of place- and community based education contrast with the current one-size-fits-all science curricula. This raises the question if all children need to learn the same to be able to contribute to a sustainable future. In our project, this was not the case. Rather, students’ contributions to the sustainable development of the community were such that their competencies and interests were matched with the division of labor in scientific practice. Hence students engaged in particular moments of scientific practice. This approach does not appeal to the so-called universally applicable nature of scientific knowledge, which is reflected in the contents of current science curricula. However, the rapidly emerging field of social studies of science clearly has shown that the universal applicability of scientific knowledge is in fact limited in local situations (Jasonoff, Markle, Petersen, Pinch, 1995). More so, cognitive scientists have shown that knowledge is highly situational—even trained mathematicians often do not use the ultimately transcendent mathematical heuristics to solve problems they encounter in daily life (Lave, 1988). Indeed, science educators struggle already for decades with the question how to design and evaluate curricula through which scientific knowledge does not only end up in isolated, artificial settings such as tests, but also leaves sustainable traces in students’ daily lives (Tobin & Roth, 2007). According to our model, such traces cannot be seen independently from the activities in which students engaged and will engage in their future. Educational design and evaluation of environmental programs should therefore appropriate the cultural-historical aspects of human activity. The effect of such programs, then, should be measured as permanent and sustainable changes in the community brought about by students as human beings rather than as caged proof-rabbits for which a sustainable future only glooms out of reach in their artificial environment.

NOTES

1 The pictures and photographs in this chapter are reused from a work published by the Public Library of Science under a Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original authors and source are credited, preferably as follows: van Eijck, M. & Roth, W.-M. (2007). Improving science education for sustainable development. PLoS Biology, 5, 2763-2769.
REFERENCES


