Contemporary Trends and Issues in Science Education 41

Michael P. Mueller
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Arthur J. Stewart *Editors*

Assessing Schools for Generation R (Responsibility)

A Guide for Legislation and School Policy in Science Education

Springer

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Praise for Assessing Schools for Generation R (Responsibility)

Indira Nair, Professor and Vice Provost for Education Emeritus, Carnegie Mellon University
Education has changed its role from transmitting "old wisdom" and propagating conventional mores only, to changing the world or at least being competent in navigating the world, and particularly a technological, global, world. It is vital that our education prepare a new generation of students to move from a very occupation-minded, instrumental view of their education to one that puts social responsibility on their life map even if not at the center. In this pioneering collection, the authors of *Assessing Schools for Generation R (Responsibility): A Guide to School Policy and Legislation in Science Education* articulate and define this new "Generation R".

The authors, all experienced educators, thoughtfully inquire what has to happen in the domains of teacher preparation and public education to effect a transition of the youth in the US "from "complacency" towards a condition of greater civic responsibility". They remind us that "free public schools itself was introduced as an aid to democratic well-being, as a vehicle for preparing citizens who possessed the intellectual wherewithal required to shoulder civic responsibilities." So, in a world pervaded by science and technology, that is what science education has to be. They discuss shifting the priorities of science education, and I would add technological education, to a place where science becomes meaningful to the students as a way of solving important problems that they see around them. Students will understand and learn science better in this process. This would involve among other things, using "caring reasoning" with a systems approach to teach science and incorporating *critical* science literacy in place of a "rote knowledge"-based literacy. Ways of assessing students' learning would involve measuring their ability to apply science rather than blindly knowing mechanics and definitions to answer disembodied and disconnected science questions. Such a pedagogy would be embedded "in a constructivist, project-based and hopefully place-based, approach to science instruction" and contain social responsibility as one of the aims of science.

This of course has to start with a new type of teacher, and a new type of framework governing public education. An outstanding and much-needed of synthesis of literature on teaching in a new way, "Assessing Schools for Generation R", could produce a new generation of teachers and produce a real ferment in the way we teach science if the recommendations are followed by those who govern and plan education and those who prepare and evaluate teachers.

Caren Cooper, Research Associate, Cornell Lab of Ornithology, Cornell University
How will the next generation develop both the wherewithal to dream of a sustainable future *and* the intellectual capacity to achieve it? This edited volume brings together inspiring stories, creative practices, and theoretical work to make the case that *science* education can be reformed to help students develop affectively and intellectually in order to grow into civically engaged citizens. Quickly departing from the notion that science education is primarily for those on a science-career

track, contributors to this book view science education as integral to the development of responsible citizens. I recommend this read not only to those involved in science education but to those who have not yet considered science education as a mechanism for sustaining a democratic society.

Nancy Tuana, Department of Philosophy, Penn State University
The rewards and challenges of science education that is grounded in authentic learning and designed to promote personal, social, and civic responsibility are at the heart of this important collection of essays. Recognizing that today's youth will face global environmental challenges, as well as complex personal and social challenges, this collection of essays provides vital insights on how science education can be designed to provide a solid foundation for knowledge *and* action. *Assessing Schools for Generation R (Responsibility)* is essential reading for all educators who care about the future.

Foreword

In June 2009, *New York Times* journalist Steven Greenhouse coined the term *Generation R* to denote the millions of US teenagers and twentysomethings who are struggling to carve out a future for themselves during the worst economic downturn in decades. At about the same time, Gill Plimmer of *The Financial Times* used the same term to describe professionals who have prospered during the recession, gaining much expanded roles and progressing faster than anticipated by taking on the work of more senior colleagues who have been made redundant through downsizing. Others have used the term simply to refer to those who graduated from college in the period 2006–2010. For example, *Generation R* (*Recession*) is a Philadelphia-based study of how the current economic recession is impacting the expectations, dreams, and aspirations of 150 young people from the high school class of 2006. In the Netherlands, *Generation R* is a longitudinal cohort study extending from fetal life in 2006 to young adulthood in a multiethnic urban population. Interestingly, *Generation R* is the name of a social networking site for Russian Jewish Americans. For this book, Michael Mueller, Deborah Tippins, and Arthur Stewart replace R for recession with R for responsibility, such that *Generation R* now identifies a generation of people who are expected to assume much greater levels of social and environmental responsibility than current citizens, and will be well equipped to do so if the editors and authors of this book succeed in establishing the kind of science education they advocate. From a range of social, economic, and environmental perspectives, it is evident that we live in turbulent times, with increasingly complex problems and challenges at the local, regional, and global levels, but science education as currently practiced does little to prepare students to address these problems carefully, critically, confidently, responsibly, and effectively. If anything, it serves to reproduce the kind of thinking and to foster the kind of values that *created* many of the problems. The basic message of this book is that we need to take the bull by the horns and implement a curriculum that focuses clearly and systematically on life in the twenty-first century in all its complexity and uncertainty; equips students with the knowledge, skills, attitudes, and values to confront the complex and often ill-defined socio-scientific issues (SSI) they encounter in daily life; enables them to reach their own views through debate and argument about where they stand on major socioscientific issues, including the moral-ethical issues they often raise; and builds responsible and engaged citizenship.

My own generation of WWII kids and the subsequent generation of baby boomers grew up in a very different world. During the 1960s, we were blissfully unaware of the extent and pace of environmental degradation; jobs were plentiful; ambitions were high, and despite the constant threat of nuclear annihilation and daily news bulletins about the evils of the Vietnam War (or American War as the Vietnamese call it), the social climate was one of optimism for the future. Young people were confident that desirable change could be brought about by collective action (marches, demonstrations, petitions, and the like), as illustrated by the lyrics of many of the pop songs of the time. The following five decades have seen a marked decline in social activism and levels of public participation. During my 40+ years as a teacher and teacher educator, I have been saddened at the lack of political interest among teachers and students, disturbed by their complacency and easy acceptance of the status quo, concerned by the apathy of teachers regarding the values implicit and explicit in the curriculum they deliver, and disappointed with their lack of courage to fight for a more engaging and socially relevant science education. We need to turn back the clock and re-instill the view that we can, should, and will strive to change the world for the better. This book can be the catalyst to reverse the trend and to fire up a new generation of people determined to make a difference and to assume responsibility for social reconstruction and environmental regeneration. The simple point is that unless we do something substantial to change the ways in which we live and do it quickly, it will be too late. Our current lifestyles and the impoverished values that underpin them have put us on a collision course with disaster.

All teachers know that the key to wide-ranging social change is education. Because the changes we need to effect encompass changes in lifestyle that will be quite profound and potentially disconcerting for many people in industrialized societies and will inevitably run counter to the goals, aspirations, and desires instilled in us by the popular media, current consumerist rhetoric, and the world of advertising, it is not just school-based education that we need to reform. We need to establish a new climate of concern and commitment throughout education at all levels, and we need to involve a much wider range of educational venues, including parks and gardens, nature centers, museums, zoos and aquaria, science centers, and environmental clubs. We need to revitalize education in the home, in the workplace, and in community centers and through advertising and public notices. We need to mobilize effective education through leisure activities; through the print and broadcast media, the Internet, and social networking media; through movies, theater, literature, music, and dance; and through examples set by prominent members of the community. Unprecedented levels of cooperation, support, and collaboration will be necessary among national and local governments, government agencies and public services, research establishments, environmental groups, formal and informal educational institutions, the business and industrial sector, trade unions, cultural and community organizations, youth groups, voluntary organizations, schools, and families. Through all these outlets, we need to focus very directly on how we live and how we should live in the future if we really want to establish and maintain a more equitable and socially just society and an environmentally sustainable lifestyle.

As far as school-based education is concerned, we need to rethink the purpose of education in general and science education in particular. Our current educational priorities are hopelessly misplaced, inadequate for the task of preparing students for responsible and active citizenship. There is, for example, way too much emphasis on preparing students for later study of science or subsequent employment as scientists, way too much emphasis on competition, way too much emphasis on pre-specified and highly detailed (but often essentially trivial) learning outcomes, way too much emphasis on rigorous and systematic testing for so-called educational standards, and way too much teacher-centered pedagogy. As a result, students are led to distrust and devalue their own knowledge, skills, values, and experiences. In consequence, they look to experts as the source of all views, solutions to problems, and decisions on socioscientific issues. To affect the kind of changes that Mike Mueller and his co-editors and authors seek, we need a curriculum that promotes problem solving, especially real-world, complex, and ill-defined problems, not one focused on the steady accumulation of knowledge. We need a curriculum that fosters critique and intellectual independence rather than conformity and compliance yet also promotes the cultivation of interdependence and potential for community building. We need a curriculum that equips students to make judgments and reach decisions on complex socioscientific issues; develops the capacity to deal with change, uncertainty, and unpredictability; cultivates the ability to ascertain what is desirable/undesirable and what is possible in the long and short terms; pays much more attention than has been usual to values issues and the active promotion of democracy and social justice; and prepares students for taking direct and indirect action in pursuit of changes they consider desirable. Of course, if students are to take effective action, it is essential that they gain robust knowledge of the social, legal, and political system(s) that prevail in the communities in which they live and develop a clear understanding of how decisions are made within local, regional, and national government and within industry, commerce, and the military. Without knowledge of where and with whom power of decision making is located and awareness of the mechanisms by which decisions are reached, intervention is not possible. Thus, the curriculum advocated in this book will require a concurrent program designed to achieve a measure of *political literacy*, including knowledge of how to engage in collective action with individuals who have different competencies, backgrounds, and attitudes, but share a common interest in a particular SSI. Such shifts of curricular emphasis will necessarily trigger a shift in pedagogy in the direction of greater learner autonomy; more extensive and imaginative use of industry, commerce, and military; and increased involvement in group work.

If students are to come to grips with SSI at any level beyond the merely superficial, they need relevant scientific knowledge. Simple common sense tells us that relevant content knowledge is crucial and that those who know more about the topic/issue under consideration will be better positioned to understand the underlying issues, evaluate different positions, reach their own conclusions, make an informed decision on where they stand in relation to the issue, and argue their point of view. A key question concerns the manner in which relevant scientific knowledge should be acquired. Should it be through prior instruction or on a need-to-know basis when dealing with a particular issue? As is so often the case in education, there is no universal answer; different situations demand different approaches, and different SSI create widely different knowledge needs. Further, no science curriculum can equip citizens with thorough firsthand knowledge of *all* the science underlying every important issue. Indeed, much of the scientific knowledge students need to know in order to make important decisions on the many important SSI they will encounter during their lifetimes has yet to be discovered. However, we *do* know what knowledge, skills, and attitudes are essential for appraising scientific reports, evaluating scientific arguments, and moving towards a personal opinion concerning the science and technology dimensions of real-world issues. It includes a robust understanding of the status of scientific knowledge; the ways in which it is generated, communicated, and scrutinized by the community of scientists; and the extent to which it can be relied upon to inform critical decisions about SSI. Students need to have a clear understanding of what counts as *good* science – that is, a well-designed inquiry and a well-argued conclusion. They need to be able to interpret reports; make sense of disagreements; evaluate knowledge claims; scrutinize arguments; distinguish among facts, arguments, and opinions; make judgments about good science, bad science, and nonscience; detect error, bias, and vested interest; and so on – all of which we have come to know as learning about the nature of science (NOS). If students are to address SSI thoroughly and critically, they also need the language skills to access knowledge from various sources and the ability to express their knowledge, views, opinions, and values in a form appropriate to the audience being addressed. We need to focus students' attention very firmly on the language of science, scientific communication, and scientific argumentation and their capacity to become critical readers of a wide variety of texts. Because much of the information needed to address SSI is of the science-in-the-making kind, rather than well-established science, and may even be located at or near the cutting edge of research, it is unlikely that students will be able to locate it in traditional sources of information like textbooks and reference books. It will need to be accessed from magazines, newspapers, TV and radio broadcasts, publications of special interest groups, and the Internet, thus raising important issues of *media literacy*. Students who are media literate understand that those skilled in producing printed, graphic, and spoken media use particular vocabulary, grammar, syntax, metaphor, and referencing to capture our attention, trigger our emotions, persuade us of a point of view, and on occasions, bypass our critical faculties altogether.

Many SSI are highly controversial, sometimes because the scientific information required to formulate a judgment about them is incomplete, insufficient, inconclusive, or extremely complex and difficult to interpret and sometimes because judgment involves consideration of factors rooted in social, political, economic, cultural, religious, environmental, aesthetic, and/or moral-ethical concerns, beliefs, values, and feelings, concerning which people may hold widely varying positions. In other words, controversy may be internal or external to science. Teachers need to make a decision about how they will handle such issues. Should they try to avoid controversy altogether, take a neutral position, adopt the devil's advocate role, try to present a balanced view, or advocate a particular position? This is an important decision for all teachers insofar as it will impact very directly on the quality of class discussion.

At the very least, teachers should enable students to identify, articulate, clarify, and critique the assumptions of a wide range of positions (including their own); acknowledge the influence of sociocultural context, religious beliefs, emotions, and feelings; address issues of rationality, equity, and social justice; and encourage critical reflection. Because many of the issues will have a moral-ethical dimension, they will also need to foster students' moral development and develop their capacity to make ethical judgments. It is also likely that many of the issues will generate strong feelings and emotions, with students' views and assumptions being strongly influenced by personal experiences and the experiences of friends and family and by socioculturally determined predispositions and worldviews. A student's sense of identity, comprising ethnicity, gender, social class, family and community relationships, economic status, and personal experiences extending over many years, will necessarily impact on their values, priorities, and preferences. Teachers introducing SSI into the curriculum need to be sensitive to these influences and able to assist students in dealing with potentially stressful and disconcerting learning situations. It is here that notions of *emotional intelligence*, *emotional literacy,* and *emotional competence* can be helpful.

These are the kinds of educational issues addressed by the contributors to this collection. One recurring theme is assessment and the nature of the high-stakes assessment regimes currently being promoted in many countries around the world. My own view is that many of these standardized and highly prescriptive schemes are philosophically unsound (because they are rarely, if ever, based on robust, contemporary, and cogently argued models of science and scientific literacy), educationally worthless (because they trivialize teaching and learning, forcing teachers to focus solely on short term goals), pedagogically dangerous (because they foster bad teaching and a narrow view of education and learning), professionally debasing (because they de-skill teachers), socially undesirable (because they project a number of powerful messages about control and compliance and promote the kind of values that created many of society's current crop of problems), and morally repugnant (because they objectify people, regard knowledge as a commodity to be traded for marks and grades, disallow freedom of expression, and allow little or no scope for creativity). It is the matter of control and compliance that is of particular concern in the context of this book. A curriculum organized and monitored along these lines is an ideal vehicle for those who seek to shape people towards some predetermined goals. It is disempowering because it rules out critical thinking, emphasizes obedience and efficiency in effecting someone else's plans, and allows no role for evaluating, criticizing, challenging, and changing the goals or intended outcomes. By inculcating a willingness to accept someone else's prescriptions for desirable knowledge and skills, and appropriate attitudes and behaviors, and by breeding an unquestioning acceptance of external control and management, we create a culture of compliance that has considerable adverse impact on both students and teachers. Education becomes a means of social reproduction, with all its existing inequalities, rather than a means of social reconstruction and a route to social justice. When the award of grades is restricted to the uncritical execution of carefully specified tasks, critique becomes devalued in the eyes of students, critical faculties atrophy through lack of use, and students soon lose all trust and confidence in their capacity to make judgments. Thereafter, decisions on all matters of importance are left to so-called experts and authority figures. Given the fact that assessment almost always determines what and how teachers teach, it could be argued that a radical shift in curriculum and pedagogy will only be possible via a radical shift in assessment policy and practice. Here, then, is a priority target for would-be reformers.

There are many other reasons why the translation of this kind of curriculum rhetoric into practical action in real classrooms will be extraordinarily complex and difficult. Such a radical change in the nature of the school curriculum puts a whole raft of new demands on teachers; it challenges many of the assumptions on which schooling is traditionally based; and it is predicated on a commitment to bringing about extensive and wide-ranging social change at local, regional, national, and international levels. Regarding point 1, there is no doubt that the sheer complexity of the teacher's role in SSI-oriented teaching can be very daunting in prospect: organizer, facilitator, consultant, friendly critic, general arbiter on all manner of disputes and disagreements, examiner, and so on. All I can say is that it gets easier with practice. Teachers learn best by critical reflection on the circumstances in which they may have "got it wrong" and by striving to work out how they might "do it better" next time, but they also need access to much more research into the kind of problems they are likely to face and the kind of strategies that may help to overcome them.

Because this much more radical and critical stance towards science, scientists, and scientific practice is in direct conflict with the traditional school model of science and the image that universities and the science professions have tended to promote. Thus, there may be strenuous opposition from scientists and from universities. There may be opposition from parents, some of whom may regard it as a "soft option" to "proper science" (i.e., abstract, theoretical science assessed by conventional means). There may even be resistance from students, especially the more academically successful ones. They, too, have expectations of science lessons and a vested interest in maintaining classroom practices that have served them well in the past. Navigating these multiple resistances to change will require considerable courage and determination and high levels of support and encouragement.

A substantial number of science teachers, as well as students, parents, scientists, employers, politicians, and others, are likely to hold the view that social, political, economic, and moral-ethical issues have no place in the science curriculum (or in any school-based education for that matter) and that sociopolitical action has no place in school. Some will believe that students are not mature enough to cope with SSI or sufficiently interested in addressing them, though my own research extending over many years indicates that these are exactly the things that students *do* wish to address through the science curriculum. There are many in society who would not welcome an articulate, well-informed, critical, and active citizenry that is willing, able, and determined to challenge and change the status quo. Thankfully, the authors contributing to this collection are not among them, and they are to be congratulated on producing an exciting, informative, sophisticated, and sometimes provocative book that will stimulate much debate about the future direction of science education.

Of course, the kind of radical curriculum change advocated in this book will only occur when sufficient teachers, teacher educators, curriculum developers, and curriculum policymakers are convinced of the importance, desirability, and feasibility of addressing SSI in the science classroom and encouraging sociopolitical action and when there is commitment to teach and confidence in doing so through awareness of appropriate pedagogical strategies, capacity to organize the required classroom environment, and access to suitable resources. We need a critical mass of teachers and teacher educators, and we need to put pressure on policymakers and administrators. The real breakthrough comes when individual teachers are able to find and work with like-minded colleagues to form pressure groups that can begin to influence key decision-making bodies. So teachers and teacher educators need to be braver than they have been in recent years, and they need to acquire a measure of political literacy regarding the ways in which educational policy is formulated and implemented. Perhaps teachers and teacher educators need to develop the educational equivalent of the public forums (consensus panels, citizen juries, focus groups, and the like) that have been used by scientists, governments, and NGOs to directly engage the public.

Finally, teachers need access to case studies of successful innovations. They will find the necessary inspiration and encouragement in accounts of teachers engaged in similar efforts to overthrow the stultifying shackles of convention. For most people, there is often much greater value (in terms of practical advice and inspiration) in listening to and/or reading the stories of those who have been intimately involved in such projects than in reading detailed prescriptions or generic rules for curriculum implementation. Teachers do not need a set of rules about “what to do”; they need rich, complex, context-specific stories about what was done, why it was done, and how successful or unsuccessful it turned out to be. This engrossing and passionately written book provides a number of such examples. It also provides the inspiration, theoretical validation, emotional support, and practical advice that teachers need to help them take the plunge into the unknown. It constitutes a very important contribution to the campaign to establish a science education that is suited to assisting Generation R in confronting the complex, challenging, and disconcerting situations in which humanity now finds itself. It should be on every teacher’s “must read” list. It should be required reading for all preservice and in-service science teacher education programs.

Auckland, New Zealand Derek Hodson

Arthur J. Stewart

Responsibility

If you are bold enough to think of
    this thing or that, you are

bold enough to act: to begin
scraping up
residuals of what you know, fragments
of what you have, to make

    that which is
            now

            better.

If in this brief time called life
you've had chance to touch
    anything living – a mouse's ear,
or fern or slender needle of pine
or rough bark, or anything
that draws upon the non-
living for what it needs
by pulling up
with energy secured
    from the sun,
or by the wind or wave from sun

    dew-drop poised
at the leaf's tip

you're ready
    now
to act
at the smallest force

this way or that. Like the lotus
    pure white blossom
held up in silence, accept this

as a menu, not the meal.


Science

Contents

Chapter 1
Reclaiming Community As We Rethink Assessment

Deborah J. Tippins, Arthur J. Stewart, and Michael P. Mueller

This book embodies the vision of a group of concerned science educators, scientists, and cultural studies scholars who initiate a conversation with policymakers and other stakeholders in the educational process about what schools are for. We are calling for serious attention to generations of youth who accept responsibility: responsibility for cultural and community integrity, environment, and the ways in which they will become part of the cultural norms. We are calling for youth who demonstrate that they are responsible without equating responsibility to "grades," intelligence quotient, or socioeconomic status. Responsibility will be embodied by the community differently depending on where we live; however, the idea of accepting responsibility with and for is a profound notion.

Collectively our aim is to offer an alternative public discourse which foregrounds the consideration of how we might best engage Generation R youth as citizens who value social responsibility as a way of living. Generation R stands for responsibility, a response to individual, cultural, community, and environmental problems, issues, situations, locations, political agendas, and a sense of place. This book is written to those who have the power to take action now or those who will acquire the power to take action tomorrow. It is written for those who are the children of today's graduates

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of schools in North America and, particularly, the United States. This book is for their children and their children's children.

The authors of this book are experts in many areas of education and are deeply concerned about the ways in which school children are not being involved in political engagement, problem(s) solving, and cultural-community-environment curricula responsive to place. Whether we acknowledge it or not, we have a *prosperity* problem. We are not teaching children how to be responsible with prosperity. What has emerged as a consequence is the tendency to act as if "anything goes," and as long as we have "earned" something, we do not need to be responsible with it. At the same time, we do not wait until children demonstrate responsibility before teaching "American" life. We do not value ethics and character-first education, where youth demonstrate they have the ethical orientations and moral character to act responsibly with the thousands of choices about how to live. So what is the big deal?

A new generation of youth is rising. These children will be more aware of and concerned about a cultural residual of deeply embedded ideological assumptions and environmental mistreatment at large. Such concepts are not easy to grasp, but these children begin to get it. They see the economic situation, political complacency, and degradation of their cultural traditions, ceremonies, narratives, and species of animals and plants lost forever to individual actions. They want to have children, but they do not want their children or their children's children to live with the consequences of a society that does not know when something is degraded or when to act. All along, they have seen other people become educated about how to treat other people in the USA or abroad with respect, care, or rights. As they engage in gardening (a popular trend in schools) or animal husbandry, they do not understand why the prices of food and animal meat are so inexpensive when they calculate the prices for open-pollinated or heirloom seeds, baby animal costs, "man-hours" involved with raising plants and animals, and the cost of feed, fertilizer, and care. At what expense has our American prosperity been gained, on the grounds of neglecting our responsibility with prosperity in school? Generation R youth will be raised to see the ways that these aforementioned variables are externalized with rapidly increasing vulnerability for the environment (habitats, flora, and fauna), the rapid loss of other people's cultural languages and environmental knowledge, the lack of concern for the welfare of animals raised for eggs and meat, and the impoverished work conditions facing some people, but not the majority of US middle-class consumers.

The cultural assumptions of anthropocentrism, individualism, competition, consumerism, environmental management, scientism, and the inherent faith of many people in "technology to save Earth" will come under critical scrutiny of Generation R children, just as patriarchy and the subjugation of women in the workforce has been (in addition to the Civil Rights movement of the 1960s). We may see ethical orientations towards animals, plants, and physical places take on significant status with Generation R youth. For certain, the cultural integrity upheld by elders in the community will play a larger role in science teaching and learning, concomitant with the health benefits for elderly of learning science throughout their life—now seen as a promising avenue for research in lifelong learning (see Chaps. 21 and 22 in particular). Science education will no longer fall within the exclusive purview of schooling and will be much more accepted by Generation R youth as the ways in which everyday people come together to learn about how to solve issues. Already these trends are manifest with citizen scientists, street medics, guerilla gardening groups, and many other facets of society (i.e., where people learn science to resolve community problems).

Therefore, as Generation R youth (worldwide) take prosperity and their responsibility with prosperity more seriously—now we are referring to the increase in national prosperity in India and China, Paraguay, Argentina, and Peru—they will take their relationships with the elderly more seriously, with plants and animals, with agricultural and natural resources, with how school success is measured, political literacy, a sense of place, media literacy, affective or emotional aspects of learning science, problem-solving encounters, and scientific literacy.

These themes are centrally related to the future of ecological and science education for cultivating responsibility—and each is clearly addressed within the book as a guiding policy for reforms. The following roadmap will hopefully make navigating this book much easier for policymakers and others who want to jump to specific areas identified as concerns within science education and for those who need to make more urgent educational choices.

Roadmap for the Book

We concur that high-stakes testing as an imperative is overemphasized through national and state mandates and too limited in scope to adequately measure the holistic nature of schools. Schools and the people that teach and learn there are inextricably embedded within their communities. Knowing this, we call for assessment practices which make sense in light of a vision of teaching and learning for and within contexts—consider more holistic metrics.

Chapter 2 is particularly positioned to introduce Generation R (Responsibility), which most importantly involves children to be born over the next 20 years. Generation R youth will be charged with watching out for the prospects of future generations beyond the social justice issues involved with life needs for today's youth. Moreover, Generation R youth will need to be politically literate and highly charged for action, and these characteristics should be cultivated in their education as we collectively forge school policy and future legislation. Chapters 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, and 29 reveal various aspects of Generation R that will be called upon, time and again, to deal with the community/ecological residual of problems that have accumulated in our educational system during the past century.

Chapters 2, 3, 4, 5, and 6 emphasize the characteristics of generations of responsibility and collectively provide a historical backdrop for thinking about community engagement embedded within science education. The transformation from generations of complacency to generations of responsibility will come with very difficult cultural assumptions that have been taken for granted by Americans for a long time (i.e., materialism, hyper-consumerism, and the limits of agricultural and natural resources). Concomitantly, Generation R youth will be required to have critical media literacy and the ability to reliably and accurately interpret what they see and hear. Even the "green" shadow now trending over our society is not out of bounds: just like the ways that breast cancer awareness has been manipulated to market and sell products, Generation R youth will have to be cognizant of the ways they can be led astray. At the core of cultivating generations of responsibility is school testing mandates, which seem to roadblock many of the educational objectives the authors highlight in this book. Some of the things the authors will say are not new. The significance of their ideas is redefined in ways that perhaps can be best understood through a rigorous public conversation about science education for Generation R youth.

Chapters 7, 8, 9, 10, 11, and 12 explore the significance of foregrounding morals and ethics in science education through involvement in controversial community and environmental issues. While many of these issues may be controversial and will be difficult to solve, they are germane to the lives of Generation R youth. They must replace the ways that most youth are presently learning science (largely without context), or students will not learn when their community or environment is degraded and needs decision-making attention. They will not know when or how to act! Babies born during the time designated as Generation R will think their world is the way it ought to be, just like many of us thought that our world was the way it ought to be when we were children. Children think this way, often without question or challenge—in the same ways, they think their teachers, textbooks, the Internet, and so forth should not be challenged. In order to wrestle with the residual or cumulative residual of situations over longer periods of time, they will need to see a larger picture of the world, drawing inspiration from the guidance of informed educators. They will need to know what controversial issues elicit science analysis and how to evaluate these concerns in enough depth to take considered action. They will need to be prepared to engage in political action by narrowing the range of reasonable actions, with judicious application of skepticism. Generation R youth will need to assess these actions in practice and then, in real life, through their science classes with teachers who understand how to help guide them through action evaluation (e.g., what are the consequences of this action versus that action?). More importantly, science teachers will be called on to guide youth in ways that consistently foster a sense of ethics and morals grounded in democracy, egalitarianism, and justice. This set of chapters provides grounded examples of how to do this.

Chapters 13, 14, 15, 16, 17, 18, and 19 offer an exploration of digital technologies and the responsibility that educators and their students will be charged with such that technologies are used responsibly for evaluating their own cultural values, traditions, and narratives. These technological tools also provide a means for contemplating layered models and scenarios for taking action when either culture or environment become degraded or are deemed vulnerable to degradation. This set of chapters goes into depth about the different ways that communication technologies are being used now in schools (worldwide) to help children analyze their culture, community, and environments. Because technology is embraced rapidly as it becomes available in schools, we emphasize recent developments in use and where it might be more effectively incorporated into science education in the future. But perhaps more importantly, we stress the need for Generation R youth to understand the implications of technology on their lives. Students should be able to see technology as they do science: as something designed by humans for humans, embedded with bias, that Generation R youth will be responsible for using wisely.

Chapters 20, 21, 22, 23, 24, and 25 encourage policymakers and those responsible for making choices about how teachers are prepared to consider the relevance of community immersion and environmental habitation, the development of lifelong interests in science education, and the correlations to our human health. The surfaces of these things are just being explored now, while the explorers (or the people who analyze such things) are being diminished and extinguished. This situation is dire: many colleges of education, for example, are undermining the importance of cultural and environmental studies requirements for beginning and experienced teachers because of the overemphasis on content-driven knowledge and fact delivery. These chapters make an especially strong case for the need to revitalize places where people live, where they breathe, work, and play. If places equate with communities and environments, then place-based science education equates with the understanding that children develop as a result of being with science teachers who know their situations well enough to guide students through them. Thus, if science education continues to position students as test takers and assessments as a device which isolates them from the process of learning, Generation R youth will not learn to become aware of their local environment or know and develop the capacity to assess its health. They will struggle in determining whether the values and cultural ideals they value are under threat, or not.

Finally, the last series of chapters targets policymakers, school policy, and legislation in science education in detailed perspectives. Standards are not the problem. There have always been standards, and there likely will always be standards, norms, and conventions for measuring the effectiveness of schools. However, standards do not have to be an exclusive measure of our schools. Other modes of situated evaluation, which take into account the diverse contexts in which students produce knowledge, must become part of the public discourse in science education. The authors of these chapters give plausible directions for those change agents who will take these ideas to the intended audience and use them to guide the development of more effective school policies. Some challenges are raised to guide advocates of Generation R, and imperatives ranging from empirical to testimonial are provided, such that they can be taken from the book to the larger community.

There are multiple ways to consider the information within this body of work. One way, represented in Fig. 1.1, shows how the themes nest with respect to each other, based on our way of thinking. Readers may wish to pursue chapters that align with one or more of these themes, or they may wish to deliberately cut across thematic sections, trekking wide. But the book is a bit like the metaphoric elephant, too: some readers will touch it and report, it is like a pillar—solid, upright, and rounded with a definite circumference. Others, touching an ear or a tail, or a trunk, or the elephant's side, may report, no, no—it is a large flap, or a tasseled rope, or a thick vine, or a crinkled wall. We think there's something here for each of you. A larger conversation will ensue.

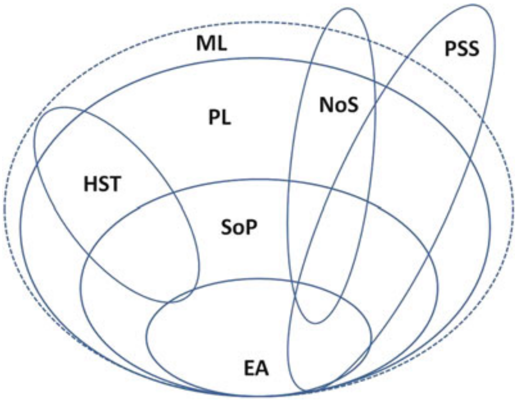

Fig. 1.1 A representation of how themes in "Generation R" nest with respect to each other. *EA* emotional aspects, *SoP* sense of place, *PL* political literacy, *ML* media literacy, *PSS* problem-solving situations, *NoS* nature of scientific literacy, *HST* high-stakes testing. The *line* denoting the boundary for media literacy is *dashed* to remind readers that this boundary can expand or retract quickly

The significance of themes that are more comprehensively addressed may represent the most urgently needed areas of school policy and legislation in science education, such as political literacy, problem-solving encounters, and a sense of place. But from a contrarian perspective, we suspect that some shrewd readers will also understand immediately that the ideas captured in the authors' chapters reveal areas that justify future attention (i.e., they have significant growth opportunity). Readers with this perspective may select chapters that strongly address one or more themes, and chapters that do not, in order to help "bound the territory" or expose the inevitable voids that can be productively addressed. In short, this policy book can help cultural studies scholars and science education investigators define and defend perspectives for grant proposals and for promising avenues for rethinking assessments.

A Mission for Readers

In today's rapidly changing world, there is an implicit recognition that media helps shape the public understanding and purpose of education. It does this, to a large extent, by extensive discourse of crisis surrounding our twenty-first-century schools and classrooms. Unfortunately, one of the most striking aspects of crisis thinking, which permeates and structures larger public conversation, is its potential for becoming a normal or permanent form of discourse. In many ways, we can trace the apparent crisis in education to the influence of essentialism, with its constant quest for certainty rooted in normalized definitions of intelligence and outcomes, and in delineating what students should and should not be taught. Inherent in this quest for certainty is the emphasis on evaluating the product rather than assessing the process which guides students and teachers in coming to know and understand the world around them.

As we begin the second decade of the twenty-first century, we celebrate the 2011 International Year of the Youth. In the midst of the rhetoric of educational crisis, our attention is drawn to the youth that will comprise Generation R and the ways in which public schools might engage them in experiences designed to release them from the search for answers and instead unleash in them a celebration of questions. Educational systems grounded in the imaginative power of questions are premised on the understanding that knowledge is inextricably linked to knowing not only what to ask but what asking means. What Generation R youth know and learn will reflect the questions they ask and ultimately the ethical commitments, community participation, and sense of responsibility they bring to the most pressing challenges of their time.

We have reached a stage in educational reform where uncertainty often prevails. Amidst this uncertainty, there is a growing recognition that the time is ripe for schools and communities to join together in mutual conversation to build authentic partnerships and modes of assessment. Such a conversation will be valuable even when we disagree. Within this book, the messages for educators, parents, and policymakers will always be open to interpretation. It is our hope that they will spark an imaginative process with the potential for meaningful change. We resist the temptation to provide a laundry list of starting points for engaging Generation R youth and their teachers in authentic, community-centered science practices (i.e., city-school newspapers, community gardens, local food initiatives). Viewed in a larger historical context, Generation R youth may face more challenges yet have more opportunities than any previous generation, where supported by teachers who inspire a passion to make a difference.

Finally, we take this opportunity to thank the authors of these chapters for their diligence, insights, and provocative instincts—such features are the essential first steps for change. But in particular, we thank, encourage, and challenge the readers, the first-round implementers of change. We hope these chapters collectively will help you begin the dialog.

Part I
Generation R (Responsibility)

Chapter 2
Introducing Generation R

Michael P. Mueller and Rachel A. Luther

Well, it was you, it was me, it was every man,
We've all got the blood on our hands.
We only receive what we demand,
If we want hell, then hell's what we'll have

Jack Johnson (2003)

Things never have to be the way they are forever. Consider a certain 14-year-old boy from the Bronx in New York City. He lives in a community where the rate of asthma is significantly higher than usual, which corresponds with air pollution from a bus terminal in a nearby neighborhood. By volunteering with other residents to map out the incidence of asthma, he was able to convince city officials to address the pollution from bus emissions (Coburn 2005). As a result, the boy's neighborhood now suffers less from degraded air and people there have a lower rate of asthma. Historically, only a small praxis is needed, by people who share some of the responsibilities for changing a community.

Many stories of youth activism go untold. Even though these stories may become obscured in the news, youth are taking responsibility for changes in their local schools and communities. These changes may become more widespread when challenged further by community and environmental issues poised to disrupt young

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lives. As youth acknowledge a spectrum of vibrant emotions for their community and environment, including positive feelings of happiness and joy, they will continue to push against social responsibility and increase activism as they organize, strategize, innovate, and become more involved. It is worth asking, what sort of person will want to get involved and want to participate more fully in the choices or democracy of a community, particularly as more problems surface from environmental concern? This "participation" should not be misunderstood as the guarantee of an opportunity or as a freedom to participate that guarantees equity and social justice through youth involvement in the market (Tobin 2010): it is a deeper participation we refer to, not merely effort to achieve for economic prosperity. Too often, school policy is guided by financial matters, even when this pathway hampers our choices in school policy.

In this chapter, our aim is to open the dialogue to a plausible transition for youth in the USA, from "complacency" towards a condition of greater civic responsibility—a condition in which citizens increasingly feel the presence of toxic chemicals and other disruptions in their bodies and decide to take action as more embodied and valued individuals in relation to others (Thayer-Bacon 2000, 2003). Thayer-Bacon (2000) explains that

> Although we are certainly greatly affected by our communities—indeed we learn our language and our culture, even our sense of who we are as individuals, through our communities—this does not mean we are socially determined by our communities. (p. 162)

As many people decide that they enjoy the tastes of organic foods and the feeling of natural and local products in and on their bodies, they will learn how to bring more of these things into their homes and become engaged to help others feel good and healthy, as well.

In this chapter, we highlight the emergence of a new *Generation R (for responsibility)*, despite the challenges of labeling such a future peoples' movement. As is true for previous generations, Gen R will have many unique affiliations, dissident identities, and cultural diversities, which are continually in process. However, we do not live without others: "we are first of all social beings who are greatly affected by others, but we also greatly affect others with our individual influence, right from the start" (Thayer-Bacon 2003, p. 251). Embedded within the larger understandings of social, cultural, and historical contexts of all generations will be many perspectives. The key point of this chapter is to explore how Gen R youth might be better prepared to more fully engage in social responsibility and social activism.

With respect to the emphasis on social responsibility, we do not suggest that previous generations (X, Y, MTV, and Millennials)—namely, Generation Rs' parents—do not feel a sense of love and commitment for the community. They do. Many espouse it deeply. What we address here is why what Generation R youth learn and know will influence how they act; how these choices and community decisions will affect themselves, others, nonhuman species, and physical environments; and how future people will know when they have a significant responsibility.

What choices will follow a more embodied sense of responsibility?

These questions are significant for thinking about what new policies need to be enacted for preparing the next few generations of youth, and why youth should be more fully involved with policymaking.

We want to make the point clear up front that Generation R youth will recognize their mounting responsibility for social action early in their lives. They will recognize the rapidly increasingly tensions between cultural systems (e.g., economic, ethical, or political) and natural systems (e.g., species and physical habitats). A problem with prosperity will be identified early, while the vast majority of people ignore their responsibility with prosperity and talk about population pressures as other nations become prosperous (e.g., China and India). Gen R youth will reclaim a conversation with the elderly in their community and learn about the cultural traditions and ceremonies that are being lost forever with elderly. They will learn about the rapidly increasing reliance on the market that other generations of youth such as the Millennials were raised. Are these things crises? Not really. They are more opportunities for responsibility than anything else. More importantly, Gen R youth will be the first generation to really consider the prospects of future generations of people through their education in schools. This idea does not mean that there are groups of people now concerned with the vulnerability of cultural traditions, ceremonies, events, aspirations and narratives, or the threat to environments. Indeed the authors of this book are deeply concerned about the future of youth in America and whether youth will even know that their cultures, communities, or environments are being degraded. With maturity and responsibility, concerns in the community are acknowledged and explored with more acuity; however, Gen R cannot be raised like their parents if they will engage our society. They will need to think, practice, and actually do what the authors of this book are calling for in terms of issues-based curricula within environmental and science education, where the focus is on learning for the sake of evaluating choices, consequences of action, and eventually taking action—even if it is to damper consumerism. Equally important, Generation R youth will build confidence in their choices and trust that the decisions they make will impact schools and their children's children for a long time. Teachers are now being prepared to engage children in these exercises, and it is only a matter of time that these policy ideas will reach fruition if we want to activate a new generation of youth whose focus is responsibility.

Can youth be trusted for their ideas? Jonathan Kozol (2005) writes that he continues to rely heavily on children's narratives about the world around them, because youth often offer less tainted perspectives than do most adults. Perhaps this idea holds some merit, when we consider and debate the larger environmental issues of educational policy. In terms of what they might offer, consider how some children are more sensitive to environmental problems developed along with the hormones and antibiotics given to factory farm livestock to increase net meat production. Earlier development of breast tissue for girls may correspond with hormones in milk and may even be contrived with increasing adolescent, preteen, and teen problems of sexuality in our schools. There is a long history of sugar intake and high fructose corn syrup and vegetable oil use in the USA, and this has surely left its mark on youth. Today, more teens suffer from obesity and related health problems such as earlier signs of heart disease (Schmidt et al. 2010). More recently, the US military has reported that it will try to avert problems with obesity by recruiting children at an earlier age (Boscia 2010). Military recruiters are finding fewer high school graduates who are now healthy enough to send into the service. Correspondingly, youth body image concerns have significantly increased. According to the American Society of Plastic Surgeons 2010 Report of 2009 Statistics, more children seek plastic surgery during their preteen and teenage high school years for breast reconstruction, nose jobs, tummy tucks, and Botox injections (cf. Zuckerman and Abraham 2008). Medical and psychological prescriptions to control behavior in schools have rapidly emerged as a "solution" for keeping students sitting in their seats. These problems are directly related to the health of children and cannot be separated from the school policies currently enacted.

The background context of youth schooling also should be considered. How will educational policy change in science education as people become more interested in the environmental efforts to be "green?" Are youth cognizant of how corporations already are taking advantage of the increase in green awareness and excitement over "organic, local, and natural" products, revolutionary diets, and ways to save money? Today's kids are being raised in a media frenzy of "green is good" and everything green is "good for us." In other words, green now equates with what is perceived as good, right, beautiful, and strong, and this idea corresponds with the emergence of a group of future people who will make their decisions based on an increasing level of awareness and responsibility for their bodies and environment. Already, many adults, particularly generations X and Y mothers, are concerned with using green household products, detergents, and food. Recycling, clipping coupons, and thrift store shopping are becoming trendy as people try to save money. Kids see this.

A rising consciousness around green trends will certainly influence how people associate with bodily well-being and this can be extended to whether soils and nonhuman animals are also well. For example, through documentaries such as *Food, Inc.* and elsewhere, children are becoming more aware that the treatment of the land and animals in factory farming can have a significant effect on their health. The food choices being made degrade soils and mistreat livestock: in short, we can choose to make a difference in what we eat, which will make a difference for the soils and forests of the future. Peter Singer and Jim Mason (2006) offer suggestions where youth can learn more about ethical food, farming, fishing, and fair trade. As tomorrow's children grow up in a culture more concerned with their health, and a corresponding health of nature, they will begin making choices based on an embodied knowledge of exponential relations. The cultural norm of social activism may be embraced and valued in much the same way it was during the 1950s and 1960s with the Baby Boomers. Let us explain further.

A Cultural Norm of Social Responsibility and Activism

According to Cornell West (2004), today's youth feel a sense of despair and hopelessness that is woven with many stories of crisis. West believes that youth are facing a huge sense of nihilism, or the idea that they no longer possess control over what will happen. What are youth to do when facing so many troubling issues daily? Are they being prepared properly in schools or at home, and in society, to do something about what they will face—the residue of times past? We believe that tomorrow's youth (Generation R) will be ready and open-minded, but they must begin to feel a means within their body. The means for social activism will be generated through experiences, reflective of both good and bad community and environmental situations, and comprised of a spectrum of feelings. The body is the important difference that makes Gen Rs' distinct. Generation R will be a humanity of deeply embedded transactions, but current generations' family, friend, and intergenerational matrices are too loosely threaded together to matter in terms of cultivating a stronger sense of social activism. Thayer-Bacon (2003), who writes extensively about relationships, notes that "it is not possible to establish caring relationships with a large number of people" (p. 247). While Internet technologies have definitely afforded increasing opportunities for collaboration and social activism (e.g., Facebook), they have also weakened the ties between people as face to face is subjugated for digital expression. We will come back to this point later on.

Baby Boomers: A Generation of Social Activism

Now let's turn to a prior generation known for social activism. Baby Boomers lived during the post-cold war era when economic, industrial, and technological innovations were envisioned and developed across the USA. They are known for their gatherings in San Francisco city parks and Woodstock where peace, love, sex, and other virtues were celebrated. These things were idolized by youth. Living together in common, or within a commons, was celebrated and promoted as virtues associated with teenagers in the mid to late 1960s. These same people gathered under desks during their elementary years in preparation for an attack from the USSR. They grew up under the shadow of the atomic bomb, which stimulated a fear of the enemy. While these experiences are memorable for many generation Boomers, they are not the experiences of everyone in this group, despite that they are experiences which are essential aspects of this generation. But this is true of every generation. Some experiences inevitably will be more powerful or influential for some than others. Boomers, for example, were the last generation of kids to learn to read before watching television—an experience that almost all relate to.

For Boomers, the 1964 world's fair displayed the promises and social imagination of tomorrow and unlimited prospects for the future. Boomers envisioned earning vast amounts of money and having a plentiful supply of jobs and were confident that new technologies would replace many household duties. Today, the Baby Boomers are called "Ageless," because they continue to seek many of the Viagra-like treatments and painful reconstructive surgeries that keep them looking vibrant and youthful (Grossman 2000). Interestingly, this enduring generation of people has taken the ideology of limitless possibilities into what comprises much of the middle class. Today, many Baby Boomers are retirees living in large houses that line the streets in many middle-class suburban cities—and yet, they are also retirees seeking more government services and care. They run the spectrum from increasingly poor to increasingly rich.

Baby Boomers were not always so self-consumed. Not being selfish people, this generation paid attention and had faith in the idea that they could choose to do some things and had the ability to change disparities in society. Although their parents, many of which were WWII veterans, created freedoms such as the pathway for feminist freedoms, civility, new music, and media, the Baby Boomers went down these paths towards new adventures in music describing loneliness, anger, and other feelings which united them in a march towards liberations—the Civil Rights Movement, Woodstock, and the Vietnam War. Churches and schools became the venues for promoting social activism, and interestingly, many Boomers took on occupations within preaching and teaching as a way to protest the Vietnam War. Despite the diversity of how Boomers came to be, they took on many socially responsible advocacy roles with and for society, and they became vehement voices of social change within all sorts of government policy. They often took on different positions—left and right, conservative and liberal, with the commonality of creating change. Boomers got involved and engaged. They were a culture of making choices for the better (or worse) of our society. These choices emerged from a deep care for the communities and environments where they live, and from patriotism, regardless of the side of the issues they argued. The key point is that Boomers lived during a time when there was an emphasis on making decisions to participate more fully in choices: this became the cultural residue of the Baby Boomer generation.

Boomers lived during a time when there was an emphasis on making decisions to participate more fully

Over the years, things have changed for Boomers. For the first time in many years, Baby Boomers cried “crisis,” when, in 1979, there was an economic downfall and gas prices soared. For many Boomers, endless limits and possibilities had perceived ends and faltered aspirations and dreams of living with more. A culture of taking action that emerged with youth began to degrade slowly as they made their way into adulthood. Consider how many Boomers supported Martin Luther King Jr.’s protest during the Civil Rights Movement of the 1960s. King asked who would march for the movement?—and it was the youth who began marching in nonviolent protests. The youth stood up—some younger than seven! While hate mounted, Baby Boomer youth took responsibility for change and actions, and desegregation happened. Love was the message, but hate was experienced as members of the KKK planted bombs and initiated hate missions across the South. Today, there are four million Boomers unemployed and facing shrinking incomes, but they continue to work. Retirement is not an option for many Baby Boomers and we all know someone who probably fits this generation. Boomers grind their teeth in frustration over failing health and job loss, and they are turning to free clinics as health-care costs climb.

Over time, Baby Boomers set lofty trends for generations to follow, such as the standard size of homes (increasing from 1,500 sq. ft to over 4,000). Boomers went from a mostly non-materialist standard to buying things on loan. This is not the way their parents, who lived through the Great Depression, taught them to live. What remains today is a cultural residue of social activism and responsibility with many Boomers. They worry about tomorrow’s generations of youth—evidenced by their messages in online blogs. They do not want to leave an unbearable burden on their children and their children’s children. Many Boomers believe they set the bar too high for future generations and suspect that perhaps they should lower it.[1] Today, there is more support than ever for the idea that tomorrow’s children need to be raised with the understanding that they do not need to have the same indefinite notions for themselves. But consider how difficult it might be to cultivate these standards of living for individuals who have dealt so long with poverty and despair. Why would Gen Rs accept the mantra of living with less and sharing and living in commons?

Back to the Future: A Renewed Sense of Social Activism

Although technological matrices (e.g., Facebook) are already in place for fostering a renewed sense of social activism, the online conditions of social networking are much less strong than the face-to-face organization and strategic planning of the Baby Boomer activists. Despite that their parents are participating more frequently online in social networks and making small changes, online activists remain mostly complacent and quiet, allowing others to speak for them. Many children these days live with a sense of entitlement. They are dubbed “trophy kids” because they expect to get a trophy for everything they get involved with. They have faith that the government, or science or technology, will solve their problems or that they can buy their way out of concerns. Today's youth, and tomorrow's, are being taught to value and respect the US economy and their financial welfare. There is a reason why today's children do not go great lengths to get involved with higher-risk social activism and policy choices: they think that they should be able to earn enough to buy these actions. Ideally, this idea focuses on purchasing choices which will not be long lived. Consequently, youth may suffer if they are not taught to reengage the world through their bodies—which also means they need to be engaged with an ethical priority and commitment for social responsibility. This is where Generation R youth may differ from Baby Boomers and their parents: they must feel a renewed sense of responsibility.

Embodied Knowing and Generation R Youth

How can we imagine a new generation of youth premised on the idea that they should share some responsibility for school policy? And what is responsibility? Responsibility implies that one should be burdened with the state of their community or environment. It is an obligation to act fully. Some authority is assumed for those who are responsible. Responsible people are expected to care deeply and love what they are responsible for. When one assumes responsibility for action, he/she may also deny others of the possibility for action—especially when individual competition is emphasized (Tobin 2010). Some responsibilities are given to members of a cultural community, such as the obligation to do what a person's parents ask them to do, or demonstrating responsibility to handle the knowledge one is taught. This sense of responsibility also comes with baggage. A person who is responsible may need to demonstrate that he/she can be reliable or that people can depend on him/her for making the right choices. Responsible people rarely miss their obligations to debtors. There is also a sense of time associated with responsibility, as people who share responsibility are often aware of their time. Time and accountability for what students learn and what they need to succeed in college are things that most teachers feel obligated to spend time doing, even if "responsibility" is not mentioned in their curriculum standards. When citizens serve their country in the form of military service, they are sometimes called responsible for the freedoms and opportunities of others. Responsibility often is discussed as an individual's civic duty. However, it is also shared between individuals as they envision or create ways to take action.

A shared sense of responsibility is similar to a general feeling about what actions should be taken in society. These responsibilities are also called civic duties or acts, and they involve choices. It is similar to the experiences in general of a particular generation. Thus, to a large degree, responsibility is the defining characteristic of youth generations of the future. In other words, a shared sense of responsibility can be advocated in the future as a cultural norm or standard of living in the same way that it was with the Baby Boomers. When this cultural standard is shared with youth through the activities they participate in, they will also begin to share ownership of the shaping of this—do not forget, today's children will be parents tomorrow.

Many school policies focus on the development of the person or individual child through testing and competition. These priorities deemphasize a shared sense of responsibility. Concomitantly, teachers often emphasize trends in society to enhance the relevance of their teaching for enduring understandings. With the green movement now very much a part of North American life, teachers are beginning to emphasize the green priorities of schools. They prioritize recycling, gardening, Leadership in Energy and Environmental Design (or LEED) certification for schools, nature clubs, hiking teams, and afterschool extracurricular projects, and use metaphors and analogies derived from visits to the local farmer's market or a restaurant using local produce to teach these science concepts. Our visits to the classroom and science teacher websites evidence these trends are beginning to intensify. Students are becoming more aware of green concerns and the importance of making choices that will reduce their impact on Earth. These things surely enhance learning, while environmental concern is increasingly advertised, marketed, and highlighted in a variety of media outlets. Youth today are growing up with both a sense of entitlement and the emerging sense that they will need to do things differently than their parents. They are being raised to think more about ecological value. What aligns with what youth perceive as good for their community and environment is sure to influence their policy decisions for schooling and social activism, in and out of schools.

Where the school curriculum and testing priorities deemphasize or ignore community health and food choices, for example, it follows that youth who embody the "green knowledge is good" mantra will want to make choices more aligned with their previous experiences and knowledge developed around increasing green understanding. Will these children advocate for educational policy if it does not align with their lifelong experiences centered on the environment? Consider how many people advocate for the community and environment in what they say online, for example, but then these ideas do not influence action. Think about those who cry, "SAVE THE EARTH," but then leave it to others to do the saving. It is more plausible that Gen Rs will advocate for things that they need to survive and reproduce, with the Earth in their purview. They will take increasing responsibility for the things they care deeply about, and with an increasing focus on the environment, the Earth will likely become a significant item in policy decisions they make. If the curriculum does not center on what they are putting into their bodies (if their bodies are getting sick), they will create policy changes that reflect the betterment of their bodies and community.

Science teaching and school policy will become aligned with what is necessary for Gen Rs to share more responsibility for these things. Correspondingly, we can identify an increasing aesthetic motivation for psychological and subjective well-being, and many people are already promoting the cultural norms or standards of living more influenced by environmental intrigue. These movements are likely to continue and become more deeply entrenched within the next few generations. As they do, they will influence youth actions and their behaviors towards others in all directions. With entrenchment, these beliefs will lead to better choices based on an increasing critical mass of leadership, organization, and strategic responsibility, similar to the face-to-face social activism embraced and valued by the Baby

Boomers. For example, Gen Rs may see that national security is compromised when there are not enough qualified individuals who can go into the military or who serve their community in various capacities. The “fitness” of youth may be deemed the culprit. If national security matters to Gen R youth and they take responsibility for it, they will begin arguing for policy that emphasizes choices that correspond with better health and foods. Ultimately, these things correspond with subjective well-being. National security, mood, food, and health are transactional entities.

During changing economic conditions, youth will be poised to make better decisions by embodying a responsibility for policy. Today, the number of children who work to support their families indicates that society is stressing children to contribute to income. If science education changes in such a way, say, students could reduce their parent’s reliance on the marketplace for their needs (which is a cultural legacy of previous generations). Then perhaps there will be less emphasis to support family with income. Spending more time with family, friends, and nature could help rebuild the relational bonds and face-to-face communications that have been degraded by today’s busy lifestyles, to which Americans have grown accustomed. Digital technologies may one day serve as *tools* to enhance higher-risk social responsibility and activism in a way never envisioned today, rather than exclusive two-dimensional contexts for imaging relations.

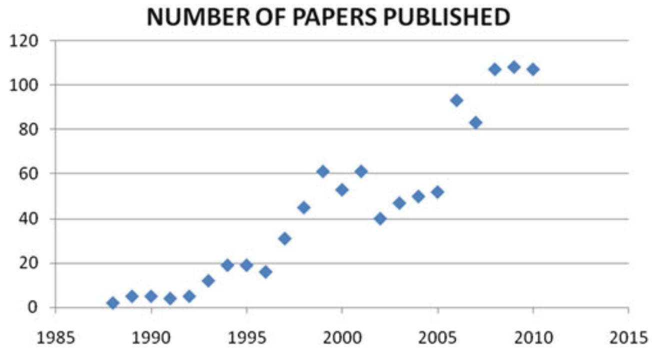
School Policy in Science Education

In order for the ideas summarized above to work, science education should shift priorities. Learning how to supplement basic family needs by relying on shared community knowledge and experiences in relation to learning from other cultural communities around the world begins fueling a curriculum centered on students’ lives. Youth may learn how to garden and become more self-sufficient or trade with their neighbors who are also growing food. They may learn from farmers in Malawi, who now are using cellular technologies to teach children about organic farming practices (Glasson 2010). Social responsibility and activism must become a norm for school administrators, scientists, teachers, and business people who want to strengthen the matrices for community actions. Tomorrow’s youth will need to demonstrate responsibility, and the obligation for using responsibility wisely may be assessed by education research. Similar to the Baby Boomers, there will be Gen R leaders and those who cultivate a wider emphasis on social activism and responsibility.

The top-down No Child Left Behind mentalities cannot work for preparing tomorrow’s children to the degree that they can monitor their bodies, cultures, communities, and natural systems, and the subjective well-being of people in relation to these systems. Tomorrow’s children will likely advocate for new science curricula and can be expected to play a large role in co-constructing their schools (Tobin 2010). Policymakers, we predict, will change with the more embodied experiences of generation R youth, as things taught in schools fail to meet the new view of needs.

When teachers are rewarded for going beyond the tests that comprise schooling today, to include assessments of social responsibility and activism, the tensions of preparing children for life in the workforce may lessen as children prepare to reenter the life of their village.

Gen R's parents already embody this renewed sense of social activism: they are starting to participate more fully in learning about whether their environment needs advocacy. This idea is evidenced by the increasing number of websites, books, and magazines dedicated to social parenting for ecological health. It is evidenced with a quick Web of Science search to see how many scientific papers turn up, by year, when the search phrase "ecosystem health" is used. In this search, the number has increased from two papers in 1988 to 107 papers in 2010.



The above graph indicates that there is a growing attentiveness by scientists for "ecosystem health" as a proxy for a more holistic view of ecosystem problems.

When this idea is viewed in terms of justice and fairness for future peoples, the revitalization of intergenerational norms can be seen as *ecojustice* (Mueller 2009). From an ecojustice perspective, the looming conditions of children's bodies developed over the last three decades, in particular, should spark interesting conversations around our prior actions and whether there is a need to analyze the limits of natural resources.

With society's heightened awareness of degraded fisheries, forestry, and other resources, we are beginning to pay more attention to issues of urban sprawl, agricultural practices, conservation, recycling and waste disposal practices, and genetically modified organisms, to name a few. We are becoming more aware of natural limits and boundaries, and these discussions are starting to diffuse into the schools. Correspondingly, the enjoyment and satisfaction of engaging in diverse community and cultural events, the traditions of elders and oral narratives of older people, and how to protect habitats are emerging in our society. There are conversations around how to get children to play outside more than a few years ago, when the latest technological fads outweighed such discussion. Perhaps we are experiencing to a lesser degree what Generation Rs will likely experience when they have to rely on themselves for policy.

The Intellect of Embodied Reasoning

A point of scrutiny for embodied knowledge is sure to arise with the downplay of intellect in this chapter. For this reason, we want to be clear that the embodied knowing we describe above is a transaction of mind and body for the full realization of epistemic development in Gen Rs. Some, if not most, Gen Rs will need to be taught how to feel and what to feel and how to monitor their bodies in relation to mind, because a disassociation of mind and body occurs commonly in schools today. Mind and body are considered largely separate and conflicting entities in education, with the mind being assumed a priority or main focus of schooling. Thayer-Bacon (2003) describes this epistemic approach as *caring reasoning* or the "art of generously and attentively listening to the other, presuming and maintaining differences (pluralism), recognizing the important of valuing and respecting the other, while at the same time acknowledging and appreciating our commonalities and our interconnectedness with each other" (p. 211). Embodiment is the transactional joining of mind and body, and the integration of reason and sensibility of rationality and emotion: for reading and thinking in the traditional sense (already captured in learning) cannot help but shift Gen R's thinking to better choices, responsibility, and activism efforts. Deeply analyzing the meanings of words, concepts, and metaphors is a virtue for influencing appropriate and significant embodiment. This embodiment of rationality is not limited to pure reason (Thayer-Bacon 2000), and it can be a motivating factor for influencing responses (e.g., policy with others to decrease pollution). For others, it is learning about the conditions of factory farms that motivates when we focus beyond our own body.

In order to cultivate and teach embodied knowledge, we need a more holistic educational policy that reaches beyond the natural sciences. Science teaching must embrace a more conceptual emphasis on intellect, fostered through interdisciplinary and dynamic schools, yet not be limited by the rapidly increasing subject area specialization. Science education that engages the body-mind will begin to tap into the epistemic journey for Gen Rs. As noted by Atkin (2007), perspectives of the humanities, such as the use of literature and poetry in science education, will develop this embodied knowledge. Wendell Berry (2000) notes that the arts and sciences are not separate outside of schools or school policy: "it may be more or less possible to know and do nothing, but it is not possible to do and know nothing. One does as one knows. It is not possible to imagine a farmer who does not use both science and art" (p. 124).

The humanities will help Gen Rs evaluate their methods of social responsibility and activism with greater clarity. Through the humanities, Gen Rs can use caring reasoning to further assess the oral narratives and printed stories of the young and old, past and present, and the minds of future thinkers. In science education, this emphasis might cultivate a metaphorical, *transformative secondary skin* for sensing and thinking that helps Gen R youth develop the understanding that they can and should change the world, in the past, present, and future of things, even if that means staying with the course or conservation of practices of an older way of life (e.g., such as Nature Study). This transformative secondary skin will likely challenge the forms of science and science education in schools that do not provide epistemic practice for body rationality.

Traditional science education tends to disembody thinking apart from feeling. This tendency encourages a sense of fearfulness and nihilism. School policy in science education that challenges complacency can contribute to the praxis of strengthened social networking and transaction with friends, family, neighbors, and community leaders. If science classes are going to be successful at preparing the youth needed to become embodied friends, neighbors, and community leaders, or to monitor their bodily, cultural, and community health, a stronger emphasis on learning through relations and experiences is needed.

So, we are reminded to cultivate embodied responsibility. Clearly, evaluating the technological advances and social networking matrices that have already enabled thousands of individuals to share embodied knowledge for responsibility and social activism has the potential to provide a shape and scope for future initiatives.

Note

1. The authors thank the Baby Boomers who offered their insights and guidance for the construction and development of this chapter.

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Chapter 3
Civic Responsibility and Science Education

Paul Theobald and John Siskar

Civic responsibility and science education are not often paired together. In fact, one would have to look long and hard to discover any connection between the two in the myriad of government reports, think tank news releases, and foundation monographs urging the nation to improve its economic dominion through more and better science instruction. Science and scientific innovation are deemed to be the engine of the economy and therefore the curricular pinnacle of the nation's schools, or so the decidedly unsubstantiated argument goes.

There is a reason why such an argument can gain traction with so little evidence to support it. For a long time, certainly the last 100 years, America's schools have been thought of as a place to acquire the wherewithal for some sort of occupational future. Very few people question this goal for schools—though a few serious questions ought to readily emerge, even at a casual glance. What about those jobs that require little formal education? Is it equitable to tie the educational fate of some to a poor occupational fate? While these sorts of questions have been asked more frequently in recent years, they were seldom asked during America's twentieth century. As a consequence, science existed for the talented students, for the college bound, and for those who would take the interesting and important jobs in society. Others didn't need much science.

It wasn't always like that. In fact, the very concept of free public schools itself was introduced as an aid to democratic well-being, as a vehicle for preparing citizens who possessed the intellectual wherewithal required to shoulder civic responsibilities. In this chapter, we will first document the original purpose of public schools, then

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chronicle when and why a pronounced shift in the purpose of schools took place, and last, we will argue that given twenty-first century circumstances, the ends of education must be rebalanced and that science in the interest of democratic well-being must again be a part of every school program.

A Look Back

By the middle of the eighteenth century, perhaps more than any other place on earth at that time, England's North American colonies, especially those comprising New England, were nearly compulsive about the creation of schools and the spread of literacy. Consider the comments of England's conservative apologist, Edmund Burke, concerning the raucous American colonies of the early 1770s:

> Permit me, sir, to add another circumstance in our colonies, which contributes no mean part towards the growth and effect of this untractable spirit—*I mean their education*. In no country in the world perhaps, is the law so general a study. I have been told by an eminent bookseller, that in no branch of his business . . . were so many books as those on law transported to the plantations. I hear that they have sold nearly as many of Blackstone's *Commentaries* in America as in England. (Thornton 1860, p. xxvii)

The prospect of independence—of throwing off the thousand year legacy of monarchy and feudalism through a war of separation from England—was a catalyst to systematize this fervor for education and make it a pivotal part of America's republican project. "Where learning is confined to a few people," wrote Pennsylvania's Benjamin Rush, a signer of the Declaration of Independence, "we always find monarchy, aristocracy, and slavery" (Rudolph 1965, p. 3). He went on to call for a unified system of public schools in his state, believing that such a system could ward off the evils of feudalism by converting "men into republican machines."

Noah Webster of Massachusetts used still more aggressive rhetoric in his attempts to systematize public education in his state. "You have been children long enough, subject to the control and subservient to the interest of a haughty parent. You have now an interest of your own to augment and defend: you have an empire to raise and support by your exertions and a national character to establish and extend by your wisdom and virtues. To effect these great objects, it is necessary to frame a liberal plan of policy and build on it a broad system of education" (Rudolph 1965, p. 77).

Robert Coram of Delaware made a similar argument in 1791, but he offered a far more expansive plan, one that would establish public schools, not just in Delaware, but throughout the United States. Said Coram, "In our American republics, where government is in the hands of the people, knowledge should be universally diffused by means of public schools." He lamented the fact that many of the new states established colleges and universities where children from privileged homes could be sent, "but no provision is made for instructing the poorer rank of people even in reading and writing" (Rudolph 1965, pp. 126–127). Such a circumstance seemed incongruent with the very idea of republican government. If the new United States were to be a success, the government could not afford to slide slowly into despotism or anarchy. For many among the founding generation, this meant that a system of public schools was necessary. Thomas Jefferson, the nation's third president, perhaps said it best:

> And say, finally, whether peace is best preserved by giving energy to the government or information to the people. The last is most certain, and the most legitimate engine of government. Educate and inform the whole mass of the people. Enable them to see that it is their interest to preserve peace and order and they will preserve them. (Jefferson 1955, p. 478)

Jefferson tried three times to convince his fellow Virginians to adopt his bill "for the more general diffusion of knowledge," which would have established a free school system for white boys and girls throughout the state. Each time he was unsuccessful.

Slavery surely inhibited the development of school systems in Jefferson's Virginia and all across the South. But even in the North, in New England itself, there was staunch resistance to the idea of taxing one man for schooling received by the children of another man. On top of this, the tight connection between education and religion—the Bible was often the primary "textbook" in colonial schools and in the schools of the early republic—meant that denominational and interdenominational schisms also worked to inhibit the establishment of free school systems. For these reasons and others, despite widespread support for schools and a general understanding of their *sine qua non* status with respect to republican government, free school systems were not established until the 1830s—some 50 years after America's ascendancy as an independent nation.

Still, there were a few key developments in the early republic that moved the new nation along a trajectory that seems to be, from hindsight at least, a natural progression toward a universal free school system. The first was the Northwest Ordinance of 1787, generally regarded as the greatest accomplishment of the United States under the Articles of Confederation. This Act stimulated planning for school systems in the states that would one day be created out of the area between the Ohio and Mississippi Rivers. An earlier 1785 Act, most often referred to as the "land ordinance," laid out the terms whereby the cash-strapped fledgling republic could generate revenue through the sale of western lands. But it included an interesting clause that would be expanded upon in 1787: "There shall be reserved the lot No. 16, of every township, for the maintenance of public schools within the said township" (Commager 1943, p. 124). The Land Ordinance was expanded by additional legislation two years later in what became known as the Northwest Ordinance.

The language surrounding the educational prescriptions was expanded as well. Said the authors of the Northwest Ordinance: "Religion, morality, and knowledge, being necessary to good government and the happiness of mankind, schools and the means of education shall forever be encouraged." While it is difficult to assess whether or not there was a direct educational impact on the original states in the Union, it is nevertheless true that three states at least, in the spirit of the Northwest Ordinance, passed legislation intended to explicitly encourage the development of schools and the spread of literacy. In 1789, Massachusetts passed a bill that required every community of 50 families or more to establish an elementary school to be in session at least six months of every year. In 1795, New York and Connecticut went a good way further by creating permanent school funds to support schools throughout the respective states. Connecticut's school fund bill encompassed the sale of Connecticut's portion of the Western Reserve. The state amassed large sums the interest from which was paid out to schools and teachers until the 1840s (Kaestle 1983, p. 10).

The language of the Northwest Ordinance demonstrates the extent to which "religion, morality, and knowledge" were seen as part of one cloth. Two distinguished historians of education put it this way:

> When they spoke about religion, morality, and knowledge, the framers of the Northwest Ordinance did not assume twentieth century definitions of these words. Their view was a holistic one. They did not assume that religion, morality, and education were essentially distinct areas of thought and practice. In fact, they saw these as interdependent, each mutually reinforcing the lessons of the other. (Mattingly and Stevens 1987, p. 2)

From a twenty-first-century vantage point, it is difficult to appreciate the degree to which religion permeated early American society, a phenomenon that profoundly affected both politics and education. Writing in the 1830s, Alexis de Tocqueville observed the following:

> Religion in America takes no direct part in the government of society, but it must be regarded as the first of their political institutions; for if it does not impart a taste for freedom, it facilitates the use of it. Indeed, it is in this same point of view that the inhabitants of the United States themselves look upon religious belief. I do not know whether all Americans have a sincere faith in their religion—for who can search the human heart?—but I am certain that they hold it to be indispensable to the maintenance of republican institutions. This opinion is not peculiar to a class of citizens or to a party, but it belongs to the whole nation and to every rank of society. (Tocqueville 1898, p. 305)

While Tocqueville was impressed with the number of schools and the percentage of the American youth attending them, he also noted that "almost all education is entrusted to the clergy." Religion and education were tightly connected for most of the nineteenth century. To be an advocate for one was to be an advocate for the other (Cremin 1980, p. 371). This is why the authors of Nebraska's 1866 and 1875 Bill of Rights thought nothing of using one clause to simultaneously defend the right of free religion and free education. Note the way the passage resonates with the words of the Northwest Ordinance: "Religion, morality, and knowledge, however, being essential to good government, it shall be the duty of the legislature to pass suitable laws to protect every religious denomination in the peaceable enjoyment of its own mode of public worship, and to encourage schools and the means of instruction" (Nebraska History and Political Science 1920, pp. 8–9).

More than perhaps all other common school leaders combined, it was two eastern state superintendents, Horace Mann and Henry Barnard, who carved out a path for common schools that could cultivate a noncontroversial version of religious education ultimately intended to yield political wherewithal. In fact, the common school curricular prescriptions advocated by Mann are sometimes described as the 5 Rs: "reading, riting, rithmetic, religion, and republicanism," though in actuality he pushed for the additional study of history, science (particularly physiology and geography), as well as vocal music. Mann believed the school was the place to engage American youth in subjects that were congruent with life in a democratic republic. This included religious teachings that were common to all Christian denominations, just as it included political lessons related to the separation of powers, the manner in which officers were elected, the route of a bill through legislative processes, etc.—common to all, but noncontroversial. Said Mann, "It is obvious that if the tempest of political strife were let loose upon our Common Schools, they would be overwhelmed with sudden ruin." If the teacher runs across a controversial passage "he is either to read it without comment or remark; or, at most, he has only to say that the passage is the subject of disputation, and that the schoolroom is neither the tribunal to adjudicate, nor the forum to discuss it" (Cremin 1957, pp. 94, 97). In the area of religion and republicanism, school subject matter would be that common to all political persuasions. According to Mann:

> The elements of a political education are not bestowed upon any school child, for the purpose of making him vote with this or that political party when he comes of age; *but for the purpose of enabling him to choose for himself, with which party he will vote.* (Cremin 1957, p. 104, italics added)

The Common School Movement

This approach to school curriculum gave greater currency to the phrase "common" school than had existed at our nation's founding. In fact, the drive for systematized free schools all across the country became known as the "common school crusade." This crusade was one of many democratic movements of the nineteenth century, including the drive to obtain universal manhood suffrage, reform prisons, reform asylums for the insane, institutionalize the dispersal of free land, establish town and city parks, abolish slavery, extend the right to vote to women, and the list could go on. It is important to note that the establishment of free schools systems coincided with the success of many of these democratic initiatives. In fact, it was a common understanding during the nineteenth century that schools existed to augment the free play of democracy, to vitalize it, and to give it meaning in the lives of all citizens. Thus common schools became defined as the place for the widespread acquisition of sophisticated literacy and numeracy skills, a thorough understanding of history and science, a working understanding of the rights and responsibilities that accompany life in a republic, and the acquisition of the moral wherewithal required by a democracy, lest self-interest erode the possibility of self-government.

Henry Barnard put it this way in a speech to Rhode Island teachers in 1849, "The cause of true education, of the complete education of every human being, without regard to accidents of birth or fortune, is worthy of the concentration of all powers, and if need be, of any sacrifice of time, money, and labor we may be called upon to make in its behalf" (MacMullen 1991, p. 101). And consider Horace Mann's view, once again:

> The theory of our government is, not that all men, however unfit, shall be voters,--but that every man, by the power of reason and the sense of duty, shall become fit to be a voter. Education must bring the practice as nearly as possible to the theory. As the children now

> are, so will the sovereigns soon be. How can we expect the fabric of the government to stand, if vicious materials are daily wrought into its frame-work? Education must prepare our citizens to become municipal officers, intelligent jurors, honest witnesses, legislators, or competent judges of legislation—in fine, to fill all the manifold relations of life. For this end, it must be universal. The whole land must be watered with the streams of knowledge. (Cremin 1957, pp. 57–58)

Contemporary political scientist Benjamin Barber, writing in *Harpers Magazine,* lamented the extent to which we have drifted from Mann's vision. Said Barber: "The logic of democracy begins with public education, proceeds to informed citizenship, and comes to fruition in the securing of rights and liberties. We have been nominally democratic for so long that we presume that it is our natural condition rather than the product of persistent effort and tenacious responsibility. We have decoupled rights from civic responsibilities and severed citizenship from education on the false assumption that citizens just happen. We have forgotten that the 'public' in public schools means not just paid for by the public but procreative of the very idea of a public" (Barber 1993, pp. 4–5).

The popular conception today that schools exist primarily to prepare students for the workplace is largely a twentieth-century phenomenon, though this is not to suggest that nineteenth-century Americans were unconcerned about the future employment of their children. Mann and other common school architects pointed out that a common school education ought to prepare citizens for whatever their future employment might be; but this was secondary. Said Mann, "The man is the trunk, occupations and professions are only different qualities of the fruit it should yield . . . the development of the common nature; the cultivation of the germs of intelligence, uprightness, benevolence, truth, that belong to all;--these are the principal, the aim, the end,--while special preparations for the field or the shop, for the forum or the desk, for the land or the sea, are but incidents" (Cremin 1980, p. 12). This sentiment was echoed by S. D. Beals, Nebraska's first State Superintendent of Common Schools, in his 1869 annual report. Said Beals,

> The public school is not only the creature of the state, but that it is for the purposes of the state, that its aid to the parent in the education of his child, *or its benefit to the child in preparing it for its future private vocation in life is only incidental and is not its leading object*. The training of the child for citizenship, the preparing of him for the performance of his duties, and the exercise of his privileges as a citizen is the prime end sought by the state. It is also true, that in proportion as the state is successful in preparing the child for citizenship, in a general way, it contributes most to fit the child for all of the ordinary duties of life. Correct habits of thought and feeling are indispensable requisites to good citizenship; they are equally necessary in every situation which calls for individual action. To form these habits, is the proper objective work of the common schools. (First Annual Report 1869, p. 52, italics added)

An education common to all citizens of a growing democracy, this was the heart of the common school movement. Its curricular prescriptions were directed toward that end. If power rested in the hands of everyone, everyone required the intellectual wherewithal to wield it. In the face of a task of this level of importance, the goal of getting a good job was secondary and seen as a natural outgrowth of a common school education in any event. It would only become the primary goal during the first decades of the twentieth century. Sweeping changes ushered in by the advent of the Industrial Revolution meant that an individual's role in society was increasingly defined by the nature of his or her employment. The widespread use of such labels as professional, manager, domestic servant, manual laborer, etc., was introduced and became commonplace during the Progressive Era. As this unfolded, the phrase "common schools" fell from use and was replaced by the Darwinian-inspired "comprehensive school" designed to match curriculum with "the evident and probable destiny" of each child (Preskill 1987, p. 39).

The Movement Toward Uncommon Schools

Before examining the forces that drove this shift in the purposes of education, it may be useful to examine what a few twentieth-century states had to say about free public education within them. It should be noted that there is a resounding resemblance, in terms of the language used, from one state constitution to the next. Almost all were heavily plagiarized. Consequently, many new states merely repeated the language from older states like Massachusetts or Nebraska, including specific language indicating that the system of free schools was to be established and maintained in order to advance the cause of democratic government. But a few, clearly, were attuned to the winds of change. Consider the Constitution of the state of Oklahoma, adopted in 1907: "The Legislature shall provide for the teaching of the elements of agriculture, horticulture, stock feeding, and domestic science in the common schools of the state" (accessed at http://oklegal.onenet.net/okcon/viii-7.html). Or the Constitution of North Dakota, adopted in 1959: "The legislative assembly shall take such other steps as may be necessary to prevent illiteracy, secure a reasonable degree of uniformity in course of study, and to promote industrial, scientific, and agricultural improvements" (accessed at http://www.legis.nd.gov/constitution/const.pdf).

These examples reflect the fact that a shift in what were perceived to be the ends of education was taking place—more and more the argument was made that an education should be near-exclusively about one's eventual occupational destiny. One hundred years later, twenty-first-century Americans have no working memory of when such an economic focus was, to use the phrase of S. D. Beals, the nineteenth-century Nebraska state superintendent quoted earlier, "merely incidental."

How and why did this happen? Charles Darwin looms rather large in the answer, or, more accurately, those who interpreted Darwin's theory and applied their interpretation to the human condition. Witness the claims of Herbert Spencer, England's great late nineteenth-century sociologist: "I am simply carrying out the views of Mr. Darwin in their application to the human race" (Spencer 1882, p. 418). It turns out that humans have quite different evolutionary histories, Spencer argued, and those most evolved are the ones who should wield the reins of government. America's great Social Darwinist, William Graham Sumner, a devoted disciple of Spencer, explained it this way: "The millionaires are the product of natural selection . . . the naturally selected agents of society for certain work. They get the high wages and live in luxury, but the bargain is a good one for society" (Sumner 1914, p. 90).

The logic of Social Darwinism seemed to argue against a *common* educational agenda, one common to all citizens in a democracy. If by virtue of their evolutionary status all citizens possessed different intellectual capabilities, a differentiated school system was required, one that could match the curriculum to the evolutionary status of the child. Clearly minorities, who were so obviously less evolved than whites, needed a low-grade education, one tied to occupations that required little educational background. We were so convinced of this that not long into the twentieth century we created tech high schools for minorities, places where minority children could receive a technical, job-focused education. Many of these still exist, though the worst excesses of exclusively occupational training have been reduced.

Ask a legislator today why we go to the expense of providing free public schools and he or she will undoubtedly say "So that kids can get good jobs." Or, if not that, it will be something like this: "So America's economy can compete with the rest of the world." In other words, the view is so limited, so tied to economics as a result of a century's worth of momentum in that direction, that they lack the ability to envision an alternative and they certainly lack the knowledge of their own nation's history that could readily supply an alternative. So what is to be done? How might the link between democratic civic responsibilities and public education be reestablished? How might the ends of education be rebalanced? And what is the role of science education in that rebalancing act? We turn now to these questions.

Science Instruction in the Twenty-First Century

Americans, and indeed citizens of all nations, face circumstances that didn't trouble earlier residents of planet Earth. The specter of environmental collapse, the possibility that humans might multiply beyond the carrying capacity of the earth, or the possibility that human economic activity might heat the world's atmosphere to the point that massive species extinctions could reverberate through tenuous ecosystems, any or all of these scenarios deserve substantive and prolonged debate. Few would argue with that. But for that debate to be productive, it will need to be informed by the results of scientific inquiry and scientific reasoning.

Today the curricular and instructional emphasis on mathematics and science, on the so-called STEM disciplines, is predicated on the fact that these disciplines are deemed to be the engines of economic growth. As long as this emphasis remains the dominant opinion on the subject, science can conveniently remain the province of the nation's college-bound—the 20–25 % of the population that goes on to acquire a college degree. This means that a mere fraction of all of those who might participate in the great debates facing the twenty-first century will have the wherewithal to do so. It also means that our chances of hitting upon far-reaching solutions are markedly diminished.

Given the environmental circumstances faced by all citizens, and given the political voice accorded all citizens in a democracy, we argue that sophisticated science instruction is required by all. One of the basic tenets of democratic theory going back as far as the Greeks is that democracy does not work when extremes in income *or learning* begin to permeate a society. Recall the words of Benjamin Rush, one of Pennsylvania's founding fathers, "where learning is confined to a few people" evils are sure to follow. When a society comes to be defined by vast discrepancies in *both* financial and intellectual power, a condition more and more Americans believe defines the United States today, it cannot hope to remain stable, at least if the study of history is any guide.

Where is the intersection of science and civic responsibility? It is in doing science, wielding it, in the interest of improving life in a school's neighborhood. The benefits of a constructivist, project-based, and hopefully place-based approach to science instruction are twofold. First, it will maximize the odds that scientific understanding is reached—as opposed to the temporary comprehension of isolated science facts, and second, students are socialized into the practice of utilizing intellectual power to improve the life circumstances of those with whom they share their place on earth. There are now countless examples of science instruction outside school walls, science instruction that has led to local government action regarding such things as water or air quality, zoning for confinement agriculture and other industrial operations, pedestrian or vehicular traffic regulation, and much, much more. Science teachers who are free to utilize their pedagogical imagination can create powerful lessons that help students learn science and, more importantly, wield it in the interest of the well-being others.

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Chapter 4
Critical Civic Literacy and the Limits of Consumer-Based Citizenship

Cori Jakubiak and Michael P. Mueller

In this chapter, we address how American citizenship is increasingly being defined through *consumption*. We suggest that this practice has policy implications for science education specifically and general education more broadly. In the present historical moment, U.S. citizens are *consumer-citizens*, people who practice their politics through the purchase of goods and services. This practice is encouraged by color-based marketing, that is, the Madison Avenue practice of labeling goods green, pink, and so forth in order to imbue these goods with symbolic meanings. Color-based marketing implies that one can remedy resource depletion, global warming, and rising breast cancer rates, among any number of other economic, political, social, and ecological justice issues, through the purchase of correctly hued products and services.

While cultural theorists and anthropologists have critically reviewed color-based marketing trends and the attendant consumer citizenship habits these trends promote (e.g., Brosius 1999; King 2006), little is being done in U.S. schools to teach students how to untangle these same messages. Color-based marketing is particularly salient to science education because many of the claims made by advertisers and corporations could be investigated scientifically. Through a lack of curricular attention to *critical civic literacy* within science education, however, public schools inadvertently perpetuate consumer-based citizenship. National and

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state educational priorities and standards even pitch the primacy of the economy and developing a consumer society (e.g., National Research Council 1996). Viewing this situation as shortsighted, we organize this chapter as follows: First, we situate consumer citizenship within *neoliberalism*, an ideological apparatus that privileges economic growth as its main priority and restructures societal relations for this objective. Second, we argue that corporate color-based marketing schemes such as green and pink, in their apparent benevolence, are problematic and further the aforementioned consumer citizenship by obfuscating other, more collective, means of civic engagement. Third, we suggest that schools can and should incorporate critical civic literacy education within science education—a move that would better equip students to decipher the thorny vines of corporate messages in society. Finally, we explore some alternatives to consumer-based citizenship and highlight their implications for educational policy.

Neoliberalism and the Shift to Consumer Citizenship

Consumer citizenship finds roots in the logic of *neoliberalism*, a broad, often contested, political label used to describe the pro-free market, anti-big government ideology that has become hegemonic among Global North nation-states and supranational institutions in the last few decades. The world order as envisioned under neoliberalism is one in which publicly funded, social service provisions are reduced, economic growth is promoted, and the primary role of the nation-state is to regulate markets and facilitate the movement of capital.

Under the regime of neoliberalism, the free market is equated with freedom—indeed, it can be equated with shared democracy (or "equal opportunity"). Maximizing corporate industries' chances for financial gain, through the privatization of social services and by easing restrictive environmental or labor laws, it is seen as on par with optimizing individuals' choices and civil liberties (Harvey 2005). Consequently, attempts to challenge neoliberalism as an ideology that puts profit before people or as a formation that harms natural systems are not only quickly discredited, but may be viewed as antidemocratic. As Duggan (2003, p. 10) notes, neoliberalism

> is usually presented not as a particular set of interests and political interventions, but as a kind of nonpolitics—a way of being reasonable, and of promoting universally desirable forms of economic expansion and democratic government around the globe. Who could be against greater wealth and more democracy?

As a way of viewing the world, then, and as a set of conceptual priorities on which principles of governance are based, neoliberalism is stubbornly resistant to critique or amendment.

Ideas of science education and what it means to be an active citizen are reframed under the auspices of neoliberalism. In the last three decades in the U.S., as four successive administrations have been in thrall to neoliberal doctrines, rates of participation in community organizations and in long-standing forms of collective, public action such as political letter-writing, union membership, and protest rally attendance have declined dramatically (Putnam 1995). Concurrently, we have witnessed a rise in more a private, individually oriented form of civic participation in science education: that of consumer politics. As consumer-citizens, people exercise political expression through the purchase of goods; they fashion lifestyles for themselves based on the accumulation of particular objects or the consumption of certain experiences (Rose 1999). Citizens are acculturated as consumers of science, technology, politics, popular culture, and media, as well as consumers of particular forms of scientific recreation and ecotourism (Russell and Russon 2007).

The self-reliant and self-shaping consumer-citizen is deemed as active within neoliberalism as s/he depends not on the state (as a passive citizen would) or on any reconfiguration of the existent social structure for happiness, security, or cultural identity. Instead, the consumer-citizen is expected—indeed, encouraged—to participate actively in the shops. Says Butcher (2003, p. 105) on how consumer citizenship promotes the rationalities of neoliberalism,

> traditional political channels increasingly invite cynicism, and many feel alienated from the institutions of government. Other institutions, through which individuals related to their society, have also declined—church, community and family. All this has strengthened, by default, the more individual form of politics—consumer politics. Far from the discredited institutions of government, it is as consumers that we are, apparently, free to exercise our choice in pursuit of a better world.

As part and parcel of consumer citizenship, then, one is expected to shop—a lot!—and to make the right purchases as one does so. Many of these "correct" purchases are color-coded to index particular politicized or socialized meanings—a discussion to which we now turn.

Colorwashing Consumer-Citizens: Buy Green, Buy Pink

Color-based marketing is a trend most Americans know well. In the last 30 years, we have seen a proliferation of green, pink, red, yellow, and other hued goods, services, and experiences, all of which are designed to link commercial purchases to broader, arguably ethical, social, or political, agendas. For example, one's selection of a green, perhaps highly priced, dishwashing detergent versus a colorless, cheaper, off-brand equivalent ostensibly allows the purchaser to engage in civic action. To buy the green dishwashing detergent is to save surface waters from an infusion of phosphates, while buying the non-green alternative suggests an acceptance of the status quo. Similarly, color-based marketing offers that the purchase of something labeled pink—e.g., a bag of chips, a blender, a pair of tweezers—allows one to raise awareness of breast cancer. Consumer citizenship, aided by color-based marketing, offers the ultimate in multitasking. One can, purportedly, accomplish yesteryear's version of a sit-in while stocking up on big-box values. The color-label advises one as to the cause, fostering a frenzy of hues around consumption. Some consumer-citizens even *desire* the related monikers of fashionista, shopaholic, or mall-rat, becoming specialists in the consumer-citizen appeal. These specialists then advise the public how to be successful, for example, in the rush for the stores on large-scale shopping events such as Black Friday, the day after many folks say they are *thankful* for what they already have.

Astute observers of color-based marketing point out that the origins of labeling products as colored—in particular, green—stem from the early work of modern-day public relations (PR) firms—namely, groups that work in the interest of profit rather than ecosocial justice. The underlying value of a company in relation to its investors drives the pursuits of corporate agenda. In the first decades of the twentieth century, PR firms in the U.S. were recruited by large corporations such as Standard Oil to fend off what was then widespread anti-corporate sentiment and to fight government efforts at regulation (Karliner 1997). As corporations came under increasing attack for causing environmental problems, many corporations directed their PR firms to shift public opinion in their favor. Over time, these corporations increasingly relied on PR firms and advertising agencies for environmental whitewash or *greenwash* propaganda, which is designed to cleanse corporations of their environmentally destructive influences/impacts and recast them as environmental advocates rather than plunderers. In the words of Karliner (1997),

> The role that the descendants of [PR firms] have played in shaping and distorting environmental issues can be traced back to the 1962 release of Rachel Carson's *Silent Spring,* the book credited with catalyzing the modern environmental movement. In response to *Silent Spring*, the Chemical Manufacturers Association (CMA, called the Association of Manufacturing Chemists at the time) recruited a young man named E. Bruce Harrison, whose job was to develop a coordinated response among the major U.S. chemical corporations to *Silent Spring's* stinging and prophetic account of the ecological impacts of pesticides such as DDT. . . . Harrison sowed the seeds of the corporate PR response to modern environmentalism. . . . As the contemporary environmental movement built momentum in the mid- to late-1960s, undermining public trust in many a corporation, newly greened corporate images flooded the airwaves, newspapers, and magazines. This initial wave of greenwash was labeled. . . 'ecopornography'. (p. 170)

As Karliner (1997) reports, late twentieth-century environmental catastrophes further popularized and created consumer frenzy around color-based marketing. He continues:

> …in the early 1990s, one poll found that 77 percent of Americans said that a corporation's environmental reputation affected what they bought. … In response to this phenomenon, the corporate world went to great lengths to market itself and its products as the greenest of the green. One-fourth of all new household products that came onto the market in the United States around the time of 'Earth Day 20' advertised themselves as 'recyclable,' 'biodegradable,' 'ozone friendly,' or 'compostable'. (p. 171)

In the years since Earth Day 20, green has become so commonplace that even the most outrageously polluting products are labeled as such. For example, as we write, an empty, plastic Deer Park water bottle sits on the desk nearby, hailing for selective attention with the following text: "Did you notice this bottle has an Eco-Slim cap? This is part of our ongoing effort to reduce our impact on the environment. … Be Green." Given the proliferation of empty plastic water bottles currently floating in the Pacific and Atlantic Oceans, it is hard to understand why Nestle (Deer Park is one of its subsidiaries) has not faced more community scrutiny.

The green barrage in the marketplace contains green versions of nearly everything, from green cosmetics to green supersized SUVs. But that's not all. Green advertising now operates very covertly. Green may take the form of ideas or things associated with being cleaner and more environmental friendly, such as more oxygen in bottled water, nitrogen in tires (Koballa and Demir 2010), and "Go Green" U.S. postage stamps. In zoos, parks, and travel destinations, green often takes the form of protected fauna, and the suffocating nature of zoo enclosures for animals is deemphasized.

Color-based deception also goes beyond green marketing. In the last few years, we have also seen an expansion in the plethora of products labeled pink and red—motives that associate commercial items with public health issues such as breast cancer awareness and HIV/AIDS. While corporate greenwashing suggests that a particular product or item is green because of qualities inherent within the product, the connection between other colors and deadly disease is purely symbolic. Take Deer Park's water bottle again. With its smaller cap, it is purportedly *less* polluting than other equivalent water bottles and is therefore a good choice purchase. In contrast, although many people think they are supporting "a cause for a cure" when they buy pink-labeled items, the pink-product market does not inherently use pink to reduce the incidence of breast cancer inasmuch as it claims to promote awareness around breast cancer as a disease (King 2006). The strategy of marking something pink so that people think they are contributing to breast cancer research, then, is a nebulous ploy that frequently goes by the wayside not only because it obscures the transnational, corporate enclosure of an often localized public health problem (Klawiter 2000) but also because very few people investigate how and in what ways corporations funnel money back toward breast cancer research (King 2006). At the same time, red T-shirts, scarves, and sweatshirts sold at The Gap do not, in themselves, reduce HIV/AIDS; rather, these red product lines entice consumer-citizens through the vague promise of promoting HIV/AIDS awareness. When one makes a red purchase, one might believe that one has actually contributed to reducing HIV/AIDS worldwide while simultaneously acquiring a new hoodie.

There has been a confluence, then, of color-based marketing with "lifestyle choice" (Rose 1999), a phenomenon that intersects tidily with neoliberalism's prerogatives and the consumer citizenship habits promoted by contemporary science education. If active, consumer-citizens practice their politics in the marketplace—that is, out of concern for the environment, they select disposable paper cups rather than Styrofoam alternatives for their next tailgate party—they can also agitate for broader, non-consumptive issues like better health care and disease reduction through color-coded purchases. Statistically, one of seven U.S. women will receive a positive breast cancer diagnosis in her lifetime (King 2006). Perhaps, due to this prevalence, U.S. citizens feel compelled to issue civic "protests" on a daily basis: pink cleaning sponges, vacuum bags, cotton balls, potato chips, and so forth continue to be popular purchases.

Consumer Citizenship's Dirty Hands in Science Education

A rose by any other name, color-based marketing and the concomitant consumer citizenship it fosters appear benign. What could be wrong with buying an apparently safer, greener alternative to standard, bleach-based bathroom cleaner? Isn't it sensitive—even morally significant—to purchase a pink-labeled kitchen mixer over an unmarked one, especially if one intends to make the purchase anyway? Who could be on the side of dirtier, more polluting cleansers, or, for that matter, against more breast cancer awareness? There are observers who would argue against the medical technologies that prolong human life in the face of increasing population pressures for the Earth (Bowers 2001) or for mandated population control because they don't argue against free choice (Wilson 2002, 2006). But herein lays the crux. Precisely because color-based marketing and its attendant consumer citizenship seem to epitomize liberty and free choice, these behaviors are difficult to challenge. If consumer citizenship affords people the chance to break free from historically characteristic class, gender, or racial constraints through the purchase of self-selected lifestyle accoutrements or the illusion that one can put pressure on corporations to make products safer or better, then why abstain from it? Should the consumer citizenry be subject to scrutiny?

One factor to consider when looking at color-based marketing and its corollary, consumer citizenship, is the way in which these practices redefine civic participation. If social action takes place primarily in the shops, both civic engagement and virtuosity are limited to those who can pay. Put differently, in the realm of Consumer citizenship, people with little disposable income—those who can ill afford, say, the extra $2 per box for green tissues made with sustainably harvested wood pulp—can neither resist indiscriminate logging nor freely express their support of the cause. Correspondingly, if breast cancer research advances through pink attentiveness and purchases, then people who lack access to pink items or the requisite funds to buy them are excluded from having a say on a significant public health problem. Activists may make matters worse by living up to the social justice agenda of inadvertently promoting Consumer citizenship by working to create "equal" opportunities for consumption. These things work together to produce a powerful underpinning for neoliberalism in the schools. Consider how easy it is to stop by a McDonald's to buy a family meal rather than purchasing apparently better organic foods from Earth Fare or Trader Joe's, when the nutritional value of organics is contentious (Soloft et al. 2010). Buying organic foods is less a conversation about nutrition than it is about ascribing virtuosity and political activism to people with purchasing power.

Illuminating the ways in which the U.S. Postal Service's 1998 issue of a pink breast cancer research stamp reflects larger, neoliberal shifts in state formation and codifies Consumer citizenship and individual responsibility for breast cancer, King (2006) suggests that Consumer citizenship, in its limits, forecloses the very democracy it purports to expand. The rhetoric of consumer-based free choice and a growing array of socially inflected consumer products obscure "who," exactly, has membership in the consumer citizenry. King writes:

> [T]he creation of the breast cancer research stamp was viewed as a way of democratizing philanthropy, of giving 'all Americans' the opportunity to participate in what is popularly understood as a self-actualizing and socially productive space. Moreover, in contrast to mandatory taxes, which are widely held to quash the civic impulses of Americans and to alienate citizens both from one another and the government, voluntary leverages are seen to elicit civic participation and personalize the relationship between citizens and the state. Thus . . . [the] discourse of 'access' and 'opportunity' works to displace questions about the ability of *all* citizens to partake equally in these new forms of civic action. (p. 74)

When everyone is preoccupied with buying, few attend to evaluations of who is absent from the shops. Under the guise of increasing opportunities for social and political engagement, Consumer citizenship actually restricts civic action to those with the discretionary funds to spend on it.

In addition to delineating who can engage in social action, Consumer citizenship also circumscribes the ways in which people can do so. To the extent that individual civic acts of consumption are celebrated as the most appropriate, even normative, forms of civic participation, alternative—perhaps disruptive—types of social activism such as protesting, boycotting, or rallying are dismissed as childish and inappropriate (especially in the ways that Baby Boomers engaged in these practices during the Civil Rights Movement of the 1960s, etc.). Observers note that media representations of people participating in non-consumptive forms of political action such as teach-ins or picket lines often portray these groups as silly, ineffectual, and even dangerous (King 2006; Klein 2002). Consequently, the medium obscures the message. U.S. evening news coverage of the 2000 Seattle World Trade Organization (WTO) protests, for example, focused largely on isolated, violent acts of storefront glass breakage instead of the underlying causes of protesters' ire—not limited to the WTO's consistent failure to enforce minimum labor safety standards in manufacturing sites throughout the Global South (Klein 2002).

This "sedentarization," to use Deleuze and Guattari's (1980/1987) term, of civic engagement to the consumptive realm also has material effects. Debates over what constitutes a green product can divert attention from the larger, structural problems that create the need for green in the first place. Brosius (1999) illustrates this point well in his ethnographic work on how a colorful, star-studded campaign to bring attention to indiscriminate logging in Sarawak, Malaysia, was effectively shut down when discussions turned from indigenous peoples' human rights to metrics of green timber certification. As Brosius (op. cit.) reports, the nomadic Penan of Sarawak garnered worldwide media sympathy in the late 1980s—even visits from the likes of popular singer Sting and Prince Charles of Wales—through a grassroots, activist-led campaign to halt logging on Penan ancestral lands. By establishing human blockades in front of logging trucks and succumbing to arrest, the Penan captured numerous actors' interest and exposed, to a global audience, how rainforest destruction threatens indigenous peoples' livelihoods and alters their traditional ways of life. However, once Malaysian government officials hired international PR firms to shift the debate away from concerns about Penan land tenure to technical and economic metrics of sustainable wood harvesting—that is, what constitutes a "green dot" on a wood product—protesters' voices were silenced and logging continued.

When corporate-driven priorities dominate social events, local peoples' concerns are often muffled. In the case of the Sarawak logging campaign, corporate interest in maintaining logging practices through green timber certification supplanted Penan grassroots activism and silenced questions about the broader relations between indigenous peoples' human rights and deforestation. A focus on the greening of products, then, can mask an interrogation of whether a particular product should even be available for market-based consumption at all. This condition represents a form of commodity fetishism: a way of removing (and silencing) the often negative conditions and associations under which goods are produced. Many so-called green products might dissolve if educators aimed for the "cradle to grave" mentality of analyzing whether advertising is honest and complete, particularly within science education.

Consider the ways in which breast cancer awareness has become commodified. King (2006) sees "pink" as working in a similar, attention-diverting, vein. The contemporary swell of consumer-based civic action around breast cancer issues (i.e., shelves of pink products and a focus on individually oriented, fee-requiring philanthropy such as "Race for the Cure") obscures numerous, politically charged questions about the disease as well as the collective's responsibilities to it. These questions include an interrogation of the links between environmental pollutants and breast cancer, how and by whom breast cancer research is conducted in the Global North, and, as King poignantly notes, whether breast cancer awareness even matters, given disparities in class and race as important determinants of who lives and who dies of the disease. She states:

> The limited focus of consumer-oriented activism . . . shaped as it is by an ideology of individualism and an imperative for uncomplicated, snappy market slogans, has allowed for the emergence of a preoccupation with early detection to the virtual exclusion of other approaches to fighting the epidemic and a failure to address the barriers, financial and otherwise, to treatment. This has resulted in a situation in which uninsured women with breast cancer have more reliable access to screening but are frequently left with no means to receive treatment after diagnosis. (p. 118)

Constrained by the hegemony of pink, the consumer-citizen is actually *dis*engaged from breast cancer activism in several ways. A sparkly pink ribbon purchase might identify one as sympathetic to breast cancer awareness, but it is a limited form of social action that forecloses other, potentially more effective, modes of expressing concerns about the origins and rise of breast cancer and dissatisfaction with the nation-states' current response to it.

Moreover, the overall association of breast cancer with pink may very well *weaken* participatory democracy, as it affirms rather than challenges preexistent cleavages in the civic collective. As Ehrenreich (2001) acerbically asserts, pink and its frilly accoutrements (e.g., ribbons) not only suggest that breast cancer is strictly a women's issue but also consolidate deeply entrenched ideals of femininity. Observing that breast cancer patients often receive items such as pink teddy bears as gifts, Ehrenreich pens: "Femininity is by its nature incompatible with full adulthood—a state of arrested development. Certainly, men diagnosed with prostate cancer do not receive gifts of Matchbox cars" (p. 46). Active civic participation is associated with full adulthood. Given the late entry of both women and African-Americans into full legal participation in U.S. society, the corporate breast cancer awareness movement's link between pink and an infantilized, pre-suffrage female is not one to be taken lightly.

Under the guises of greater freedom and wider choice, then, Consumer citizenship and its bedfellow, color-based marketing, actually narrow peoples' opportunities for participating in and actively constructing the broader social world in which they live. Because lively engagement in a consumer citizenry is contingent upon personal, self-financed acts of consumption rather than on *esprit de corps*, consumer-citizens' foci is on their wallets, products, and people-as-products rather than on broader questions such as why particular social problems exist in the first place and what the role of larger, collective entities is in solving them. Although a dizzying array of color-coded goods in the marketplace might suggest infinite possibilities for self-shaping and political action, Berger (1972) explains that choices *among products* are really not choices at all:

> Every publicity image confirms and enhances every other. Publicity is not merely an assembly of competing messages: it is a language in itself which is always being used to make the same general proposal. Within publicity, choices are offered between this cream and that cream, that car and this car, but publicity as a system only makes a single proposal. It proposes to each of us that we transform ourselves, or our lives, by buying something more. This more, it proposes, will make us in some way richer—even though we will be poorer by having spent our money. (p. 131)

A panoply of consumer options, Berger suggests, actually reflects a diminishment of choice and political agency. To choose between a two-by-four bearing a green dot and an uncertified lumber piece does little to address the wider, transnational problems that rainforest destruction ultimately creates. Issues such as global climate change, increased geopolitical instability between the Global North and Global South, or rapid species extinction cannot be addressed by the marketplace alone. People who vote exclusively with their pocketbooks are, in the end, not voting at all.

Equally or more importantly, Consumer citizenship—indeed, neoliberalism in general—allows certain, usually privileged, individuals and groups to disavow their responsibility for and investment in the protracted vulnerability of certain groups and natural systems worldwide. Preoccupied with constructing their own lifestyles through color-coded purchases, consumer-citizens need not address the more unsavory sides of the global capitalist network in which they participate. So it is that exploitative labor practices, ecological degradation, and the myth that some people are disposable (Wright 2006), among other consequences of what economic geographers call the globalization tendencies of late modernity (Dicken 2003), remain perpetually outside consumer-citizens' fields of vision. In fact, as Butcher (2003) observes, the grand narrative of globalization actually encourages a sense of impotence among individual people about their personal role in the global economic grid and their ability to affect change upon it. He explains:

> Globalization is often invoked to emphasize the interconnected nature of society—we are all bound together through the market. But globalization often carries the underlying implication that the market is beyond human intervention. Hence whilst we are encouraged

> to see ourselves as ethical in our role as consumers, the basis on which we consume, the power relationships between nations and between social classes, appears beyond us. (p. 107)

Facing an economic globalization juggernaut that seems to possess agency and a will of its own, consumer-citizens may feel powerless. Color-coded purchases, at least, offer people the appearance and suggestion of taking some personal responsibility.

A final reason for looking more cautiously at Consumer citizenship and color-based marketing is that these practices reconstitute the nation-state in a very specific way. By furthering and reinforcing neoliberal interests, consumer-based citizenship practices naturalize and reaffirm the idea that good governance is measured primarily by *market growth.* Other, arguably more social justice-oriented, metrics of institutional efficacy such as whether a nation-state's government reduces (or contributes to) social and economic inequality, furthers (or erodes) geopolitical stability, and aids (or hinders) lively community building are swamped by the market mantra. As Hamilton (2004) observes, under contemporary political conditions in which the primary role of the nation-state has shifted from providing social services to greasing economic engines at multiple scales, "[H]uman beings have become 'consumers' and human desire has been defined in terms of goods; it follows that the only way to make people happier is to provide more goods. In other words, the objective [of government] is growth" (p. 8). This logic fosters a climate in which a nation-state's obligations to its constituency begin and end with an expansive marketplace. In other words, if Christmas shopping is up and economic growth rates are higher than the previous year, a government is said to be doing well by society.

The limitations of the equation "economic growth equals good government" are fairly obvious. In the main, this perspective absolves governments of responsibility for preserving or supporting natural systems, building community *joie de vivre*, or taking care of its weakest members, among other utilitarian considerations of what helps to constitute the "good life" for the greatest number of people in any country or what promotes the prospects of the future. Despite the illusory promises of endless economic/fiscal growth, scholars have demonstrated repeatedly that increased capital accumulation does not necessarily equal more happiness, an improved quality of life, or greater security, either for individuals or communities (Folbre 2001; Hamilton 2004).

In the end, the role of a representative or delegated government is to respond to and represent the interests of its citizens. The commonwealth may be doing itself a disservice by maintaining its enthusiasm for consumer-based citizenship. Unwittingly, consumer-citizens may be helping to develop an infrastructure in which public institutions work mainly to augment and safeguard peoples' shopping experiences rather than their present or future health and happiness.

Ironically, schools are places where the norms of Consumer citizenship may best be challenged. However, citizenship education in schools is often restricted to the traditional venues of social studies and civics classes; it is not included as part of science education. We now shift our discussion toward the ways in which critical civic literacy education might be more fully integrated throughout the curriculum.

Critical Civic Literacy Within Science Education

According to Cook-Gumperz (2006), "[L]iteracy is usually taken to refer not only to the ability to understand written and printed inscriptions, but also to the socio-cognitive changes that result from being literate, and from having a literate population" (p. 21). Literacy, then, operates as a social formation—one that alters people and culture, often in historically contingent, highly ideological, ways. In the seventeenth and eighteenth centuries, literacy in the U.S. was non-standardized. People used oral and written literacy traditions for various purposes, including entertainment, education, and to challenge dominant political ideals. Consequently, apologists for the status quo of the time often feared widespread literacy and actively prohibited its spread (think Frederick Douglass). However, once *schooled literacy*, or standardized literacy practices, became institutionalized as part of public schooling in the nineteenth century, literacy became a means of strict social control—one necessary for acculturating a compliant industrial workforce and a way of demarcating virtuous citizens from the less so (Cook-Gumperz 2006). That is, as literacy became increasingly defined as the first of the two 3 R's—oral recitation and rote copying rather than a flexible, social repertoire of fluid skills one might use for self-determined purposes—it was illiteracy, not literacy, that came to be viewed as a looming social danger.

The role of literacy continues to be contested today. While academics have issued calls for recognizing a plurality of literacies including, but not limited to, multimodal literacy (Gee 1991; Street 1984), community-based literacy events (Heath 1983), media literacy (Hobbs 2007), and even Hiphop literacies (Richardson 2006), there has been a federally supported rise in a "unitary account" of literacy (Collins and Blot 2003). This is a version of literacy in which drill-based phonics are the norm, discrete skills are stressed, and reading and writing are often taught through glossy, commercial, prescriptive literacy kits (Larson 2007). The unitary account of literacy is put forth by "pedagogical fundamentalists . . . who argue that in essence reading and writing are matters of decoding and encoding language in a text" (Collins and Blot 2003, p. 173). Similar to how nineteenth-century schooled literacy was disproportionately the province of the poor and used to maintain social control, the contemporary unitary account of literacy (wrapped in the cloak of making schools "accountable") is used disproportionately in under-resourced classrooms. It operates as a means of teaching economically vulnerable (often minority) students lessons in rote compliance rather than critical thinking (Cook-Gumperz 2006).

Advocates of *critical literacy*, however, are engaged in an ideological struggle to take literacy back as a tool of social critique and personal freedom. The critical literacy perspective is concerned primarily with political empowerment, social engagement, and political agency. As Dozier et al. (2006) put it,

> Critical literacy means developing a sense that literacy is for taking social action, an awareness of how people use literacy for their own ends, and a sense of agency with respect to one's own literacy. . . . Critical literacy also requires . . . understanding the ways in which that tool [literacy] works—for example, how language is organized to reproduce race, class, and gender roles. (pp. 18–19)

From a critical perspective, literacy is about using the tools of print, text, and semiotic signs to critique and re-make the world (cf. Friere 1970/2003). Expanding upon Dozier et al.'s notions of critical literacy, then, we define *critical civic literacy education within science education* as a politically engaged, socially active practice in which people use literacy skills to analyze the meanings of their own lives in relation to society and as a way to interrogate dominant notions of public life and active citizenship. Critical civic literacy education prepares students to strategically attend to the social and linguistic foundations that frame them in particular ways, for example, as shoppers.

Within a critical civic literacy perspective, then, people can use literacy skills to interrogate apparatuses such as color-based marketing schemes that demand little more of them than that they make color-coded purchases, for example, if they are concerned about the environment. A science classroom exercise in critical civic literacy education might entail examining advertisements depicting green and pink purchases and the ways in which such images and print copy bespeak particular ethical and ecological commitments. In reference to the aforementioned Deer Park water bottle, for example, students might be asked to question whether its "smaller cap" makes it green, when the bottle of the product itself is considerably wasteful. Alternately, students might be asked to read and analyze their school's mission statement and course descriptions, looking for embedded assumptions of consumer-based citizenship (e.g., foreign language courses often cite "useful for global business" as the main reason to learn Spanish or French, while school mission statements often stress the importance of creating "global entrepreneurs"). While schools certainly offer one venue for analyzing unnoticed and unchecked assumptions of Consumer citizenship, the larger educational domains of neighborhoods, grocery stores, and shopping malls may also serve as outlets of systematic influence where the unquestioned assumptions of consumerism could be examined.

In an age in which the reverberations of neoliberal policies are often felt in U.S. schools, critical civic literacy education in science education may be more important than ever: it is an issue of equity. Government divestments from U.S. education in the last few decades have often left certain (usually cash-strapped and urban) schools with little choice but to adopt corporate-donated books and curricula, particularly in content area classes like science. These materials often naturalize corporate-friendly versions of the world as well as consumer-based citizenship. To illustrate, Karliner (1997) writes that "The American Coal Foundation provides a [free] curriculum that makes no mention of acid rain or global warming, but rather helps students 'identify the reasons coal is a good fuel choice'" (p. 187). Further, he notes that Exxon is

> rewriting the history of the Valdez oil spill for an audience of the nation's impressionable youth. While an Alaska jury was awarding 10,000 fisherfolk, 4,000 Native Alaskans and another 20,000 plaintiffs more than $5 billion in damages from Exxon, the company was distributing, free of charge, its version of the truth to 10,000 elementary school teachers, for viewing by kids who were too young to remember the devastating oil spill in Prince William Sound. While the jury determined that the spill had destroyed much of the plaintiffs' livelihood, damaging fishing and native hunting grounds, the Exxon video—which is filled with shots of stoic scientists cleaning cute, furry marine mammals—told a new generation of potential environmentalists and soon-to-be consumers that the spill did not decimate wildlife in Prince William Sound. (pp. 186–187)

Multinational corporations' donations of books, videos, and other curriculum materials to under-resourced U.S. schools, then, can neutralize particular social events and redirect peoples' responses to them. Given that under-resourced schools may have a pragmatic need to accept corporate-donated materials, the students in these schools are more inundated with corporations' versions of social events and their implicit calls to consumer-based citizenship than are the students of well-heeled institutions. In the end, critical civic literacy education (or lack of it) is a social justice issue akin to scientific literacy. Students who come from wealthier homes and social classes in which critical civic literacy education is taught explicitly or as part of a community's norms will learn multiple ways of exercising political agency. Other students—those youth whose schools are cash-poor—are more likely to rely on corporate-donated curriculum materials and may learn about public life through messages marketed by the likes of Exxon.

Alternatives to Consumer Citizenship: Life Beyond the Shops

A rising call for alternatives to Consumer citizenship can be heard coming from educators and activists alike. Among them is Noddings (2005), who champions a version of civic engagement that we term here *global-environmental citizenship*. Broadly, this version of citizenship aims beyond the neoliberal agendas of nation-states, moving instead toward a global society in which all beings—people, plants, and animals—are equally connected through and similarly situated in biotic networks. As members of a global-environmental citizenry, people are just one of many living things, and their civic loyalties and obligations are to the larger, single, environmental community in which they live. Citizenry and political action in a global-environmental citizenry are enacted not through the singing of national anthems or the purchase of green products but by protecting the environment or larger ecosystems, finding pleasure in connecting with nature, and living sustainably—and peacefully—within one's means.

Spring (2004) observes that a global-environmental citizenship is radical in that it not only challenges traditional notions of the nation-state but also displaces "civics" with environmental and science education. Educating students in a global-environmental citizenship paradigm requires teaching them not about war victories or how to generate wealth on Wall Street, but rather how to derive pleasure from nature, to recognize their diminutive yet powerful roles in the biosphere, and how to be environmental stewards. While the Consumer citizenship ideal measures the quality of lives through material resources, cars, "bling," and one's possession of correctly colored products, a global-environmental citizenship ethic defines the metrics of a well-lived life as the extent to which individual people live in harmony with their surroundings, others, and the idea that perhaps less is always more.

Another alternative to Consumer citizenship, what we call here *locally based citizenship*, draws upon the works of scholars such as Berry (1990) and Orr (2004). Locally based citizenship calls for active engagement with and intimate knowledge of one's local, immediate community: its people, its land, its animals, and plant species. Advocates for locally based citizenship view "the global" as a scale beyond reach or understanding—something outside the purview of individual action. Instead, locally based citizenship practices are tailored to the climate, temperament, and history of particular places. Where locally based citizenship differs from global-environmental citizenship is in reminding us to attend not to the global biotic community but to our immediate surroundings. Locally based citizenship advocates argue that problem-solving and civic action become more fully manageable viewed from a local, rather than global, perspective.

Another benefit of locally based citizenship is that it might offer people a way to express and feel agency in the face of a seemingly homogenizing globalization. Locally based citizenship, Klein (2002) suggests, increases overall diversity: cultural, ecological, and political. Given that Consumer citizenship thrives on the flattening of thinking—for example, "Everybody Go Green!"—a locally based citizenship alternative means that, in the end, perhaps people may not have to sacrifice thinking for consuming.

Implications for Science Education Policy

In this chapter, we have highlighted the ways in which the rationalities of neoliberalism produce and maintain Consumer citizenship as a dominant form of civic participation in the U.S. We have argued that color-based marketing practices such as green and pink further one-track, consumer-based citizenry by conflating political action with individually oriented consumption. We have cautioned that these practices of Consumer citizenship foreclose some other, perhaps more inclusive and transformative, means of public engagement. With a nod to literacy studies, we have suggested that Consumer citizenship might be challenged by robust critical civic literacy education measures in science education. Careful to note how literacy has been historically tied to various ideologies, we have cautioned that critical civic literacy education, too, risks being inequitably distributed among attendees of inequitably resourced schools. We have connected with other educational writers to recommend alternatives to consumer-based citizenship, broadly categorized here as global-environmental and locally based citizenship.

In closing and through the consideration of three key questions, we suggest some implications of our work for educational policy. For one, to what extent do current standards-based curricula naturalize neoliberalism and its attendant Consumer citizenship practices? If an overarching aim of U.S. public education is to create a democratic, participatory citizenry (Gutmann 1987), schools' (even inadvertent) strengthening of Consumer citizenship habits among youth may serve as a negative counterweight to that goal. Students who believe that civic engagement begins and ends with a green or otherwise correctly colored purchase are, ultimately, distanced and disengaged from public life.

Second, how and in what ways does the contemporary focus on singular metrics of educational efficacy, such as annual yearly progress (AYP) in discrete subjects such as science, obscure other measures of educational achievement including, but not limited to, students' abilities to apply critical civic literacy skills in various contexts? For students to meet standards on their respective states' high-stakes science tests, for example, yet fail to notice (or protest) the daily use of disposable, Styrofoam lunch trays in their school cafeterias belies a lack of science "achievement" as well as critical civic literacy. Educational policymakers would do well to attend to the ways in which AYP does or does not provide information on the way content knowledge is applied in real life or toward the greater social good, rather than just reproduced for testing purposes.

Third, and perhaps most importantly, to what extent are critical civic literacy skills—or alternative modes of citizenship—being taught with parity to all students across different schools? Similar to how organically, locally produced food is most often available to people of high socioeconomic status, affording already-privileged people increased amounts of cultural (and health) capital as they make socially conscious food choices, the ability to choose among various citizenship practices and put them toward social ends may be a skill offered to only a privileged few.

Imagine where this type of critical civic literacy in science education will be implemented first or is already happening (Hodson 2011). Typically, students in high-performing schools learn multiple means of engaging in public life (e.g., attending political events, researching the political process, consuming various public news sources, and critiquing them), while students in low-performing schools may only receive reductive instruction in "the basics." This process not only leaves normative ideas of consumer-based citizenship largely intact (Spring 2004) but also denies certain groups political traction. Inequitably distributed critical civic literacy education, then, can result in a tragic situation: People who lack the know-how to politically advocate for themselves come to have their vulnerabilities blamed on a perceived lack of political self-interest. It is time for educational policy to attend to issues of civic literacy—if not now, then when?

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Chapter 5
Fostering Independence: Assessing Student Development

Danielle V. Dennis

A few months ago, I was eating lunch at an outdoor restaurant overlooking the Gulf of Mexico. Below the deck where I was sitting, a child was fishing from the bow of a boat. As I watched the child, I realized how much knowledge he displayed about fishing and the Gulf. He knew how to line the fishing rod, bait his hook, troll along the boat to attract the fish, operate the rod and reel once he caught a fish, identify the fish (before it breached the surface!), recognize that the fish did not meet size and weight requirements, and gently detach the hook to release the fish safely back into the water. Further, the child was completely engaged in this activity for no less than 30 minutes, breaking his concentration only long enough to exclaim to his parents, "It's a grouper!" At that point, I turned to his parents and asked how he knew so much about fishing and how he was able to engage in the practice independently. I was not surprised to learn that the family fished together almost every weekend, over school breaks, and during the summer. The father explained that he began using the technical vocabulary with his sons from a very early age, spent time describing the similarities and differences between fish species and their habitats, and allowed his sons opportunities to succeed and fail during their numerous fishing adventures.

I was, however, surprised to learn that this child was retained in third grade. Florida law requires that students who do not score proficient on the reading portion of the third grade Florida Comprehensive Assessment Test (FCAT) be retained in grade. Shaking his head, the child's father said, "It still doesn't make sense to me. Kyle devours every magazine we have on fishing, and he can tell me everything he reads in those magazines." The parents went on to explain that teachers' comments often portray a very different child than the son who was catching grouper a few feet away, one who is disengaged in the classroom.

As educators and teacher educators, we have a responsibility to ensure that our students leave with the ability to problem solve, observe, create, and participate as

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citizens in a democratic society. Although the current educational context largely denies students these opportunities, this chapter offers suggestions for stakeholders to provide equal opportunity for students to see the world through a lens that magnifies beyond school walls. I first discuss research on students' myriad abilities as measured by multiple assessments and explain how those abilities are lost in a high-stakes testing environment. Then, I address the current landscape of high-stakes assessment and the resulting consequences of underlying accountability processes. I offer examples of the possible marriage between accountability and meaningful indicators of student as citizen and address our responsibility as educational stakeholders to be accountable for Generation R and choices that we make between viewing these students as a single test score—or as responsible members of our democratic society.

(Dis)Ability: Focusing on What Students Bring to Classrooms

Since No Child Left Behind (NCLB) was authorized in 2001, schools have been under pressure to demonstrate student learning through high-stakes standardized assessments in math and reading in grades 3–12, with additional assessments in science in grades 5 and 8 and, in some states, grades 3 and 11. Despite scores on standardized assessments representing only a snapshot of students' learning during the school year, decisions about student ability, teacher effectiveness, and school impact are made using the results. An unintended consequence of this situation is that classroom practice has focused largely on direct instruction of the skills addressed on these assessments (Linn 2000). Yet, for many policymakers, the US achievement gaps persist and students are not scoring statistically higher on most standardized assessments than they were when NCLB began.

Based on high-stakes standardized assessment scores, as many as 25 % of K-12 students are identified as struggling readers, fueling a crisis-based discourse. This discourse influences federal and state policies that increase the time spent on instruction of discrete reading skills, such as phonics and phonemic awareness (Pressley and Allington 1999). Yet, research examining the literacy abilities of students who earn below proficient scores on high-stakes standardized assessment demonstrates that these students enter our classrooms with varying abilities (Dennis 2009).

Let's look at four sixth-grade students in the same classroom—Shenea, Paul, Enrique, and Jacob. Presume that each of these students scored below proficiency on the state standardized assessment in reading, and each was subsequently placed in a remedial reading class focusing on decoding and phonics skills. A deeper analysis of formative assessments indicates that each student brings operational knowledge to the classroom, though each has strengths in different areas. Paul's reading level is only slightly below grade level on both narrative and informational text. He has a strong command of phonics and good word-analysis skills but needs support building his vocabulary and comprehension. Shenea also has a strong command of phonics and word analysis but has difficulty with content vocabulary and comprehension.

Similar to Paul, she needs support reading and creating content-area text. However, Shenea reads text two grade levels lower than Paul and will need access to texts that match her instructional reading level and support her ability to build knowledge of both reading and content. Enrique decodes rapidly but reads at a level well below grade level. There is a discrepancy between his comprehension of narrative and informational text, with narrative text comprehension being his strength. However, Enrique comprehends text provided at an appropriate level with teacher support. Jacob is the only student in the group who will benefit much from support decoding unknown words, as he has difficulty with phonics and word analysis, as well as with comprehension.

All too often, these four students will be asked to complete literacy-related science tasks in school, which include reading the science text, completing a brief experiment, and responding to questions about the reading and experience. Although these students can comprehend science content, using science texts that are adopted by school districts—which are often written two or more grade levels above that in which they are used (Chall and Conrad 1990). But using adopted science texts will make the task too difficult for these students. Further, suggesting that their scores on standardized science assessments—which are as much tests of reading abilities as they are of science content—represent their aptitude in science dismisses what we should be learning about our students' abilities from assessments. All four students are capable of engaging in authentic science content learning, but generally speaking, the instruction, the texts, and the assessments provided to these students should match their reading abilities.

Time focused on rote instruction of skills is time taken away from learning opportunities in areas such as science. It is time taken from connecting scientific explorations with text and creating text based on new understanding of scientific content. In other words, it is time taken away from authentic learning experiences that connect students to real-world phenomena, giving them choice in their learning, providing time to question, and allowing for participation in a democratic classroom. Instead of focusing on what students know and are able to do—like Kyle's deep knowledge of fishing—the current educational climate addresses only students' inability to proficiently respond to answers on a test, rather than focus on inquiry and curriculum innovations.

Florida: Race to Uniformity

Currently, Race to the Top exemplifies the federal educational agenda in the United States (USA). Following the second round of proposals, the US Department of Education awarded a Race to the Top (RttT) grant to the state of Florida. Florida's proposal focused on six strategies: (1) Standards and Assessment, (2) Data Systems to Support Instruction, (3) Great Teachers and Leaders: Professional Development, (4) Great Teachers and Leaders: Effectiveness, (5) Great Teachers and Leaders: Equitable Distribution Across Schools, and (6) Turning Around the

Lowest Performing Schools. Each of these strategies is connected to evaluation and measurement based on standardized assessment results, with the general assertion being that by increasing standards and measuring success on those standards, teachers and schools will become more effective and gaps in achievement will disappear. Each teacher will be evaluated on how well their students perform on each subject-specific standardized assessment (i.e., reading, math, science, etc.), and their pay and employment status will be based primarily on these scores. The goal of the Race to the Top is to make students in the USA globally competitive.

PISA: "A Wake-Up Call"

Following the release of the 2009 Programme for International Student Assessment (PISA) scores, Secretary of Education Arne Duncan (2010) posted a notice on his Facebook page, "We have to see today's PISA results as a wake-up call. The U.S. came in 23rd or 24th in most subjects. We can quibble, or we can face the brutal truth that other high-achieving nations are both out-educating us and out-competing us." An obvious question is *what exactly are we waking up to*? It seems that those mandating specific curricular materials and increased testing continue hitting the snooze bar on the alarm clock. At some point, they must realize students do not learn by one mode of instruction, but instead need opportunities to question and explore. Learning involves much more than what is measured on a test—it is an integrated process facilitated by teachers who support the local context and student inquiry.

OECD (2010) released the PISA scores in a volume focused on describing the tasks and skills required of students. It is clear from their definition of *scientific literacy* that the OECD views science as a process that shapes students' knowledge and that their ability to achieve on the assessment is based more on their awareness of this process than their memorization of specific (and usually decontextualized) scientific facts. In other words, the underlying assessment paradigms are both reductionist and ineffective.

> PISA defines scientific literacy as an individual's scientific knowledge, and use of that knowledge, to identify questions, acquire new knowledge, explain scientific phenomena and draw evidence-based conclusions about science-related issues; their understanding of the characteristic features of science as a form of human knowledge and enquiry; their awareness of how science and technology shape our material, intellectual and cultural environments; and their willingness to engage in science-related issues, and with the ideas of science, as a reflective citizen. (OECD 2010, p. 137)

Students in the USA earned scores that were statistically similar to the OECD average, but based on the rhetoric presented by Secretary Duncan, the public is led to believe that we are underachieving. Yes, other countries score significantly higher than the USA on this international assessment—but US students continue to demonstrate their ability to use scientific knowledge. Students in the USA scored an average of 502 points, which places them in Level 4 of a possible 6 levels. According to OECD,

> At level 4, students can work effectively with situations and issues that may involve explicit phenomena requiring them to make inferences about the role of science or technology. They can select and integrate explanations from different disciplines of science or technology and link those explanations directly to aspects of life situations. Students at this level can reflect on their actions and they can communicate decisions using scientific knowledge and evidence. (p. 147)

Students in countries that score at Levels 5 and 6 demonstrate the ability to use inquiry as a means for "developing solutions…to unfamiliar scientific knowledge… on a *local*, *social*, or *global* level" (original emphasis, p. 147). In other words, students performing at levels higher than the average student in the USA are doing so in areas that require opportunities to ask questions about scientific phenomena, use their knowledge of the world to solve problems, seek guidance through multiple resources, evaluate and revise decisions, and authentically portray their solutions. These are skills that must be learned through practice in real-life situations, rather than through a textbook aligned with the requirements of the mandated state assessment. Thus, we must take instruction beyond the desire to pass the test.

Minnesota: The Way We Were

From 1998 to 2001, I worked as a Science/Environmental Education Specialist at an elementary school in Duluth, Minnesota. The school was dedicated to its environmental theme, and each grade level (K-5) spent the year developing, planning, and conducting a service-learning project related to the local environment. The students were engaged in the process from the first day and, with the guidance of classroom teachers, chose the question they would research throughout the year in order to complete the project. My job was to provide the needed science content to support their learning and to do so in integrated, hands-on ways. We were fortunate to have several acres of land with trails, a creek, and woods that nicely demonstrated the forest's succession. The projects followed a developmental progression across grade levels, starting with a focus on the schoolyard in Kindergarten. The projects moved towards the neighborhood in third grade and incorporated a global context in fifth grade. This progression allowed students to experience their world from a unique, developmentally appropriate lens.

For example, during the 1998–1999 school year, the fourth-grade students focused on the St. Louis River, which flows through Duluth as the largest tributary to Lake Superior. Although many of the students had never visited the river, it bordered the neighborhoods served by the school. For years, sanitation and wastewater treatment facilities released effluents into the river, causing substantial environmental impacts. The Environmental Protection Agency and the Citizen Action Committee developed a Remedial Action Plan (RAP) for the river and habitats supported by the river in the Duluth area. The students spent the first part of the year learning about the river and its role in the local area. They read about the river, wrote about the river, learned scientific concepts about the river, applied mathematical knowledge to better understand the size and impact of the river, and learned about historical uses of the river. One Monday, a student walked into a fourth-grade classroom and asked where the drains at the end of driveways led to, “Ms. Dennis, where does the water go when my dad washes his car?”

The next week, an educational partner from the Western Lake Superior Sanitary District visited the class to show diagrams of the city’s wastewater process. She allowed students to trace the path to the river. It was at this point that the kids determined their area of inquiry—what was the impact of households on the river? From there, we worked with the students to create surveys for their parents and neighbors, we contacted the Coast Guard to give us a tour of the river on one of their vessels, and we compiled data to better understand our impacts on the habitats supported by the river. At the end of the year, the students decided that their service-learning project would be to paint signs on all of the neighborhood wastewater drains that read, “Do Not Dump, Flows to River.”

Dennis (2000) determined the impact of the environmental theme on students’ academic progress by comparing progress of students in the environmental theme school to that of students from a school with nearly identical demographics (i.e., serving the same neighborhoods as the environmental theme school). Students at the environmental theme school had significantly higher growth over time on standardized science assessments, and students receiving special education services demonstrated growth nearly five times larger than matched pairs (Dennis 2000). Students at the environmental theme school initially earned lower scores on the standardized science assessment in grade 3, but their growth over time was significantly greater than the growth of students at the comparison school, and by fifth grade the students’ scores at the environmental theme school surpassed those at the comparison school on the assessment.

The approach to the elementary curriculum at the elementary school in Duluth occurred before the authorization of NCLB. At that time, there was less emphasis on standardized assessments and greater support for an integrated curriculum. Teachers at each grade level were not held accountable for their students’ scores on the mandated assessment, so growth over time was a more acceptable outcome. Although this is an isolated example of the impact of student-led, teacher-supported, integrated education, it demonstrates the impact of environmental problem solving and decision making, as the students became responsible citizens and demonstrated gains on standardized assessments.

Capitalizing on Kyle’s Knowledge: How Teachers Can Support Generation R

Let’s think back to Kyle’s knowledge and expertise. Kyle, an avid fisherman and recreational reader, is currently unsuccessful in an academic context. However, his classroom teacher may choose to capitalize on his understandings to develop meaningful and purposeful instruction. What might this instruction look like? How might the classroom teacher facilitate authentic learning experiences and engage Kyle as a citizen in a democratic society?

In 2009, angler laws changed in the state of Florida due to overfishing of grouper. Scientists discovered that although the grouper population was relatively healthy, the rate of harvest was unsustainable given current fishing law. The law reduced the total number and size of fish anglers could keep year-round and nearly eliminated catch during spawning season (February–March). An integrated curriculum, supportive of Kyle's knowledge and expertise, could address this social and environmental issue and allow Kyle to explore scientific concepts related to the laws.

In this scenario, Kyle could read newspaper and magazine articles relating to the laws, as well as science texts about fish, ecosystems, and sustainable fishing. All of these texts should be available at Kyle's independent or instructional reading level and may require support from Kyle's teacher. The teacher, understanding the plethora of information available on the topic, could select several possible texts and provide Kyle with *managed choices* (Allington and Johnston 2002). Managed choice allows students to select from a wide array of appropriate materials on a specific topic and extends beyond classroom textbooks to trade and web-based materials. The teacher supports students by selecting a variety of materials but allows the student to choose the materials that best meet his individual needs. Such selection requires Kyle to understand a variety of text genres, how to negotiate those genres, how to comprehend and use the vocabulary, and how to evaluate the tools for quality.

Once Kyle reads the various materials, develops questions pertaining to the content, and selects the topics that best represent his area(s) of interest, he may decide to create a video to represent his findings. The video could include graphic representations of the fish, the ecosystems, and overfishing regulations. The graphic representation of the fish supports and demonstrates Kyle's knowledge of measurement and estimation, as well as his understanding of the cyclical nature of living organisms; his representations of the ecosystems and regulations demonstrates his knowledge of the need for protection of living organisms, as well as his understanding of geographic areas impacted by the laws—all of which are requirements of the Sunshine State Standards in Florida. The video also could require Kyle to write, rehearse, and edit a script that supports the graphics he creates. Kyle then would need to organize the material logically so that he scaffolds the knowledge of novice and expert anglers alike. In developing a script that supports the video, Kyle would meet the Sunshine State Standards in composition and support his reading fluency and comprehension (Scheckelhoff et al. 2010). Each of the standards can be assessed using a rubric, conferencing, or through measures such as anecdotal records.

Kyle then could share his video with authentic audiences, including his peers, local fishing groups, and legislators. Because the video is transportable and does not require Kyle's presence—since his *voice* is represented throughout—the archive can be sent to local and national groups via web-based pathways. Kyle could choose to reply to his audience via blogs, comment features, or with video snapshots. Evidence of Kyle's mastery of the Sunshine State Standards would be evidenced through both the process and the products; such mastery would be indicative of real-world application, which is also called for but often overlooked in the standards.

Further, Guthrie and Humenick (2004) report that providing students with choice and interesting texts influences student motivation. Engagement in science content also is influenced by an alignment with interesting texts that support scientific concepts learned through practice (Guthrie and Davis 2003). Most importantly, Kyle would use his own interest and knowledge to scaffold his development of skills and strategies that he will be able to use throughout his life: these types of classrooms are where students have a participatory voice in their own assessment.

Tying It All Together

Sir Kenneth Robinson (RSA Animate 2010) describes a factory-line mentality that is currently pervasive in education. He argues that we are currently educating our kids in batches as though they are on a conveyor belt in an assembly line: only those who meet product standards are passed on, while the others are removed from production. In this model, there is little room for realizing the potential not addressed through standardized assessments. In the current NCLB and Race to the Top accountability schemes, advanced growth models are celebrated and recognizing student growth vis-à-vis problem solving and collaboration is not discussed, because such factors are more difficult to ascertain. Further, these schemes promote a narrow view of achievement, which condemns the economic, cultural, psychological, and difference factors implicated throughout this chapter.

Yet, results on international assessments such as PISA demonstrate that our current educational paradigms do not support a goal of our students being competitive in a global market. The results suggest that US students are not growing as a result of rote instruction of discrete skills and increased assessment. Instead of racing to the top, we remain among average OECD nations. Finland, consistently one of the top nations on international education assessments, celebrates aesthetic education: Finland educators favor the idea that students should have opportunities to explore the natural world and the arts and that students need opportunities to participate in the development of their education. Finland supports the growth of Generation R—students who are invested, not only in their education but in their local, social, and global context. Perhaps as we Race to the Top, we should develop a deeper understanding of what occurs at the top and strive to develop the whole child. Kyle, and many other students like him, would be much better served by an educational system that supports student abilities through authentic learning experiences that guided their development in a responsible society.

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Chapter 6
Assessing Interdependent Responsibility

Molly Ware and Rosalie Romano

Love, death, the cruelty of power, and time's curve past the stars are what children want to look at. (Carol Bly from Letters from the Country)

A human being is part of the whole called by us universe, a part limited in time and space. We experience ourselves, our thoughts and feelings as something separate from the rest. A kind of optical delusion of consciousness. This delusion is a kind of prison for us, restricting us to our personal desires and to affection for a few persons nearest to us. Our task must be to free ourselves from the prison by widening our circle of compassion to embrace all living creatures and the whole of nature in its beauty. The true value of a human being is determined by the measure and the sense in which they have obtained liberation from the self. We shall require a substantially new manner of thinking if humanity is to survive. (Albert Einstein, 1954)

We may become powerful by knowledge, but we attain fullness by sympathy. The highest education is that which does not merely give us information but makes our life in harmony with all existence. (Tagore)

Introduction

> It will take big, creative imaginations for us to evolve to the next step. Imagination is not fed by fear, but by beauty. (Lappe 2009)

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Education has the potential to engage youth and make space for them to step into their power[1] as they experience and critically consider themselves part of the wider world, live in ways that reflect this connection, and envision beyond the immediacy of their lives at the moment. As educators constantly seeking ways of facilitating this sort of learning, we are committed to working with youth to make sense of their world and to co-create awareness and understanding that fosters robust responsiveness and sense of responsibility to community, world, planet, one another, and one self.

This has become particularly challenging and critical in an environment where schools are subject to mandates and pressures that reflect the influences of business principles and capitalism. School reform discourse is recently directed and influenced by top-down managerial or business motives that push students in our nation's public schools to be more responsible by evaluating what is learned or not using narrow measures for which teachers are held responsible. Policy makers have created education policies and assessment measures based on a sense of responsibility as accountability. However, the trends we are observing in our work with students point to the serious consequences of such a narrow, outcome-focused model of education. Are we reproducing a cultural, environmental, and economic dead-end for youth and ourselves through thinking that teacher-insured responsibility to achievement on tests ensures the health and well-being of society for generations to come?

We believe that accountability mandates actually lead youth away from the type of responsibility that leads to a responsive and engaged population in interconnected worlds. Instead, youth are engaging in a system of education that narrowly defines learning as reflected on standardized tests. Such teaching creates an invisible framework of "learning" as clearly defined ahead of time and constructed by experts for their consumption, setting up youth to expect authority to tell them whether or not they are responsible.

We need a more evolved, organic sense of responsibility to be integral to our learning with youth in education – one that makes space for youth to experience learning from the inside out and from the outside in; to experience their capacity to imagine, innovate, and create in context; and to produce knowledge and understandings that they use in transforming themselves in the world. This sort of responsibility necessitates a definition of learning as "a matter of transformations in the learner that are simultaneously physical and behavioral—which is to say, in biological terms, *structural*. Learning is certainly conditioned by particular experiences, but it is 'due to the learner's own complex biological-and-experiential structure, *not an external stimulus*'" (Davis and Sumara 2006, pp. 12–13, emphasis added). What might this sort of responsibility look like and how can we measure this sort of learning and responsibility in schools?

In this chapter, we explore the answer to this question as we look at three types of responsibilities for Generation R youth that education could foster. We explore how well these types of responsibilities lead to learning (structural transformations) that will engage and empower youth. Drawing on voices of participants (teachers, teacher-candidates, and seventh-grade students) involved in a service-learning experience, we explore the consequences of an education that fosters each of these three types of responsibilities – dependent responsibility, independent responsibility, and interdependent responsibility. We emphasize specifically the potential of an education that fosters *interdependent responsibility*. In considering the nature of learning in an education for these responsibilities, we also consider the role of assessment and explore how we might assess for interdependent responsibility.

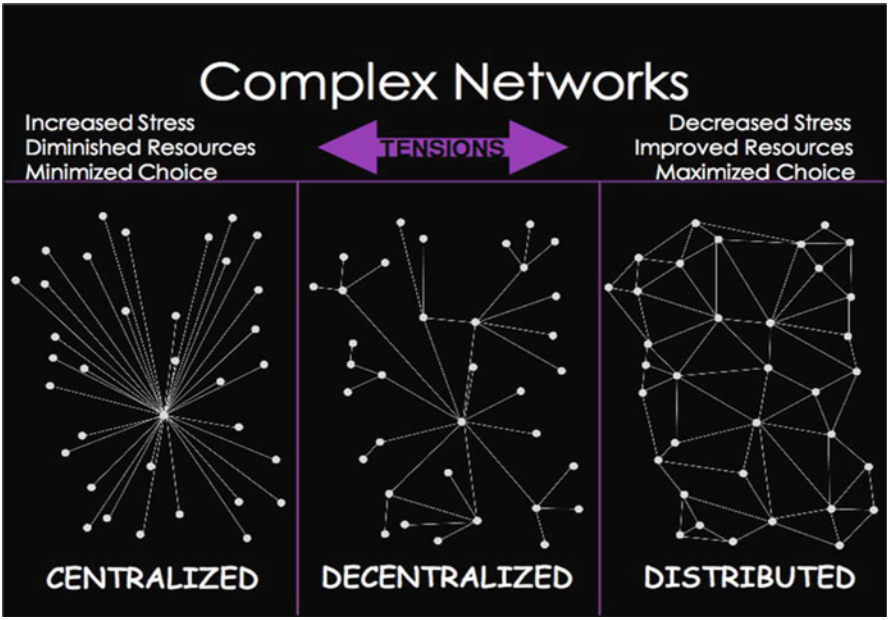
What Does Educating for Responsibility Mean? Considering Learning and Assessment Within Three Types of Responsibilities

> Our responsibility, at this watershed in our history, is to face the past honestly and do the things necessary to heal *ourselves* and our planet. Healing our society will require the patient work not primarily of politicians but of artists, ministers, gardeners, workers, families, women, and communities. It will require new forms of governance, work, and education that are much more participatory and democratic than those collapsing all around us. It will require enlarging our vision and *decolonizing our imaginations*. (Boggs 2011, pp. 164–165, emphasis added)

The statements integral to the following sections stem from two sources:

1. Words collected from the written work of and interviews with those involved in a service-learning experience at a local middle school. In this experience, secondary education teacher-candidates worked with groups of four to six seventh-grade students on math concepts while exploring the idea of sustainability as they examined their community's carbon footprint and consumption patterns. The teacher-candidates were seeking teaching endorsements in multiple content areas: many had minimal experience teaching math and found themselves learning and exploring with these students throughout the service-learning experience.
2. Words obtained from a TED talk[2] given by John Hunter and his middle school students on their engagement in a classroom based on a real-world problem-solving task called the world-peace games.

In addition, we have integrated three images of complex networks (Davis and Sumara 2008) that correspond to the three types of responsibilities we explore. These images are intended as a tool for visualizing and considering the physical structures that might correspond to systems of education for each type of responsibility. As we consider these networks alongside each type of responsibility, we acknowledge that neither end of the continuum is "intrinsically good or bad… what is bad, or unhealthy, is…overemphasis of one tendency and neglect of the other" (Capra 1996, p. 9). Thus, in considering the power of an education that fosters interdependent responsibility, which aligns with the decentralized network, we attempt to depict a harmony (a fitting or flowing together) (Davis and Sumara 2008) between dependent and independent responsibility rather than implying that interdependent responsibility is a balanced, static state that can be achieved and, then, maintained.

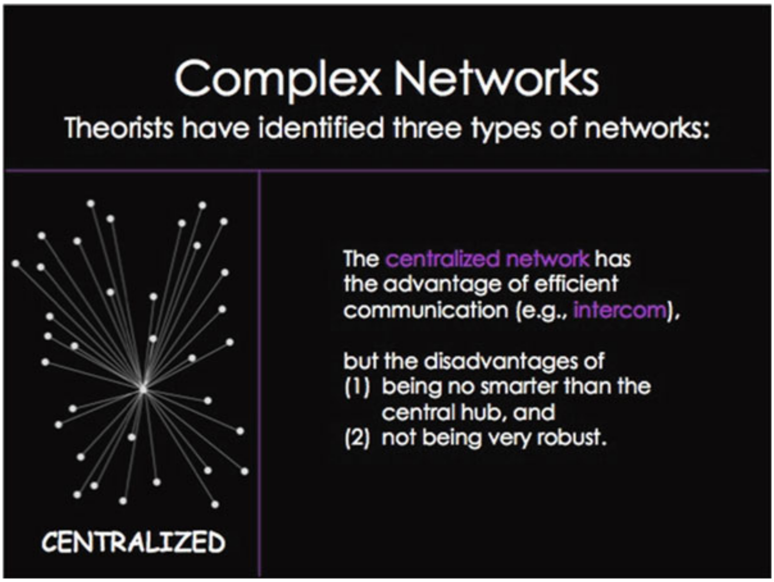


Responsibility Meaning #1: The State of Being Accountable or to Blame for Something

Synonym: Dependence

> …the tendency of educators to perceive of time as a scarce resource may be one of the main reasons that the most common organizational strategy in the contemporary classroom is the centralized network, with the teacher at the hub and the individual students at the ends of the spokes…pressures to cover a broad curriculum in a limited time, imposed evaluations, and other reductions on classroom autonomy prompt many teachers…to believe that their only choice is direct, centralized instruction in which all information is made to pass through the central hub. Of course, this sort of organizational structure militates against an intelligent collective, as it prevents agents from pursuing their own self-interests and obsessions, which in turn prevents the representation and juxtaposition of diverse interpretations and actions. (Davis and Sumara 2006, p. 89)

Image: Centralized networks exemplify the traditional teacher-centered classroom; systems that are built in ways that are decentralized often "decay into a more vulnerable (but informationally efficient) centralized network if stressed" (Davis and Sumara 2006, p. 88).



(Davis and Sumara 2008)

Power structure: Teacher is the central hub; expertise and power reside primarily with the teacher.

Assumptions about learners and learning: Learning is defined as modification of behavior, which occurs when the learner takes something external (external stimulus) and uses it to change oneself, often because this behavior is readily accepted and will result in external rewards (perceptions of success like grades). Learning is commodified. Learners are assumed to have various deficits and needs and are perceived as "isolated and insulated individual[s]" (Davis and Sumara 2006, p. 14). Learning is often assumed to happen in a linear progression and becomes about *acquisition* of knowledge and skills (answers). When progressive methods, such as inquiry, are used, students are typically asked to interpret data in the correct way in order to learn the right thing that the teacher knows. In this model it is assumed that learning can happen without meaningful engagement in lived experiences.

Assessment: Behavior modification tends to be measured by the teacher. Formative assessments often are used to help teachers and students determine what misconceptions students possess so that these can be corrected through specific, planned learning experiences. Students may be involved in assessing their own progress and growth in relation to predetermined criteria of quality. In this assessment system, students can benefit by underperforming initially, and then inflating their performance at the end, so as to convince the teacher of significant progress and to earn the desired, external reward. Summative assessments are often used to judge, categorize, and determine students' acquisition of desired knowledge, skills, and understandings (outputs) or "learning" by standardized tests or other decontextualized and narrow measures. Outside expert/authority dictates what has or has not been "learned" according to the prevailing "official knowledge" prescribed in the curriculum.

The culture present in many schools today is an example of a system that principally fosters top-down dependent responsibility. One of the primary structural transformations learners experience in this sort of educational environment is to become reliant on experts for answers, which often results in marginalizing their own wisdom and capacity to make meaning, a devaluing of the experiences and funds of knowledge of Generation R youth. The capacities and potential that each student brings with them into the classroom are often rendered invisible or reframed in ways that align superficially with a predetermined, external measure of achievement. What students do not know or cannot do is the starting point for schools trying to demonstrate progress on achievement measures. In an interview with one seventh-grade student (identified by the system as a "special-needs student"), the effects of an education for top-down dependent responsibility are expressed clearly:

> I got help from other students but I wasn't very comfortable in asking them because I've already been put down in this school year and don't have many friends, so it's kind of scary to me. I'm afraid of people being mad at me or getting upset or disappointed or something. That's why I haven't really made much [sic] friends. I've been here one year and in the year I've lost friends. [When the teacher-candidates were here] we did activities I understood so people weren't mad at me. That made me feel safe and comfortable. The 2 teachers were really nice. They actually listened to what I had to say and really liked it. [This experience] gave me some ideas for a car that can breathe air. If we can breathe air, why can't a car breathe air?
>
> – Seventh-grade "special-needs" student A

> You have a lot of interesting ideas, [student name]
>
> – Teacher educator

> Yeah, I'm just kind of scared to say it
>
> – Seventh-grade "special-needs" student A

The ways in which students' potential and engagement in learning is limited in an environment where they are expected to internalize and *consume* authoritative knowledge and understanding were well articulated by the seventh-grade teacher after he observed his learners in this experience: My students "got a kick out of teaching the college kids math. 'Hey, we're better at math than we thought,' said [student name]…so excited that they were able to teach and not just be taught to. *Helping someone who's their teacher really empowers them*."

One seventh-grade student noted how working with teacher-candidates who were co-learners with students (and who were not necessarily experts in mathematics nor did they have the answers to the complex challenges at hand) changed the nature of the learning environment in significant ways: [The teacher-candidates] "weren't really like teachers—do this, this, and this." Instead, they approached their work with us more like this: "We'll do this *with* you. It wasn't so secluded….

so pressured. It taught [our teacher] something. Lately he's let us do our own thing rather than being in front of the whole class."

In environments where top-down dependent responsibility is the norm, teachers often interrupt conditions that make rich and meaningful learning possible for all learners. One teacher-candidate who worked with the seventh-grade students illustrates this: "Kids would be far better served by teacher-candidates who actually understand math. You're doing them a disservice as a teacher of [x subject]. I feel frustrated because I don't have the answer. I feel terrible when I don't know what to tell the students, and it's extremely stressful as a result."

Further, when classrooms operate as centralized networks based on the assumption that the teacher knows and students need the teacher in order to know, understand, and learn certain information/concepts, teachers are encouraged to see their students through a deficit lens (Britzman 2003). One teacher-candidate discussed how working *with* his students allowed him to cut through this lens:

> I learned a great deal by working with [special needs student] – a perfect example of the futility of 'categorizing' students. Is he 'gifted' or 'special needs'? I think that depends on our reaction to him. I do know that he can't spell and he struggles with math, but he's brilliant if he is allowed to show his understanding in a different medium.

Thus, in an education that fosters top-down dependent responsibility, we are told as teachers that we are responsible for teaching so that proficiency tests reflect student learning, which is assumed to be the same for everyone, regardless of their context and experiences. In such an environment, an emphasis on expert-authority teaches students (both high-achieving and those identified as high needs) to discount or even distrust their own understandings, capacities, experiences, and selves. In this model the learner is relegated as an object that needs to be filled and tested. There is little energy or impetus to acknowledge the soul, spirit, or wholeness of a human being as having the potential to make decisions and act in ways that are imaginative, independent, and collective.

When we do not heed or trust our own thinking, when we look to "experts" to solve our problems, when we seek simple solutions in the face of complex, contextualized dilemmas, we feel a sense of reduced power and doubt our own capacity as agents. When this model of learning is internalized, students are divorced from their own actions as well as from consequences of their actions. Students learn to be afraid of creative ideas and innovations, which deviate from authoritative knowledge.

Because students are learning to be fearful, to not recognize their capacities as needed or valuable, or to believe other dangerous assumptions associated with the top-down dependent responsibility model of education, we inadvertently foster unchecked consumerism and an increasing sense of powerlessness[3] in youth:

> Having power (the capacity to act meaningfully in the world) is a basic human need and if man is not able to act [he attempts] to restore his capacity. One way is to submit to a person or group having power [expert, authoritative knowledge]. The other way [is] to destroy. Can we consciously reframe this deep need for agency in ways that align with the laws of life, with life itself? Can we shift from control as the primary expression of power and experience power as co-creating with nature?
>
> (Lappe 2009, p. 135)

But Don't We Need to Depend on Each Other?

YES! Ironically, the picture we paint of dependent responsibility and the centralized network is bleak. Dependence, as it currently exists, rests on a hierarchical power structure where domination over others is the primary expression of power. "However, there is another kind of power, one that is more appropriate for the new paradigm—power as influence of others. The ideal structure for exerting this kind of power is not the hierarchy but the network, which…is also the central metaphor of ecology" (Capra 1996, p. 10).

When we transition from top-down dependence, where one individual is considered more knowledgeable, worthy, and valuable than another, to networked dependence, a crucial shift occurs. Because no one is superior and all are worthy and valuable, each member of the network (student, teacher, teacher-candidate, legislator, etc.) can give ***and*** receive in meaningful ways (rather than mandating, controlling, and dominating). Learning happens from the inside out and from the outside in. We begin perceiving our functioning as a system in which "ultimately…there are no parts at all. What we call a part is merely a pattern in an inseparable web of relationships…[in which] the properties of the parts…can be understood only within the context of the larger whole"[4] (Capra 1996, p. 37). All experience connection and a deep sense of belonging.

This feeling cannot be experienced in a top-down, dependent system, where individuals seldom, if ever, have the opportunity to bring what they really love and have to offer (inside out). Because hierarchical systems communicate that most of our inner resources are not valuable or needed, individuals often seek external resources that others will perceive as valuable:

> The fact is, knowledge alone cannot provide the happiness that springs from inner development, that is not reliant on external factors. Indeed, though our very detailed and specific knowledge of external phenomena is an immense achievement, the urge to reduce, to narrow down in pursuit of it, far from bringing us happiness, can actually be dangerous. It can cause us to lose touch with the wider reality of human experience and, in particular, our dependence on others. (Dalai Lama 1999, p. 10)

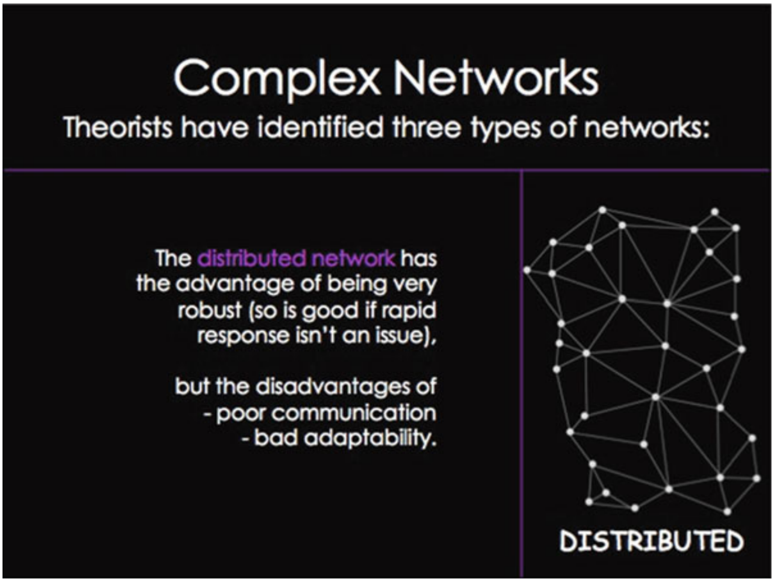
Recognizing, feeling, and experiencing our dependence on others (humans and organisms) including this planet is one essential transition that must occur as we transform our ways of being into those that are sustainable and connected to our place in the larger whole. And "logic does not lead us from the fact that we are an integral part of the web of life to certain norms of how we should live. However, if we have deep ecological awareness, or experience, of being part of the web of life, then we *will* (as opposed to *should*) be inclined to care for all of living nature. Indeed, we can scarcely refrain from responding in this way" (Capra 1996, p. 12).

Thus, we must work towards more networked dependencies (Senge et al. 2000), where giving and receiving is mutual and reciprocal, rather than top down and unidirectional. This will help us to transition from dependence that leads to insatiable consumption of the external (knowledge and things) toward healthy, sustainable dependencies in which consumption and production are fitting and flowing together freely.

Responsibility Meaning #2: The Opportunity or Ability to Act Independently and Make Decisions Without Authorization

Synonym: Independence

Image: The distributed network is applicable to some "currently popular student-centered approaches" and tends to exist where resources are abundant and stress is low. In this representation, students learn to pursue individual interests, rather than relying on the authority/expert or teacher to tell them what to do, when to do it, and what to learn.



(Davis and Sumara 2008)

Power structure: *Students have considerable power in shaping their own learning experiences and pursuing their own interests. Expertise resides jointly in the students and teachers*.

Assumptions about learners and learning: Definitions of learning vary in this model. Learners' interest, experience, and understanding are central in determining the nature of learning experiences and in shaping the form learning takes. Learning occurs because people possess unique interests and skills and are encouraged or allowed to pursue these. Learners' experiences, interests, and capacities assumed to be important and learning experiences build on these. However, learners are likely assumed to be an "isolated and insulated individual" (Davis and Sumara 2006, p. 14). Learning can be about acquisition of knowledge and skills gained from the understandings generated from one's experiences in the world. Learning does not tend to be focused so much on the right answer, but, instead, on progress. Learning frequently is connected to experience.

Assessment: Formative assessment, especially self-assessment, is essential in measuring growth and learning. Students and teachers alike could be involved in assessment, and students and peers might generate quality criteria and use these for examining their own learning and growth. Forms of assessment make space for students' funds of knowledge and for learning that occurs that is not predefined.

A distributed network of learning points to projects or problem-based teaching where students have the opportunity to research and apply or synthesize their learning in some way. Such approaches to teaching and learning might be supportive of Kyle's background and knowledge (described by Dennis in the previous chapter). If, for example, Kyle was learning to apply math concepts to his own understanding and experiences with fishing, we could agree that learning would move towards an opportunity of engagement and possible discovery, linking his experiences with new concepts in math. There are two keys in this case: (1) Kyle's learning is contextualized rather than abstract, and (2) Kyle is encouraged to engage in learning from the inside out not just from the outside in because his interests, passions, and strengths are integral to the learning that occurs. Research in learning supports this approach to deeper learning and higher engagement because the new learning is attached to experiences that are meaningful to particular individuals (Dweck 2007). In a more active learning situation, such as where Kyle is applying math to figuring out a problem or project about fishing, he is able to see some value to what he is being asked to learn, and this vision is supported by his own interest in fishing. However, this is still Kyle's learning, to be assessed though his life experiences, which helps contextualize the work of math. At the end of the day, Kyle's learning is considered in terms of "what did you learn?" rather than "what problem did you solve for today?"

In this model, assessment shifts towards summative evaluation of the learning through, for example, a presentation to the class or to the teacher, in which Kyle demonstrates his understanding of the math concept by explaining how he applied math to fishing. When Kyle demonstrates proficiency with the math concept, he walks away with a sense of self-worth and greater confidence in his capacity to learn in an academic setting.

Simultaneously, there might be a more formative assessment, in which Kyle assesses his learning at different benchmarks throughout the learning process. Both Kyle and his teacher could identify learning targets at the beginning and throughout the learning experience as Kyle and his teacher begin to see more clearly what is needed to further his learning. As such, assessment becomes contextualized, not isolated and abstract. Both teacher and student can take a valid look at what is being learned as Kyle experiences himself engaged in context and understands what is working well and what he needs to learn.

Formative assessment allows for both students and teachers to play an integral role in the learning process and has the potential to empower students as they articulate and name what is occurring in their lived experience (Freire 1970), generating ways to respond to challenges they are encountering in a contextualized learning experience. In this model, students have the potential to recognize the consequences of their actions and decisions during learning experiences because they are active in shaping their learning.

But Is Independent Responsibility Sufficient?

A distributed network and independent responsibility have potential to allow space and create a structure for authentic learning to occur. But independent responsibility is not sufficient for engendering a sense of connection. One might assume erroneously that when one experiences independence that automatically one feels empowerment. But we argue that is not the case. Independence can be overwhelmed by the daunting challenges we face today. An unintended consequence could be that a person feels independent and helpless because they feel disconnected from others. Hopelessness thwarts action, and we are left alone and paralyzed.

In the previously described service-learning experience, the classroom teacher emphasizes the necessity and power of moving beyond independent responsibility:

> It was cool to see them [my seventh-grade students] working as a team and they would live up to the expectations of the other person. They might not do homework when it only impacts them. "Oh, it's only my grade. Whatever." But it was cool when those posters – they had barely any time – it was crazy. And I was thinking "Oh man, I hope they can do this." Because sometimes they won't do a 5-minute homework assignment even though they get 24 hours. They built that bond and [could] see how their actions impact those around them, which I don't think they normally see in the classroom. Really, who do you affect when you don't do your homework? Yourself, really.
>
> – Seventh-grade math teacher

In this experience, four to six seventh-grade students worked closely with two teacher-candidates and built relationships as they used math to explore our collective consumption. At the end of the quarter-long experience, each team of seventh-graders created a representation of their ideas on a poster. The seventh-grade students traveled to the university to present their learning to university students and faculty. In this comment, the teacher is explaining that while his students were unlikely to do a brief homework assignment that was for only their benefit, he was surprised at students' willingness and commitment in completing the posters at home prior to visiting the university because they had built relationships and their actions had consequences that they could see affected someone other than themselves. The cooperative and reciprocal learning conditions that occurred during this service-learning project were integral to students' engagement in thinking critically about challenges facing all of us. Students wrestled with contextualized knowledge and were given intellectual space to generate ideas and questions relevant to their future. As evidenced by these seventh-graders' serious engagement with difficult problems of resource consumption, independent responsibility becomes powerful when passions and commitments are collective—where what happens to one affects the others. This is systems thinking, where all parts interact and influence each other. Nothing is independent here.

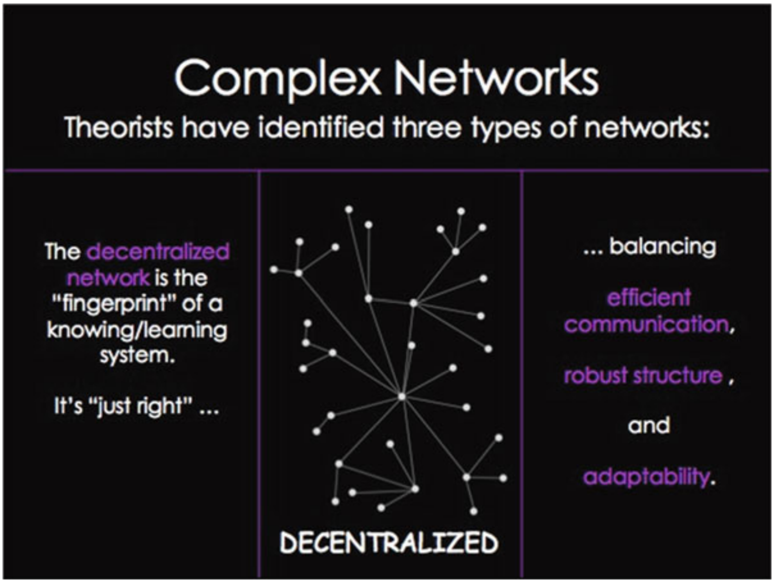
Responsibility Meaning #3: A Moral Obligation to Respond in Respect Of

Synonym: Interdependence

> I believe that our every act has a universal dimension. In the past, families and small communities could exist more or less independently of one another. If they took into account their neighbors' well-being, so much the better. Yet they could survive quite well without

> this kind of perspective. Such is no longer the case. Today's reality is so complex and, on the material level at least, so clearly interconnected that a different outlook is needed. (Dalai Lama 1999, p. 161)

Image: "…in the decentralized network, agents have opportunities to specialize and for mutual affect…the decentralized network is the architecture necessary for an intelligent system" (Davis and Sumara 2006, p. 89).



(Davis and Sumara 2008)

Power structure: In a decentralized educational network, expertise resides in both students and teachers. Students work with other groups of students, and the teacher plays various roles, depending on communication needs and expertise, experiences, and capacities of the students in the group. Collective wisdom is greater than the wisdom of one. The teachers and their students search for synergies as they work across difference rather than examining tensions in terms of trade-offs (Lappe 2009). *Assumptions about learners and learning*: "Learning is a matter of transformations in the learner that are simultaneously physical and behavioral—which is to say, in biological terms, *structural*. Learning is certainly conditioned by particular experiences, but it is 'due to' the learner's own complex biological-and-experiential structure,[5] not an external stimulus" (Davis and Sumara 2006, p. 13). A learner is assumed to be a "complex unity that is capable of adapting itself to the sorts of new and diverse circumstances that an active agent is likely to encounter in a dynamic world" (p. 14). Each learner is simultaneously considered "a coherent unity, a complex of interacting unities, or a part of a grander unity" (p. 14). Learning is not assumed to happen because collective knowledge and individual understanding are separate from one another, meaning the learner needs to acquire something outside of oneself. Instead, collective knowledge and individual understanding establish a nested dynamic. Learning is about the ongoing fitness of collective knowledge and individual understanding to be reshaped and modified together. As such, both collective knowledge and individual understandings are "subject to continuous tinkering to maintain viability" (p. 62). Further, collective knowledge and individual understanding are always unfolding together. As such, the learner contributes actively to the shape of collective knowledge in his or her own transformation.

Assessment: Students are key in assessing their own learning. Assessments must allow for educators to see beyond behavior modification (i.e., acquisition of exclusively external knowledge) to behavioral and physical transformations.

An unspoken hunger for becoming a part of the world resides in the cultures of young people today. This desire can, perhaps, be described as a longing to be active, rather than passive; to experience connection, rather than separation; and to engage from a place of love, which frees and connects, rather than from a place of fear, which divides and separates. More specifically, students will willingly take responsibility for their actions, which ultimately allows them to engage in ways that are responsive to self, community, world, and planet—to learn interdependent responsibility. Students want to pursue their own interests, but engage more fully and consistently when they experience themselves as part of a greater collective—when they see that their engagement is for "mutual effect" (Davis and Sumara 2006, p. 89). As two different seventh-grade students described:

> In our math books we do these things that are competitions, but that gets boring. It doesn't really matter. And this matters. It's a big deal. We realize how much we're affecting the earth – how much we're taking advantage of – how much we need it, but we don't really need to use it as much. It was a really nice change to add math with it and make it fun at the same time.
>
> – Seventh-grade student B

> I thought [this experience] was cool because I don't think we realize how much we're actually using, but then we see the numbers and realize we're using a lot, a lot. And so we kind of realize it and say, 'Oh, I can turn the faucet off.' If everyone did that then everyone would save a lot.
>
> – Seventh-grade student C

A critical transition in an education that fosters interdependent responsibility involves shifting from a belief system of scarcity and lack to a belief system of sufficiency (Twist 2003). In so doing, whether youth are those we would call high-achievers or at-risk, the "experience of fulfillment and sufficiency becomes accessible to them when they take the resources they have, at whatever level those may be, and choose to make a difference with them. When they use what they have to support their highest ideals and commitments, and express their deepest values, their experience of their own true wealth expands" (p. 89). In expanding our own true wealth, we experience connection with others. We find ourselves engrossed in part of something much greater than a collective of individuals in pursuit of external resources (knowledge, money, power), that is, "…we can discover the power within each of us to change the world by changing ourselves" (Boggs 2011, p. 168). When our seventh-grade students B and C reveal their intellectual engagement, they do so because they see themselves in the struggle, because they see themselves as part of both the problem as well as potential solution. Empowerment and engagement are fundamental aspects of interdependent responsibility.

Essential transitions in teaching and learning for interdependent responsibility are:

1. *"Students, as they are increasingly posed with problems relating to themselves in the world and with the world, will feel increasingly challenged and obliged to respond to that challenge.* Because they apprehend the challenge as interrelated to other problems within a total context, not as a theoretical question, the resulting comprehension tends to be increasingly critical and thus constantly less alienated" (Freire 1970, p. 81, emphasis added). Independent interests, capacities, and commitments are pursued from a place of belonging and connection, which encourages engagement and action from a place of love (healthy, giving and receiving, and life-giving) rather than fear or insufficiency (endlessly consuming "empty calories" in an attempt to satiate a deep hunger). One teacher-candidate described his perception of this sort of responsive engagement when he and his students used a systems diagram to explore our consumption:

   > When we utilized systems diagrams, all of our students became engaged. There was room around the table for any particular student to carry a point or idea as far as they wanted to. Although what was happening around our group table may have seemed like chaos to the uninitiated observer, it was far from it in reality. The students in our group challenged each other and none of them declined any challenge to engage…as they wrestled with some very difficult concepts.
   >
   > – Teacher-candidate

2. *Space must then be made for students to engage and learn from experience so they can physically and behaviorally transform themselves* (Davis and Sumara 2006). As John Hunter, lifelong educator, described in his recent TED[6] talk, "I don't try and deny [students] that reality of being human. I allow them to go there and through their own experience learn, in a bloodless way, how not to do what they consider to be the wrong thing. And they find out what is right their own way their own selves" (TED 2011). Such an educative experience fosters transformation on the part of learners (Romano 2000).
3. If learning is truly transformative, *learners must play an integral role in assessing their own learning, because much of what transpires in taking interdependent responsibility while engaging with a complex challenge cannot be assessed based on predetermined learning aims*. As John Hunter noted after one student describes his experience and learning engaging in the world-peace games: "I get chills every time I see that. That's the kind of engagement you want to have happen. And I can't design that, I can't plan that and I can't even test that. But it's self-evident assessment. We know that's an authentic assessment of learning" (TED 2011).
4. *Teachers must get out of the way and redefine what it means to serve*[7] *youth*. John Hunter describes how he does this in his teaching: "Their collective wisdom is much greater than mine and I admit it to them openly. I throw them into this complex matrix and they trust me because of this deep, rich relationship together…who's in charge of that classroom. [*audience laughs*] It's a serious

question. Who is really in charge? I have learned to cede control of the classroom to the students over time. There's a trust and an understanding and a dedication to an ideal that I simply don't have to do what I thought I had to do as a beginning teacher…"

Hunter relates a moment in the World Peace Games when one particular student, who was representing a nation, decided to attack in a world peace game, which violated the rules of engagement of the game. John Hunter and his students were very frustrated and the teacher assumed he had failed. Why was this student attacking another country in a world peace game? However, the following day the group recognized, as the game proceeded, that the attacking student had managed to avoid a world war in her decision to attack one nation. Hunter describes the situation as follows: "She was able to see the vectors and trend lines and intentions long before any of us and understand what was going to happen and made a philosophical decision to attack in a peace game. Now, she used a small war to avert a larger war so we stopped and had a very good philosophical discussion about whether that was right—conditional good—or not right. I could not have designed that in teaching. It came about spontaneously through their collective wisdom" (TED 2011).

Concluding Thoughts

> We are the leaders we've been looking for… [we] cannot return to the old separation between we, the people, and those we elect to office. (Boggs 2011, pp. 159 and 165)

We face turbulent times as local, global, and planetary communities, which necessitate different ways of thinking and being. We perceive the complexity of these challenges as a welcome invitation to step into ways of engaging and being in education that are humane, life-giving, and connected. As the complexity of challenges that we encounter increases, the need to leverage and draw on the diverse capacities of all becomes crucial. Critical conditions, such as climate change, urgently invite us to move into forms of education where collective knowledge and individual understandings are dynamic and synchronous. We must turn to forms of education that honor our connections with all life and this planet.

We look forward, then, to ways of thinking about learning, teaching, and assessment that foster this sort of empowerment and engagement —that *root us* (dependence) in engaging and living with a recognition of our part in the greater whole (Boggs 2011) and that encourage us to *expand and free* (independence) ourselves to live from a place of love, which leads to life-giving, connected ways of being (interdependence). To conclude, we leave the reader with the image Gyre (Jordan 2009) as a way of visualizing the necessary components of an education for interdependent responsibility and the power we have to transform our world as we engage with Generation R youth in transformative learning for interdependent responsibility.

Running the Numbers II: *Portraits of global mass culture (2009–2011)*

Gyre 2009
(Jordan 2009)
8 × 11 ft, in three vertical panes

Depicts 2.4 million pieces of plastic, equal to estimated number of pounds of plastic pollution that enters the world's oceans every hour. All of the plastic in this image was collected from the Pacific Ocean

(3 different zoom levels shown here)

Notes

1. Capacity to act.
2. TED, Technology, Entertainment, Design—is a nonprofit organization devoted to Ideas Worth Spreading. The mission of this organization is to spread ideas. TED believes passionately in the power of ideas to change attitudes, lives, and, ultimately, the world. As such, TED has built a clearinghouse that offers free knowledge and inspiration from the world's most inspired thinkers and also a community of curious souls to engage with ideas and each other (http://www.ted.com/talks/).
3. Frances Moore Lappe articulates root assumptions that lead to powerlessness and empowerment. At the heart of the "Spiral of Powerlessness" is the same assumption that lies at the heart of the top-down dependent responsibility model of education: LACK. This model of education assumes students need to be changed and that what they have is not enough and needs to be made better (http://www.smallplanet.org/content/spiral-powerlessness-spiral-empowerment).
4. "In the shift from mechanistic thinking to systems thinking, the relationship between the parts and the whole has been reversed. Cartesian science believed that in any complex system the behavior of the whole could be analyzed in terms of the properties of its parts. Systems science shows that living systems cannot be understood by analysis…Thus systems thinking is 'contextual' thinking…" (Capra 1996, p. 37).
5. Here structure is assumed to be *incompressible* because of the complexity of a living system… "Although many of that structure's traits might be characterized in global or general terms, the finer details – and, perhaps, most of the vital details…can never be known or replicated precisely." This stands in contrast to the following sense of structure: "the vital aspects of a building or other static

form can be specified with considerable precision, and usually in highly compressed forms such as blueprints or maps" (Davis and Sumara 2006, p. 14). Thus, learners, who are living systems, have nuanced structures that are difficult to capture in a general sense.

6. TED, Technology, Entertainment, Design—is a nonprofit organization devoted to Ideas Worth Spreading.
7. In *Multicultural Education in the 21st Century: From Theory to Action* (panel discussion at Western Washington University on May 23, 2011), Augustine Romero described that the best way to serve is to believe and engage with youth in ways that honor their intellectual capacity—to see their assets and operate from a place of love. This perspective revolutionizes the student-teacher relationship.

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Part II
Responsibility with Scientific Literacy, Environmental Literacy and Experiential Learning

Chapter 7
Thinking (Scientifically) Responsibly: The Cultivation of Character in a Global Science Education Community

Dana L. Zeidler, Marvin W. Berkowitz, and Kory Bennett

Defining what it means to think responsibly in a pluralistic society is both an academically interesting challenge and a task that is necessary to support the quality of our physical, organic, and social world. In facing this challenge, we need to consider the thought that western dominant science worldviews and indigenous science worldviews are fundamentally cut from the same cloth. Humans are bent toward inquiry, exploration, understanding, and acting on personal and social knowledge representing parts of the same fabric woven into the human community. We will analyze and evaluate the boundaries of these concepts in order to reveal the common threads that weave through them. By viewing our ever-fluctuating social and environmental contexts through a lens of common social tapestries (structures), we can begin to understand what it means to think and act responsibly as human beings in the modern world. Subsequently, we formulate a foundation for scientific literacy, characterized by responsible decision-making informed by scientific understandings. We will find that thinking in scientifically responsible ways requires features of character, which in turn requires the formation of conscience through the development and practice of reflexive judgment (Green 1999). In other words, responsible science depends upon the character of both the scientist and the public at large, and that character includes reflexive judgment applied to scientific knowledge and ethical standards.

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It is important to clarify some central tenets early on; our argument is one that views the bifurcation of science into nonnormative components (e.g., data gathering, observation, predictions, scientific methods, and processes) and normative components (e.g., prescribing courses of action, choosing to create selected products, decisions about what ought to be done) as one that is fraught with peril. While such a distinction is, arguably, conceptually important, it can create a splintered view that allows for the abdication of any sense of responsibility during the practice of science. The worldview of science we advance in this chapter is one also noted by others that have challenged the distinction historically made between the context of discovery and the context of justification of scientific claims (Giere 1988; Gillies 1998). In short, studies in the history and philosophy of science have pointed out that the practice of science is actually quite "messy," and the decision-making associated with that practice entails both value judgments and ethical propensities influenced by culture, personal beliefs, and the like (Abd-El-Khalick 2003; Zeidler and Keefer 2007).

Equally important, is our realization that the notion of conscience does have two senses that mark it off as distinct. On the one hand, there exist external constitutive norms rooted in what Durkheim (1893/1997, 1897/1979) called the collective conscience. Here, one's beliefs get weighed and gain approval or not, against empirical community norms holding up a "public bar of judgment" (Green 1999, p. 60). On the other hand, there is an internal voice of conscience, an interior bar of integrity to which one, who is so inclined, strives to measure up. This is a critical voice directed not so much at what one believes but aimed at the extent to which one evaluates the degree of consistency between fulfilling their capacity to appear in reality to be all that they really are. No pretexts. No illusions. This is also the inner voice of reflexive reasoning, and failure to listen to that voice becomes dissembling and disingenuous.

It is our hope that the frameworks we propose will inspire and move both policymakers and science educators toward creating school environments conducive to the formation of virtue (character). We aim to convey through our analysis that scientific literacy, as we conceptualize it, is intricately linked to both senses of conscience. In order to convey this admittedly novel understanding of scientific literacy, we must look more closely at the socially shared and socially constructed community of science.

A Community Worldview of Science

We dwell in a world that is fundamentally distinct for each of us. We all hold our own *worldviews* constructed by shared experiences but tempered by the Zeitgeist, language, and our own unique interpretations of contextualized experiences. Yet we find enough common ground in the memes, norms of cultural experiences, and the human modes of psychological and social construction so as to not be relegated to a Tower of Babble. While our understandings of one another are partial and fragmented, it is possible to create and construct some degree of shared social knowledge and thus engage in socially shared inquiry. The open questions are, of course, to what degree can our shared knowledge be gathered up to form one comprehensible tome? Is it feasible to have a common system of knowledge that transcends culture? While some would argue that science does not situate itself in any one culture, others might argue that scientific knowledge itself is culturally grounded and, therefore, results in situated knowledge. Recent discussions on the hegemony of scientific traditions (e.g., positivism, indigenous science) and its impact on both formal (structured classroom experiences) and informal (beyond typical classrooms such as aquaria, museums, media, family-based experiences, and self-exploration) science education suggest that all is not quiet on the western (science) front (Brayboy and Castagno 2008; El-Hani and Bandeira 2008; Kincheloe and Tobin 2009). This, in turn, raises another question as to whether we, as a community of scientists and science educators, can come to consensus as to what constitutes responsible scientific thinking. Put differently, is it possible to have an agreed sense of scientific literacy to be found in everyday decisions informed by scientific knowledge? To the extent that scientific literacy is inseparable from the formation of character, as we will argue and expound, we may also need to ask ourselves what common features of character exist in a pluralistic community?

That we are the authors of our own life story through our deeds and actions, but not the interpreters of that story, as that narrative resides outside our existence for others to create and interpret, has been recognized for some time by sociologists (Arendt 1958). If this is indeed the case, then the collective works, deeds, and actions of scientists may be understood as a kind of public social fabric threaded together and assigned meaning by others who reside in a loosely connected scientific community. While those who are part of that community possess their own unique discipline-specific language, as well as their own *cultural and personal identities*, norms, languages, and traditions, they hold in common a commitment that science embodies a common set of overlapping traditions established by those who wish to partake in a journey of inquiry where knowledge is socially shared, challenged, and discussed in some forum and open to revision.

To elucidate the notion of science as the formation of cultural identity, let us first consider Angrosino's (2004) parsimonious definition of culture as "a system of learned and shared material productions, interpersonal relations, and the ideas about what those productions and relations mean" (p. 6). We suggest that within the pluralistic culture of science, the concept of culture must be broadened, as Angrosino's definition allows, including the idea that individuals typically do not shape nor are shaped by only *one* culture. Rather, multiple cultural streams, made possible by the shared knowledge of human interactions, impact each of us. While we may declare our allegiance to one *culture*, our perspectives are nonetheless shaped by experiences made possible by multicultural knowledge and interactions. This view, consistent with the cultural-embeddedness tenet of the nature of science, allows for the fact that one's understandings of scientific phenomena are shaped by normative values and belief systems.

Using this expanded concept of culture, we can discern more nuanced patterns that may characterize a given community. In terms of the scientific community (which necessarily includes teachers of science and science educators), we can view the *community* of science as a loosely knit group of individuals acting in and constituting a system of learned and shared material productions, interpersonal relations, and ideas about what those productions and relations mean. Within this holistic view of the scientific community, communities of scientists are indistinguishable from the systems of science that are produced. Ontological, epistemological, and methodological commitments are intertwined into a range of knowledge-meanings and material productions. The processes and products of science are, therefore, conceptually intertwined. While this constructed system is based upon a degree of commonality in the ways people think and act, it is important to realize that the community itself is in flux with the unique contributions that each person brings and is constantly being reshaped through human discourse and meaning-making.

In a sense, this understanding of science may be likened to the distinction that Tönnies (1887/1963) evokes while describing the social structures of Gemeinschaft and Gesellschaft (community and society). While Tönnies' description of Europe's Middle Ages and its transformation into the "modernization" of European society might at first blush seem out of sorts with a modern form of community, key features of these two concepts are instructive in understanding the common ground of science. Communities based on Gemeinschaft shared a common work or calling, kinship or neighborhood, spirit or mind – hence common beliefs, virtue, and morality could spontaneously arise. Thus, an artisan or professional could create and produce goods without calculation of units of time and compensation. Conversely, Gesellschaft represented a process, as well as a state of affairs in which individual associations were guided by a network of legal and moral relations that were not naturally produced but imposed with calculation to aggregate citizens into a type of polis based on instrumental economic utility. "… In Gemeinschaft they [individuals] remain essentially united in spite of all separating factors, whereas in Gesellschaft they are essentially separated in spite of all uniting factors" (Nisbet 1966, p. 76).

When imperfect unions are imposed within the community of science, a forced state of Gesellschaft takes hold. Scientists (and science educators) remain fundamentally separated in spite of all the uniting factors that attempt to link us together from external mandates and political (i.e., politically correct) pressures. In this case, historically different ontological, epistemological, and methodological commitments, hence different paradigms, may be deeply steeped in traditions that stand distinct to one another. In contrast, when the scientific community reaches a degree of consensus that arises organically out of common interests, like the pursuit of knowledge through evidence-based inquiry, a state of Gemeinschaft is achieved. It is within the latter realm of this continuum that we wish to dwell, at least for scientists and science educators that recognize that whatever our distinct traditions, we all bear a sense of responsibility for our deeds, words, and actions.

Actions, Character, and Scientific Responsibility

What does it mean to think responsibly about scientific issues? We recognize the need for our future scientists to be insightful and well grounded in their respective research programs. However, we are also concerned about the larger majority of students who will not seek scientific professions but who, nonetheless, need to be functionally scientifically literate and make informed judgments about decisions that impact the biological, physical, and social environment.

We have argued elsewhere that Roberts' (2007) description of Vision II scientific literacy, which moves away from prioritizing decontextualized science concepts and focuses instead on understandings, decision-making, and the use of science in situations removed from traditional boundaries of science, is the conceptual framework that best aligns with the socioscientific issues (SSI) framework. We have pushed that boundary to explicitly subsume moral reasoning, ethical considerations, and character development as part of that understanding (Zeidler and Sadler 2011). However, if the crux of making informed judgments depends on being scientifically literate, and the expression of scientific literacy is defined in terms of *responsible* decision-making, then we find ourselves in the mist of tautology.

To clear the mist, let us consider the following conceptual distinction. We need to ask ourselves if we can imagine a world where one can be properly identified as being scientifically literate yet bear no responsibility to subsequent decisions made about policy, research, community, family, and the like. We would likely agree that such an individual would possess technical competence but lack the *inclination* to enact that knowledge with due consideration of the physical or social environment. In the alternative, can we imagine a scenario in which one makes consistently responsible decisions that impact the world around us and lacks scientific literacy? We would be hard pressed to imagine such decisions not being *informed* by knowledge of or about science. It would seem that some manner of scientific literacy is a prerequisite to making responsible decisions, though not a sufficient condition for such decisions to occur. While literacy may not require a moral compass, scientific literacy, in the sense that we are prescribing, does.

So what establishes sufficiency in making responsible scientific decisions that are endemic to human and ecological affairs? In addressing that question we also need to consider how thinking and acting in scientifically responsible ways is bound up with character. Many definitions abound as to the essence of character. Berkowitz (2012) offers one helpful description and suggests that character is bound by a set of psychological characteristics that collectively influence a person's ability and inclination to do what is right – to function morally. These characteristics make up what he calls the “Moral Anatomy” of a person (Berkowitz 1997). Character, then, arises out of the establishment of moral values, moral reasoning, moral emotion, moral identity, and meta-moral characteristics (attributes that are not moral in and of themselves but support or add technical competence to moral functioning). Berkowitz (2002) suggests moral anatomy:

> …entails the capacity to think about right and wrong, experience moral emotions (guilt, empathy, compassion), engage in moral behaviors (sharing, donating to charity, telling the truth), believe in moral goods, demonstrate an enduring tendency to act with honesty, altruism, responsibility, and other characteristics that support moral functions. (p. 48)

To this we wish to add that doing what duty, fairness, obligation, principle, conscience, or social justice requires (i.e., doing the right thing) is something that should not be done in rare cases or by happenstance. Character is something that must be associated with habitual excellence. It should be something on the forefront of everyday deeds. The Greeks referred to this kind of moral excellence as Arête – which was isomorphic with virtue. Virtue, understood in this context, was consistently doing the “right thing.” The moral life could not be envisioned as punctuated with “Whoops! Damn! Sorry about that!” Virtue was thought of as a state or quality inherently present – where one fulfilled their potential and did so consistently with grace and eloquence.

The ability to act with virtue is linked to the ability to hold one’s beliefs, words, and deeds up to internal and external (conscience and community) scrutiny. This requires the capacity to raise normative questions of self-evaluation: “Did I do that well? Could I have done that better?” This is a type of reflexive judgment that is habitual and active. We can think of this type of automatic, internal self-evaluation as a form of *reflexive thinking* (relative to one’s own gauge of virtue) helping each of us understand the structuring of our emotions (Green 1999) and acting as a precursor to more explicit forms of thinking or acting. Since virtue is equated with excellence (note Book Two of Aristotle’s *Nichomachean Ethics*, 1975), one can argue that a virtuous life is one filled with deeds par excellence. More importantly here is that the *desire* to consistently hold one’s actions up for internal scrutiny is a fundamental feature of conscience and ultimately a forerunner to the development of character. And the existence of conscience is a precursor to scientific literacy in that one needs to possess the capacity to seek evidence in confirming and disconfirming ways – to be challenged and challenge their own understandings of scientific evidence, including the probable short- and long-term outcomes associated with decisions related to that evidence. In the absence of conscience, moral education becomes an exercise in futility because such pedagogy presupposes the existence of conscience. While a more detailed discussion of this may be found in other writings (see Zeidler and Sadler 2008), it is important to highlight a main argument by Green (1988), who further suggests that a precursor to conscience *is* prudence. The claim here is that prudence, being more fundamental and natural than learning about morality, is tied to social norms within communities and, therefore, intricately linked to others:

> Being prudent, in the sense of looking after one’s interest, is not something that needs to be taught at all. Persons may need to be taught what is in their own interests, and they may even need to be taught how to pursue their own interests. But they do not need to be taught

> to pursue their own interests. Left alone, they will do that. Sometimes they will do it ineptly, sometimes shortsightedly, and sometimes with little self-knowledge. And, thus, they will make mistakes…. Being moral, seen in this way, requires education, but being prudent does not. This is one sense in which prudence is prior to morality. (p. 138, italics added)

Moving acts derived from prudence to be scrutinized by a sense of conscience is something that requires the formation of character, which we discuss in our concluding section. But a few more points are in order.

That conscience is tied to a sense of prudence – a sense of acting in one's own interest – is a central point in connecting character to scientific responsibility. Here, a dynamic tension between prudence and scientific responsibility is an interesting notion as there is a kind of duality present:

> …prudence [is] associated with foresight; it entails planning and is evaluative or reflective in nature. To plan ahead, to plot one's next move, form practical judgments about public affairs and do it well also requires a sense of looking backward; examining one's prior experiences and understanding them in contextual hindsight is necessary to contribute to a collective, socially-shared ethic of memory (see: Margalit 2002). (This is the reason Aristotle thought it difficult to teach ethics to the young for they did not have adequate experience for establishing a sense of history.) The importance of a collective memory may be understood in at least two related forms: 1) it requires cultivation of empathy about past humanity – a necessary condition to form emotive ties to the present and future; and 2) it provides a foundation of moral commitments to humanity (in contrast to parents, friends, people directly in our affairs) on which a general sense of care and morality is built. Reflective foresight then cannot be achieved without the ability to look backward – without attention to its counter part of memory. Taken together, looking forward and looking backward are the yin and the yang of prudence. (Zeidler and Sadler 2008, pp. 204–205)

The important tenet that bundles these ideas is that the *scientific community* can be thought of as mirroring the "organic free market" state of community proper (Gemeinschaft). In its ideal form, the scientific community is open and inclusive to the free exchange of arguments, propositions, and ideas. What unifies our discourses, therefore, is the recognition that scientific knowledge has both personal utility and social value and rests on evidence and the social construction of that knowledge. Such a *worldview* subsumes both the cannons and orthodoxy of western science (i.e., positivism, scientism) (Gauch 2009) as well as that which western science describes as *ethnoscience* (i.e., native, science, indigenous ways of knowing) (Brayboy and Castagno 2008; Kincheloe and Tobin 2009).

We are aware that some may see such an inclusive view of "scientific" knowledge systems as conflating western science and ethnoscience (El-Hani and Bandeira 2008; Matthews and Smith 1994). But therein lies the point: when practical utility is coupled with the derivation of knowledge through persistent observation and exploration, when reasoning and the subsequent decisions that follow are based on known *evidence*, when one can provide justification for thinking and actions yet be open to criticism, revision, or refinement, thereby reconceptualizing that knowledge, then an open, unfettered state of (scientific) *community* (Gemeinschaft) may be said to exist.

In this conception of science, prudence is expressed by virtue of the fundamental utility found in the deliberate choice of what works and makes sense with respect to the quality of life for each individual, as well as how it contributes in morally just ways to community survival. As decisions are evaluated in terms of their future ecological consequences, and in terms of how the amelioration of historical wrongs may be leveraged, conscience may now be allowed to emerge. This describes a world, perhaps a best-case scenario, where the practice of science becomes *inseparable* from acts of responsibility. In such a world, we recognize prudence as the cultivation of scientific responsibility through the expression of social justice in the scientific community. While many scientific communities are loosely articulated around the world, we believe that we must view science and science education as a global endeavor, unified by conscientious scientific thinking and acting through the formation of character. In this world, the processes of science become causally linked with the products of science. And because so much of what we do scientifically has potentially global consequences, responsibility becomes even more ethically obligatory.

Thinking and Acting in a Pluralistic World

Science Education as a Human Activity: Shared Social Inquiry

All human beings are interconnected by actions that require obligatory responsibility. Accordingly, *science education would benefit if teachers and researchers come to understand scientific inquiry as a fundamental human activity that connects us all*. While knowledge-generation and scientific understandings may vary or even be idiosyncratic across peoples, there are processes similar in kind operating during the construction, evaluation, and dissemination of knowledge that are tied to responsibility, care, and concern about the environmental and social worlds that we inhabit. The educational experiences characterized by the immersion of students in their surrounding communities have tacit links to the experiences of others in different locations around the world. That is, the social fact that others in the world also build, evaluate, and disseminate knowledge provides a *collective global community norm* against which local knowledge can be judged. This is obviously a daunting task; however, we must begin to look beyond our limited local science teaching practices and recognize how seemingly isolated experiences impact a larger world's backyard. Those that view science education as a forum for social/environmental activism understand that the education of students can be nothing short of human empowerment situated in an interconnected pluralistic world community.

For example, Aikenhead (2006a) and Aikenhead and Ogwa (2007) suggest that school science has attempted to facilitate the enculturation of students into a western scientific "way of knowing," thereby reinforcing typically positivistic notions of scientific knowledge that are combined with ontologies of realism and Cartesian duality, ultimately feeding on *reductionists and mechanistic practices* in order to advance an *ideology of dominion over nature*. In his quest toward decolonizing the Pan-Canadian science framework, Aikenhead posits "the first step toward establishing an accessible science curriculum is to recognize Indigenous knowledge as a knowledge system that describes and explains nature in culturally powerful ways" (2006, p. 388). Aikenhead, therefore, advocates broader conceptions of science that still entail rational and empirically based descriptions and explanations of nature but also allows for the inquiries, problem-solving, and decision-making activities anchored in indigenous worldviews. If science education is to reflect the practice of science as a human endeavor in a pluralistic world, then we must scrutinize identified cultural and personal boundaries in order to bring into relief shared human attributes underpinning our collective and personal conscience.

Accordingly, we should be equally interested in the educational practices occurring in the Ecuadorian Amazon, inner city Tokyo, the Appalachian Mountains, as well as the community in which we reside. Doing so will lead us to developing a scientific sense of community that transcends western scientific ways of knowing. Perhaps through the dissection, dissolution, or restructuring of the "formal" practice of science, science educators may gain clearer insight into scientific discovery and problem-solving while moving toward a *Gemeinschaft* of *science education.*

While it seems "dated and Western" to appeal to the reform agenda of Project 2061, which was aimed at developing scientific literacy for different grade levels for all Americans (AAAS 1989), its hegemonic roots, to some degree, may be uprooted if we advance the idea that we find certain *attitudes/habits of mind* manifest in various shared rhetorical forms across our human population:

> There are… certain features of science that give it a distinctive character as a mode of inquiry. Although those features are especially characteristic of the work of professional scientists, anyone can exercise them in thinking scientifically about matters of interest in everyday life… All sciences share certain aspects of understanding- common perspectives that transcend disciplinary boundaries. Indeed, many of these fundamental values and aspects are also the province of the humanities, the fine and practical arts, and the social sciences. (AAAS 1990, p. xii)

These desirable human habits of mind begin with three: curiosity, openness to new ideas, and informed skepticism. Coupled with creativity, these fundamental habits are crucial to the common human struggle for progress and survival. Dewey (1910) writes in his classic *How We Think*, "The history of culture shows that mankind's scientific knowledge and technical abilities have developed, especially in all their earlier stages, out of the fundamental problems of life" (p. 167).

If our approaches to science education begin to reflect the commonality of thinking found throughout the world community of science, then the utility of "formal" and "informal" science education will meet the needs of students who wish to become scientists, as well as those who do not (National Science Teacher Association [NSTA] 1999). We suggest that by encouraging the practice of basic human modes of thinking (i.e., habits of mind, the propensity to wonder and explore, raise questions, challenge others' evidence, act with environmental and social conscience), we will also provide our students with modes of thinking that will transcend the realm of orthodox science. More importantly, we increase the likelihood that students will develop adaptive, organic lenses of viewing the world founded on reflective/reflexive thinking, intersubjectivity, and the practice of valuable habits of mind manifest in our actions and material products. Doing so, to our way of thinking, is a form of responsible education closely aligned with the practice of social justice.

By encouraging responsible scientific thinking, we aim to foster conscientious scientific practices for all students. Within the scientific community, "conscientious" may be viewed as the attitudes and actions that demonstrate great care and attention to conducting any task. However, this requires not only technical competence but moral aptitude as well. There must be present a sense of *rigor* that stands in contrast to what many engaged in "professional ethics" would think of as merely a "sense of right and wrong." In contrast, we would like to suggest that (science) education, in the pursuit of rigor, focus on formation of what Green (1999) terms the *conscience of craft*. The metaphors typically used here include phrases like "hitting the mark" and "perfect practice" reflecting traditions of the classic Greeks who equated morality with skill and craft. It is in this sense that we wish to advance rigor as the ability to skillfully craft judgments and initiate actions out of a cacophony of partial and often conflicting evidence. These are tools of virtue – crafted in such a way as to live skillfully and prudentially (Roberts 1988). To this we emphasize that membership in community – being part of a pluralistic world – carries with it moral obligations to the welfare of that community. (It is interesting to note that the Greek word for "individual" was *idiotes* for someone who was disengaged from the polis and all aspects of public and community life. Of course, contemporary etymological derivation gives us the word "idiot.")

Throughout history, human communities around the world have negotiated their environment by collecting and interpreting data in order to construct, critique, alter, and disseminate knowledge. It is important to understand that all of our students possess their own forms of indigenous knowledge and understandings of locally developed problem-solving (scientific) inquiries. The sooner students' background experiences and personal explanatory frameworks are acknowledged and honored, the more readily their educative impact may be actualized. A fishing trip with an elder, building a fort with a friend, and the artistic expression of dance and music are all experiences that afford valuable tacit information derived from the practice of human habits of mind. If we view the collective experiences of our students as sources of important information that can help guide our pedagogy and determine modes of assessment, then we will strengthen our ability to forge stronger normative bonds with our students. Moreover, as science educators and researchers, we will find common understandings for conceptualizing scientific literacy as a human activity.

Conscience of Craft Through Socioscientific Reasoning

Zeidler and Sadler (2008, 2011) and Sadler et al. (2007) have depicted socioscientific reasoning (SSR) as a principled form of functional scientific literacy on analytic grounds, identifying features of practical reasoning that appear to apply to a wide array of contextual socioscientific issues (SSI). The SSI framework seeks to involve students in discourse and decision-making entailing current social issues with moral or ethical implication embedded in scientific contexts (Sadler 2004; Zeidler and Keefer 2007; Zeidler et al. 2005). These issues provide opportunities for teachers to engage their students in active reflection by providing them with experiences in which to consider how those issues relate to their own lives, as well as the quality of life in their community. Socioscientific reasoning abilities include *recognition of complexity of SSI, examining issues from multiple perspectives, understanding that SSI are subject to ongoing inquiry,* and *exhibiting skepticism*. This model is constructed upon a foundation of practical human attitudes/habits of mind, which provides our students with the means to evaluate and construct their own ways of thinking along common denominators. The assumption here is that the greater epistemological sophistication along these dimensions, the better students can apply their thinking to varied contextual matters across disciplines and cultures. While the content or contexts of what students' reason about vary across different subject areas and even different cultures, the kinds of SSR structures evoked, reflecting foundational habits of mind, remain essentially consistent. The ability to do so in intellectually honest ways would be a model case of functional scientific literacy in action.

When framed in the above manner, providing the conditions necessary to facilitate functional scientific literacy becomes a necessary priority for all realms of science education, establishing an essential experience for all our students no matter their future objectives. Not only will each individual benefit from acquiring the tools necessary to understand our science, technology, engineering, and mathematics (STEM)-impacted society, they will also have the opportunity to develop and practice the kind of habits of mind that will ultimately lead to the crafting of conscientious moral judgments in any realm of social discourse.

Fostering Responsible Scientific Thinking Through Agency

Sociocultural perspectives in science education have compelled those who recognize the power and potential benefits it holds for our students to mesh scientific literacy with a sense of personal identity. Equally important is the development of shared commitment to collective agency at the group and community level. To help realize this, pedagogy needs to be transformative in both formal classroom contexts and informal social settings (Aikenhead 1996; Albright et al. 2008; Kelly 2011; Lemke 2001; Zeidler et al. 2011). Both identity and agency entail the ability to engage in reflective thought and apply one's awareness of epistemic schemes to new environments and social settings. This may be likened to an evaluative perspective, whereby "schemas" are turned upon themselves through reflexive thinking (Green 1999). Sewell (1992) describes the notion of agency in the following manner: "Agency entails an ability to coordinate one's actions with others and against others, to form collective projects, to persuade, to coerce, and to monitor the simultaneous effects of one's own and others' activities" (p. 21).

It seems reasonable, then, to use the construct of agency to foster responsible scientific thinking and ultimately the development of character. We may envision the role of science educator as a facilitator offering gateways to specialized content knowledge. Concomitantly, science educators also provide students the opportunity to acquire and *structure* schemas (see Sewell 1992 for further discussion of how his "schemas" connect with his Theory of Structure) in a manner that allows them to reflexively evaluate their scientific knowledge and adapt their thinking about that knowledge to different contexts with openness of mind. Doing so is *transformative* in that it allows freedom of thought and the liberating power to engage in and be part of the social and natural environment. The semiotic medium, of which these schemas are constructed, includes basic human sensory data, the practice of certain desired habits of mind, human interactions, and particularly discourse (Berkowitz and Simmons 2003). The challenge before us is to develop educational experiences that allow students to interact in meaningful ways that prompt the development of flexible schemas. Moreover, we must encourage investigations of the processes by which schemas are constructed and articulated into more *inclusive* and more sensitive to *global community structures*. Finally, it is helpful to remember that the construction and assembly of schemas requires more than communication through words; it necessitates deployment with actions and deeds.

We should recognize that each student arrives to our science classes with various schemas, which are fastened together with differing degrees of rigidity. As science educators, we have the opportunity to encourage students to evaluate the processes by which they have come to acquire, construct, deconstruct, and arrange their personal schemas. Through this process of self-evaluation, reflective judgment, as well as reflexive thinking, students may begin to recognize how the habits of mind they already practice as human beings, their common human ways of solving problems, constructing knowledge, forming understandings, and interacting with others, should be linked to contributing to and residing in a global scientific community. Therefore, we must strive to provide authentic experiences for our students that will help them cultivate an awareness of their own/shared reasoning, the processes by which they structure, refine, and evaluate their understandings to the evidence they have to work with, in order for them to learn to adapt their personalized schemas to an ever-changing pluralistic context. By doing so, we encourage students to take ownership of their thinking.

As we strive to promote functional scientific literacy characterized by reflective judgment, the formation of conscience and the development of responsible scientific thinking that they together comprise, we find that the formation of character becomes a necessary component to foster responsible agency in the global science education community. What to do then? In order to develop ways to negotiate science education in our pluralistic society, we have to consider each student and accentuate common human ways of thinking in order to make science accessible. Getting to these structures may be in reach of science educators by providing opportunities to acquire agency that equates functional scientific literacy to lifelong learning. To fully realize this aim, to provide the conditions necessary to prompt students to construct flexible schemes and structures – aiding them in understanding and participating in the community of science – it is imperative to consider the development of psychological characteristics that lead to the formation of character.

The Formation of Character in Science Education

When considering the nature and nurture of character, including the pedagogical implications for science (or any) education, one ought to begin with the end, i.e., the outcomes. We have already noted many characteristics of character that can be the focus of education for responsible scientific literacy and practice, e.g., conscience, moral agency, moral reflection, and a social-justice orientation. For us, character is the set of psychological characteristics that motivate and enable one to function as a competent moral agent (Berkowitz 2011). In essence, one needs a composite set of cognitive, affective, and behavioral (performance) characteristics wedded to a moral identity or moral self-system (including a conscience). It is unrealistic to expect that science educators can or should be solely responsible for the moral formation of their students, just as that would be too much to expect for any educator. Education happens in a context and with a wide array of experiences and forces at play. But, as we have argued, science education *should* play a role in contributing both to the formation of character in students and to the application of character to responsible scientific functioning. In fact, like any aspect of schooling, science education cannot avoid impacting student character development. No matter how hard educators (of science or any other subject) try to dodge the responsibility of character education, every educator unavoidably impacts student character development. There is no off switch to character education; it inevitably comes with the territory of education. The remaining question then is whether an educator will embrace this reality and adopt intentional effective strategies or simply allow his or her impact on student character to be unguided and perhaps harmful.

Several pedagogical strategies are effective in contributing to the formation of student character (Beland 2003; Berkowitz 2011; Berkowitz and Bier 2005). Among these are constructivist/experiential teaching, peer interactive activities and structures (especially cooperative learning and moral-dilemma discussions), service to others, and moral reflection. These are not mutually exclusive components; their strategic inclusion in teaching can foster the development of character and encourage responsible scientific thinking and acting.

We focus for a moment on the former classroom of Ron Berger (2003), to provide a concrete example of the ideas above. Ron, now field director for Expeditionary Learning Schools, was an elementary school teacher in rural Massachusetts for 28 years. While not exclusively teaching science, he did rely heavily on science as a means of fostering character and, as the title of his books suggests, “an ethic of excellence” and “a culture of craftsmanship.” Ron used project-based learning as his teaching mode and built his classrooms around it. One of his more ambitious projects exemplifies this approach well. A friend and colleague of his approached him about using a new piece of scientific equipment (Inductively Coupled Plasma Mass Spectrometer; ICP-MS) at a local college to test the well water at homes in Ron's rural town. Because this is amply chronicled in Ron's book, we will only offer a few highlights here.

The 11-year-old students in Ron's class (many of whom came from homes where higher education was lacking) were going to do a scientific study of the well water at each residence in the town (including their own and Ron's homes), scientifically, responsibly, and professionally. They began with a pilot study of surface water, using simpler methods. They learned about scientific protocols and relevant information about water, heavy metals, etc. Students from the college worked with them to learn about the instrument, spread sheets, web sites, etc. Ron worked with them to talk about scientific ethics (all data were confidential and anonymous), etc. Doing so applied the method of moral reflection as they talked about issues of privacy and confidentiality. The project was structured to be done in student teams (cooperative learning, peer interactive methods). The products included individual diagnostic and, when necessary, remediative letters to each family and a scientific report to the community (opportunities for moral action).

The students found this work engrossing and took the moral responsibility very seriously. Berger (2003) reports:

> Did they take the work seriously? You bet they did. People's health depended on their accuracy. The whole town and lots of nervous families were anxiously awaiting their findings. When we got our first data sheets with test results, each child in the class analyzed the results of a particular family well in order to prepare a report for the family. We were about fifteen minutes into the study analyses when one boy noticed a level of a metallic element that was above federal standards. He began to cry. Other students gathered around him. Though we had discussed this for weeks and had memorized federal standards exactly for this purpose, it took on a new meaning when it was real data. This was a family's drinking water; this affected the life of a kindergartner in our school; a boy we knew and loved. (pp. 112–113)

These were the same students who at the outset were hoping to find problems with water. Doing real work with real import for real people changed that perspective. Having meaningful and complex discussions about moral topics provides the impetus for the kind of moral discourse that is critical to the development of moral reasoning (Berkowitz and Simmons 2003).

The social context and responsibility were not limited to issues surrounding the quality of people's water either. When real estate agents caught wind of the project, they became very threatened by the prospect of potentially dropping property values. Ron actually created a legal committee of 11-year-olds and a parallel media committee to deal with press inquiries. When lawyers, real estate agents, or reporters contacted the school, they had to deal with the student committees. Rather than an abstract lesson on environmental threats, this was real-world SSI that contextualized learning about the interface of science, society, and ethics.

Earlier we discussed the notion of a conscience of craft. The Character Education Partnership has embraced the duality of character as including both moral character and performance character (following Lickona and Davidson 2005). Berger (2003) exemplifies this notion of a wedding of both moral agency and an ethic of excellence. His goal is overtly to influence student development so that they not only acquire both an ethic of excellence and a conscience of craft but to have them invariably linked to a moral compass. Science is one particularly appropriate way to do so.

By relying on pedagogical methods that are known to impact the formation of moral and performance character, science educators can promote student development through science education. If the goal is to achieve scientific literacy through responsible science, then applying character education methods to science education is the perfect solution. Berger (2003) intuited the complex interplay of academic science learning, service learning, and community at many levels. He worked hard to build an ethical learning community in his classrooms, around science and other content areas. Students learned about, reflected upon, and crafted a moral learning community of scientists. Berger states that "Many of these students hope to become scientists. In fact, as Maria said to her fellow students, We already are!" (p. 116). But he also worked hard and deliberately to bridge the classroom and school community with the broader surrounding community (e.g., the safety of well water in all the homes in his community). Furthermore, he let students construct a deep and complex understanding of the moral responsibility that science requires. His projects were infused with moral discourse about implications, obligations, impacts, and ethical research concerns. This moral reflection upon the responsibilities of doing science was in large part what made his classroom a place of power, a power that fostered simultaneously the craft and conscience of science.

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Chapter 8
Assessment of Socio-scientific Reasoning: Linking Progressive Aims of Science Education to the Realities of Modern Education

Troy D. Sadler

This chapter begins with a reflection on the contributions of the previous chapter. While the previous chapter looks broadly at the notion of scientific literacy and how it relates to thinking responsibly, this chapter focuses specifically on one idea raised by Zeidler, Berkowitz, and Bennett: socio-scientific reasoning. The origins of socio-scientific reasoning as a measurable construct are explored, and its sub-components are defined. The chapter discusses how socio-scientific reasoning has been assessed and ways in which the current work needs to be extended in order to impact practice and policy.

Relating This Chapter to the Previous Chapter

In the previous chapter, Dana Zeidler, Marvin Berkowitz, and Kory Bennett start with the idea of what it means to think responsibly. As a part of their conceptual analysis, they situate responsible thinking in social contexts and draw explicit connections to the realm of science. This leads to a discussion of scientific literacy, and the authors' take on scientific literacy is admittedly broad. They invoke Roberts' (Roberts 2007) notion of Vision II scientific literacy, which itself is expansive relative to many traditional conceptualizations of scientific literacy that focus exclusively on science content and/or process. But Zeidler, Berkowitz, and Bennett take scientific literacy broader still by linking the notion to character "which in turn requires the formation of conscience through the development and practice of reflexive judgment." As the authors unfold the argument, they draw on theory, history, philosophy, ethics, and etymology to craft a sophisticated and compelling account of what education, and science education more specifically, ought to be about.

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My intent in writing this chapter is considerably less ambitious. Whereas the previous chapter draws on a breadth of scholarship across multiple domains, this chapter will address a more limited focus. It will address issues that relate and respond to the demands and constraints of today's political climate. Theory, philosophy, ethics, etc. fit nicely in academic discourse; not so nicely in political discourse. I don't mean to suggest that theoretical arguments, like those offered by Zeidler and his colleagues, don't have a place in discussions of policy – but I do suggest that they need to be balanced with pragmatism. Zeidler, Berkowitz, and Bennett offer a conceptually sound argument for transforming education, but the question of how their call will be translated at the level of policy and practice remains unclear.[1] This entire volume intends to challenge us to think differently about issues of policy and assessment, and the previous chapter certainly accomplishes this goal. But I suspect that science teachers and curriculum specialists, school administrators, and legislators will struggle to translate these broad and ambitious ideas into practices and policies.

In this chapter, I identify potential connections to policy and practice; therefore, rather than considering comprehensive notions of scientific literacy and responsible thinking, I focus on a specific aspect of these constructs. Zeidler, Berkowitz, and Bennett tackled the problem of promoting responsible thinking by framing a very broad discussion of scientific literacy and character formation. This chapter follows a different approach by examining one element raised in the previous chapter, socio-scientific reasoning, and exploring its implications for teaching, research, and policy.

Socio-scientific Reasoning

Origins of the Construct

If the phrase socio-scientific reasoning had been used in a specific way, my research group was unaware of it when we started thinking about the idea in 2005. At the time, we were working on a curriculum and technology implementation project, which featured a socio-scientific issue as the central organizing theme (Barab et al. 2007). Before that project, I had spent quite a lot of time thinking about how people negotiate and make decisions regarding socio-scientific issues (SSI; complex social issues with substantive connections to science). In implementing the project, we partnered with a group of educational technologists and learning scientists interested in using games and virtual environments to transform educational contexts. One of the environments they created featured an environmental issue-based SSI. This platform and partnership opened the door to new opportunities in studying how SSI could be incorporated in classrooms and what the effects of integrating SSI in classrooms might be.

[1] Having worked with Dana Zeidler extensively, not to mention the fact that I count him as one of my closest friends, I offer this critique carefully.

As we considered research design decisions, we discussed fairly standard metrics for documenting student learning. We created tools for measuring student understanding of related science content and planned to examine how student performance on those measures changed following participation in the project. This was a reasonable plan for considering how the curriculum and technology supported content understandings, but we were not satisfied that this approach was able to document what we were trying to do in terms of structuring instruction around a SSI. Our dissatisfaction related to the question of why we should teach science in the context of SSI in the first place. In short, what is it about SSI-based education that makes it worth pursuing? Evidence shows that teaching science through SSI can increase learning of content (e.g., Dori et al. 2003); however, several other approaches to science teaching that do not make use of interesting, real-world issues have shown similar results. Advocates of SSI-based education certainly want students to learn science content through their explorations of SSI, but science content learning is seldom the only or even the primary reason for using issues as contexts for science education. Those of us who argue that SSI should play an important role in science education tend to emphasize the significance of SSI as a curricular tool for supporting development of progressive notions of scientific literacy. This takes us back to Roberts' (2007) notion of Vision II scientific literacy and Zeidler, Berkowitz, and Bennett's progressive goals for science education.

As my colleagues and I considered how we ought to proceed with our classroom-based research efforts, we found ourselves at loggerheads between a desire to make claims about the usefulness of our SSI intervention in terms of Vision II scientific literacy and the research tools at hand that only allowed us to say something about content understandings. Other projects had tackled this problem by using other measures as a proxy for Vision II scientific literacy. Some of these variables have included student interest and motivation (e.g., Harris and Ratcliffe 2005), argumentation (Zohar and Nemet 2002), and reflective judgment (Zeidler et al. 2009). We opted to address the challenge more directly.

Defining the Construct

Rather than trying to measure a variable that related tangentially to some aspect of scientific literacy and SSI, we sought to create a construct that directly captured what it was that we hoped students would learn through explorations of SSI. We identified this construct as *socio-scientific reasoning*. The idea was to create a construct that subsumed some of the things that people had to do if they were to engage in informed decision-making related to SSI. We did not want to focus on specific knowledge or practices important for only a single issue (e.g., genetically modified foods) or a class of issues (e.g., genetic engineering); rather, we sought to identify and describe understandings and practices relevant to all or at least most SSI. Given the highly contextual nature of SSI (by definition), the identification of invariant features of SSI was challenging. In attempting to identify these invariant features, our conversations were influenced by several lines of research including scientific argumentation, nature of science, scientific habits of mind, and scientific inquiry.

Ultimately, we framed socio-scientific reasoning in terms of four practices essential for responsible decision-making in the context of any SSI. The four practices, as presented in our original work in this area, are:

1. Recognizing the inherent *complexity* of SSI
2. Examining issues from multiple *perspectives*
3. Appreciating that SSI are subject to ongoing *inquiry*
4. Exhibiting *skepticism* when presented with potentially biased information (Sadler et al. 2007, p. 374)

These four practices (*complexity*, *perspectives*, *inquiry,* and *skepticism*) became the substance of what we sought to document in terms of students' socio-scientific reasoning.

Our basic argument was that science education should support students becoming progressively more adept at engaging in the practices subsumed by socio-scientific reasoning. For example, learners may initially consider a particular SSI as relatively simple. We postulated that a successful science education would help students recognize the inherent complexity of all SSI. Consider the issue of global climate change. A naïve response to climate change would be to suggest that simply cutting emissions of carbon dioxide would solve the problem of global climate change. We would like to see students move toward a more sophisticated conceptualization of climate change, one that recognizes the complex dynamics among issues related to atmospheric composition, energy transformation, the economics of energy and pollution control, politics, etc. We were not suggesting that all students should become experts in atmospheric science, economics, and politics; however, we were arguing that science education should help students become more aware that issues like climate change tend to be underpinned by various complex interrelationships. Simple, straightforward solutions to these kinds of issues rarely (if ever) produce expected or desired results.

The previous paragraph outlines the range of practices associated with the *complexity* dimension of socio-scientific reasoning. Similar ranges of practice could be constructed for the other three dimensions: *perspectives*, *inquiry*, and *skepticism*. Students may naively begin analysis of a particular SSI by considering only one perspective. These students' practices would become more sophisticated if they actively sought to analyze the issue by taking into account the varied perspectives that may be adopted in response to the issue. Likewise, students may naively assume that the current state of understandings is sufficient for resolving a SSI, despite the fact that one of the defining elements of SSI is the idea that SSI are areas of open inquiry. That is, there are always unanswered questions related to SSI in terms of the underlying science, social implications, or both. It would be desirable for students to come to appreciate this need for ongoing inquiry and even be able to identify the kinds of investigations needed to answer those open questions. Finally, the initial formulation of socio-scientific reasoning offered skepticism, a scientific habit of mind, as an important practice. Naïve reactions to a particular SSI and information presented about that SSI from sources with vested interests may not adopt appropriate levels of skepticism. With experience, one might expect that individuals would become more likely to exhibit skepticism in the face of potentially biased information. Together, these aspects (complexity, perspectives, inquiry, and skepticism) were positioned as the constitutive elements of socio-scientific reasoning.

The language we used originally to justify the socio-scientific reasoning construct remains relevant:

> Socioscientific reasoning is presented as a theoretical construct designed to uniquely capture the array of practices fundamental to the negotiation of SSI. By proposing socioscientific reasoning as an educationally significant construct and framing it in terms of specific practices, we have intended to provide a more tangible response to the question guiding this paper: What do students gain by engaging in socioscientific inquiry? (Sadler et al. 2007, pp. 377–378)

Socio-scientific Reasoning and Policy

Before launching into the details on socio-scientific reasoning and its sub-components, I suggested this chapter would attempt to say something about policy. The aim of the sections that follow will be to make connections between the socio-scientific reasoning construct and policy issues. Today's educational climate is dominated by notions of accountability and large-scale assessment. I (Sadler and Zeidler 2009) and others (e.g., Linder et al. 2011) have argued elsewhere that efforts to promote progressive visions of scientific literacy can only be successful in this climate if tools become available making it possible to document ways in which student achievement and performance improves. This is where socio-scientific reasoning becomes useful.

If we (advocates of SSI-based teaching or other innovative approaches to science education) want to affect today's science teaching and learning on a broad scale, then we have to show how students are progressing. This chapter has already highlighted why traditional measures of science content fail to hit the mark in this area, but these traditional measures – mostly forced-choice recall-type exams – are what is available. If we fail to offer viable alternatives, then the same standardized tests will continue to be the metric of choice. We need other options that showcase student understandings and practices beyond recall of scientific formalisms. Socio-scientific reasoning as a specifically defined construct has potential to serve as a framework for assessment that can offer these kinds of alternatives.

Assessment of Socio-scientific Reasoning

Our initial work in the area of socio-scientific reasoning used interviews to document variation in student practice associated with the four aspects of socio-scientific reasoning (Sadler et al. 2007). In this study, we worked with middle school learners who had recently completed a SSI-based science unit and challenged these learners to demonstrate their abilities to recognize issue complexity, examine multiple perspectives, prescribe ongoing inquiry, and exhibit skepticism on issues related to, but not the same as, the SSI confronted during instruction. This work resulted in the development of a framework for characterizing diversity of socio-scientific reasoning practices. Table 8.1 presents the range of practices observed.

Using interviews to measure student aptitude is obviously not a strategy that will work for large-scale assessments, but this work helped us think about the kinds of practices that we might assess and how we might do that in contexts more amenable to larger samples.

Our next attempt to assess socio-scientific reasoning came in the context of an intervention study conducted in local classrooms. We were interested in studying implementation of a SSI-based unit within “normal” classroom environments. I say “normal” just to indicate that there was nothing unusual about the schools, classes, or teachers, other than the fact that they were willing to let us come in and observe how they implemented SSI teaching. My research team worked with the teachers to develop curriculum to fit their class needs, but the teachers implemented the units and made their own pedagogical decisions.

We ended up working with two teachers from two different schools, five different classes, and 151 students. Our goal for the project was to closely examine SSI implementation and document ways in which the SSI unit supported student development of related science content and socio-scientific reasoning. The unit was based on global climate change, and in terms of content, we focused on the particulate nature of gases, atmospheric composition, and chemical reactions with emphasis on the combustion reaction. To assess content learning, we developed tests of content using open-ended formats that challenged students to articulate ideas specific to the material covered as well as multiple choice items aligned to the state science standards upon which the unit was based. Students demonstrated statistically significant gains on both tests following the SSI unit (Klosterman and Sadler 2010).

Not surprisingly, assessing socio-scientific reasoning was far more challenging than assessing content knowledge. Building on what we had learned in the initial interview-based study, we developed the “Socio-scientific Issues Questionnaire” (SSIQ), an online, adaptive testing protocol that allowed us to collect forced-choice as well as short-answer responses (Sadler et al. 2011). The adaptive functionality made it possible to customize questions to some extent. For example, following a question that challenged students to think about the kinds of information that might be needed to solve a particular SSI, we could pose different kinds of follow-up prompts based on a student’s initial response.

The SSIQ challenged the students to consider a localized SSI. Students were presented with a narrative account of an issue accompanied by a diagram and then asked to respond to several questions. The instructional context used climate change as the organizing theme; the issues used in the SSIQ were related in that they were SSI and touched on environmental issues, but they were not focused specifically on climate change. One of the scenarios used and its accompanying questions are presented in the Appendix.

Table 8.1 Range of socio-scientific reasoning practices

	Level 1	Level 2	Level 3	Level 4
Complexity	Offers a very simplistic or illogical solution without considering multiple factors	Considers pros and cons but ultimately frames the issue as being relatively simple with a single solution	Construes the issue as relatively complex primarily because of a lack of information. Potential solution tends to be tentative or inquiry based	Perceives general complexity of the issue based on different stakeholder interests and opinions. Potential solutions are tentative or inquiry based
Perspectives	Fails to carefully examine the issue	Assesses the issue from a single perspective	Can examine a unique perspective when asked to do so.	Assesses the issue from multiple perspectives
Inquiry	Fails to recognize the need for inquiry	Presents vague suggestions for inquiry	Suggests a plan for inquiry focused on the collection of scientific or social data	Suggests a plan for inquiry focused on the collection of scientific and social data
Skepticism	Declares no differences among stakeholders	Suggests that differences likely exist among stakeholders	Describes differences among stakeholders	Describes differences among stakeholders and discusses the significance of conflicting interests

Information excerpted from Tables 1 and 2 in Sadler et al. (2007)

Table 8.2 Rubric used for scoring the inquiry aspect of socio-scientific reasoning the SSIQ

Level 0	Level 1	Level 2	Level 3	Level 4
Suggests that additional inquiry is not necessary	Suggests that additional inquiry is necessary but does not identify a specific line of inquiry	Suggests that additional inquiry is necessary and identifies one specific line of inquiry	Suggests that additional inquiry is necessary and identifies two specific lines of inquiry	Suggests that additional inquiry is necessary and identifies three or more specific lines of inquiry

Information excerpted from Table 4.5 in Sadler et al. (2011)

We relied heavily on the conceptual and empirical work that had been done in conceptualizing socio-scientific reasoning and its subconstructs for designing the SSIQ and the rubrics used for scoring responses. We did make one distinct change relative to the initial formulation: the *skepticism* and *perspectives* components were combined into a single sub-construct. Conceptually, both of these components relate to students' abilities to anticipate how parties with different interests might react to a particular issue; therefore, we decided to combine these as a single measure.

We created three rubrics, one for each of the aspects measured: *complexity, inquiry,* and *perspectives* (which subsumed the original *perspectives* and *skepticism* aspects). The rubrics followed the same basic format. Each had five levels (0–4). The first level (0) indicated that a student did not understand a particular socio-scientific reasoning sub-construct. The next level (1) indicated that a student understood the basic idea but could not offer an example in support of that idea. The three highest levels (2–4) offered more detailed descriptions of the sub-construct. One of the rubrics is presented in Table 8.2 as an example; the other two followed the same basic form.

Teaching for Socio-scientific Reasoning

Unlike the comparisons of pre- and posttests of science content, the students participating in the SSI unit focused on climate change did not show statistically significant gains on measures of the three socio-scientific reasoning aspects (*complexity*, *perspectives*, and *inquiry*). The immediate interpretation of this result is that students' socio-scientific reasoning practices did not improve. However, there may be several different explanations for this result.

First, this particular unit may not have been designed or implemented well enough to affect changes in socio-scientific reasoning. One of the things that we, as curriculum designers, struggled with was deciding how much to generalize the SSI instruction. By definition, SSI-based education is linked to a particular issue. The hope is that learner experiences with specific issues will better prepare the learners for engaging with other issues. That is the whole idea behind socio-scientific reasoning – developing practices that can transfer across particular issues. However, as a community, we have little empirical evidence of how this happens. It might be the case that science educators need to take an approach akin to the "explicit approach" championed by many researchers and teachers interested in supporting students' understandings of nature of science (Lederman 2007). To transfer practices from one socio-scientific context to another, it may be necessary to be very explicit about how practices for one issue may be applicable to other issues. This was not a general principle adopted in the SSI unit in question.

A second possible explanation relates to the timing of the unit and the nature of the socio-scientific reasoning construct. The global climate change unit was implemented over 2 weeks. Given the constraints teachers feel related to the coverage of content and the limits on their time (Louis et al. 2005), we felt grateful to have our partner teachers focus on a particular SSI for this length of time. However, two weeks may not be enough time to change practices as complex as socio-scientific reasoning. It could be the case that assessable changes in socio-scientific reasoning would only be reasonable to look for after much more sustained efforts. Again, though, we do not have enough empirical findings to confirm or reject this conjecture.

A third possible explanation of the findings relates to the assessment process. The instrument and assessment rubrics may not be designed well enough to document changes at levels commensurate with what can be supported through classroom science. This explanation challenges us to improve the ways we measure the construct. Improving the instrumentation and scoring protocols undoubtedly would benefit this line of research and ultimately SSI-based education.

Where We Go from Here…

This chapter began with a critique of the previous chapter in terms of its pragmatic utility for informing policy, practice, and research. I argued that calling for character education as a part of science education may be an excellent idea, but translating this idea in today's climate of politicized education is uncertain. Despite the conceptual strength of integrating character education into science teaching and learning, advocates of this progressive orientation must attend to how teachers, administrators, and legislators will respond to these calls without provisions in place that acknowledge the values and priorities of modern schools and the political systems in which they are situated.

One could legitimately level the same critique against my chapter. I am not offering a foolproof method for improving student learning and performance that teachers can start using immediately – of course, no such method exists. Nor does this chapter offer a proven measure of scientific literacy that states can immediately enact as a means of responding to calls for accountability. However, this chapter does provide a new link between the progressive aims of science education that so many of us in the science education community have been calling for and the prevailing demands for documenting gains in education.

Calls for accountability, measured largely through standardized assessments, are a reality of today's schooling, and if we are to remain relevant, the science education community must engage in this discourse. Whether we like it or not, the significance of standardized tests is not going away soon. I think we have to offer better alternatives to tests that measure the wrong things. It is relatively easy to measure student recall of scientific formalisms, and so, it is not surprising that these are the kinds of measures in use for large-scale testing (Orpwood 2001). The SSIQ, discussed in this chapter, is by no means ready to be incorporated as a part of large-scale testing, but developing strategies for valid and reliable assessment of socio-scientific reasoning is a step in the right direction. The development of good measures will allow the community to begin answering key questions related to the promotion of socio-scientific reasoning, including the following:

- To what extent is socio-scientific reasoning transferable across contexts?
- How does socio-scientific reasoning develop over time?
- How can instruction support socio-scientific reasoning practices?
- What kinds of learning experiences are most suitable for supporting socio-scientific reasoning practices?

Better measures also will help offer better arguments to teachers, administrators, and legislators that scientific literacy must involve more than relatively simple recall of scientific facts and that *responsible* assessments of students and programs must capture a greater range of what students may actually gain through their science education experiences.

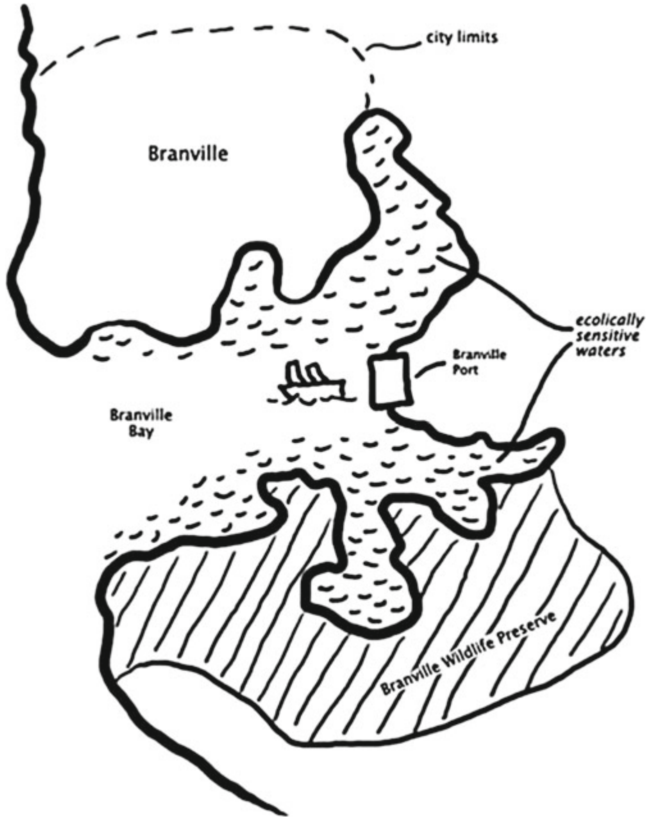
Appendix: SSIQ Prompt and Questions

Branville Bay is located on the Gulf of Mexico. The city of Branville has built up along the northern border of the bay, and a wildlife preserve has been established along the southern border. The Branville area was the ancestral home for several tribes of Native Americans. More recently Branville has become a major shipping port. Ships from all over the world dock at Branville Port delivering products like oil, clothing, toys, and fruit. These products are then distributed throughout the United States. Businesses in the US also use the port to send their products around the world (see the figure below).

Branville Bay is a sensitive ecological area serving as the breeding grounds for many fish, birds, and other wildlife. There are strict laws that govern fishing in the most sensitive areas of the bay. However, these laws do not apply to the Native Americans still living in the area because they've claimed ancestral fishing rights in the area.

Managers of the Branville Wildlife Preserve have started reporting declines in fish counts, bird counts, and water quality measures. These managers have concluded that the heavy ship traffic moving in and out of Branville Port is damaging the Branville Bay ecosystem. Port Authorities claim that their ships stay in deep water channels and do not travel into the most sensitive waters of the bay. They argue that the Native American fishers are the most likely culprits because they use boats and fish in the bay's most sensitive waters.

Local leaders are trying to decide what to do.



Map of Branville Bay and the surrounding area

Questions:

1. Can the Branville Bay situation be solved easily?

   (A) Yes
   (B) No

   If A, then: Explain why you think the Branville Bay situation should be easy to solve.
   If B, then: Explain why you think the Branville Bay situation cannot be solved easily.

2. If you were responsible for deciding how to resolve the Branville Bay situation, would you need additional information regarding the situation before making your decision?

   (A) Yes, I would need to have additional information to make a decision.
   (B) No, I have sufficient information to make a decision.

   If A, then: What kinds of additional information would be necessary for you to make a decision regarding the Branville Bay situation?
   If you were responsible for deciding how to resolve the Branville Bay situation, what would you recommend doing as a next step? Please explain why this would be an effective strategy.
   If B, then: If you were responsible for deciding how to resolve the Branville Bay situation, what would you recommend doing? Please explain why this would be an effective strategy.

3a. In the previous prompt, you were asked to suggest a course of action for the Branville Bay situation. Describe the strengths of your proposed approach.
3b. Describe the weaknesses of your proposed approach.
4a. A group of concerned Branville citizens gathered to discuss a solution for the Branville Bay situation. The group suggested that Native American fishing permits in the most sensitive waters of the bay be reduced by half and that ship traffic be reduced by 1/3 (i.e., only 2/3 of the current number of ships traveling in the bay could continue coming into the bay).
4b. How do you think Branville Port Authorities would respond to this suggestion? Please explain your response.
4c. How do you think Native Americans in Branville would respond to this suggestion? Please explain your response.
4d. How do you think managers of the Branville Wildlife Preserve would respond to this suggestion? Please explain your response.

5. In response to the previous questions, you commented on how three different groups (Port Authorities, Native Americans, and Wildlife Managers) would respond to a proposed solution. Which of the following statements most accurately reflects your responses?

   (A) The Port Authorities, Native Americans, and Wildlife Managers would have similar responses to the proposed suggestion.
   (B) The Port Authorities, Native Americans, and Wildlife Managers would have different responses to the proposed suggestion.

   If A, then: Explain why you expect the Port Authorities, Native Americans, and Wildlife Managers to have similar responses to the proposed suggestion.
   If B, then: Explain why you expect the Port Authorities, Native Americans, and Wildlife Managers to have different responses to the proposed suggestion.

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Chapter 9
Assessment Across Boundaries: How High-Quality Student Work Demonstrates Achievement, Shapes Practice, and Improves Communities

Alison Rheingold, Jayson Seaman, and Ron Berger

The 2010 Deepwater Horizon oil catastrophe illustrates the increasing need for citizens to understand the scientific underpinnings of the economic, social, and environmental conditions affecting their lives. The broad impact of the disaster made it clear that science is everybody's business. Scientific literacy is now crucial not just for marveling at the sophistication of modern technology but for evaluating its risks and benefits as well as for imagining solutions to historically new problems. Schooling can play a substantial role in developing scientific literacy of this sort, especially when children engage in research that contributes to improving the economic, social, and environmental landscape of their own communities. Such engagement also moves beyond science as a purely academic exercise, helping children become stakeholders in their own economic and environmental futures.

In this chapter, we ask readers to imagine what "accountability" would mean if schooling is organized around scientific literacy and community engagement, to imagine community members and organizations collaborating to support the work students do in school, and to imagine "assessment" as a practice that not only measures progress toward academic goals but also ignites students' abilities to deal with authentic community issues. In this chapter, we discuss two exemplary cases of student-led, science-based research that demonstrate these principles.

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The concern motivating this chapter is that a singular emphasis on test scores as the marker of student and school success not only risks obstructing the social, economic, and environmental dimensions of scientific work, or scientific literacy, it also diminishes the powerful role assessment practices can play in school reform. Two core aspects of educational work in particular suffer when test scores are elevated above all other indicators of school quality: (1) products of student effort (i.e., the actual work students do in school) and (2) school and community relationships that undergird the development of real-world skills and knowledge. Our examples, which profile scientific literacy, show how expanding accountability to emphasize these aspects of schooling also can positively impact educational success. Expanding accountability to include multiple stakeholders inside and outside of schools, and to include varied indicators of school quality, can enhance academic success while strengthening the relationship between schools and communities.

We elaborate on three areas in particular: (1) thinking of student products and performances that produce "tangible results" as indicators of student achievement; (2) emphasizing the role of local community participation in education; and (3) expanding how assessment is considered, in general. These elements are used to envision reform programs that could make schools and communities jointly accountable not only for the growth and development of individuals but also for enhancing the praxis of social, economic, and environmental well-being of present and future generations.

We focus on two projects from urban schools that demonstrate the potential for high-quality student work to catalyze learning and provide tangible results to communities. We outline the projects' overall goals, the ways students engaged with disciplinary knowledge, the roles played by community partners, and the quantitative and qualitative indicators of the projects' lasting impacts. We apply *sociocultural theory*[1] to explain how these projects exemplify an integration of assessment practices, actual products of student work, and community involvement throughout the process of incorporating the accountability dimensions we propose herein. Our aim is to show how tangible results can be leveraged to improve educational quality to a greater extent than standardized testing alone. We conclude by discussing the policy implications for school science.

Cases

The schools below not only feature extraordinary student research projects, they are succeeding on traditional measures of achievement—test scores, graduation rates, and college acceptance rates. Students at the Springfield Renaissance School in

[1]Although there is a wide array of theories encompassing what is broadly known as sociocultural theory, we draw more specifically on activity theory (also known as cultural-historical activity theory or CHAT). For a comprehensive overview of this theory, see Roth and Lee (2007).

Springfield, Massachusetts, score considerably higher on math, reading, and science tests than those at comparable schools around the city and state. In a city where most cohorts of students do not surpass a 50 % graduation rate, 100 % of 9th graders entering school in 2006 graduated from high school in 2010 and all were accepted into college. Likewise, at the Genesee Community Charter School in Rochester, New York, students outperform district and state peers in reading, math, and science by large margins.

Aside from exceptional results on conventional measures, these schools are committed to having students and community members collaboratively generate meaningful work that addresses authentic social, economic, and environmental issues and a policy structure that supports it. Students engage in citizen science, actively researching solutions to civic problems while becoming stakeholders in their own work. We consider the development of this kind of scientific literacy to be a crucial aspect of public education—providing opportunities for students to engage in scientific inquiry whose tangible results matter to community members and to themselves and thus helping students use "scientific knowledge to negotiate and resolve complex societal issues" (Barab et al. 2007, p. 751). Both schools are also based on the whole-school reform model called *Expeditionary Learning* (EL). EL began in 1993 as a federally funded innovation for the New American Schools Foundation to implement their comprehensive reform model in ten schools. Currently operating in over 160 schools throughout the United States, the EL design combines school-wide pedagogical and cultural practices, centering on *learning expeditions*, which are extended, case-based explorations of academic topics focusing on larger guiding questions and shorter-term learning targets.

Case #1—Powering the 21st Century

Setting. The Springfield Renaissance School in Springfield, Massachusetts, describes itself as "college-bound." It opened in 2006 as a regular public district school with 6th- and 9th-grade cohorts and by 2010 serves grades 6–12. Six hundred and sixty-two students attended the school in 2009–2010; 74 % were students of color (26 % African American, 40 % Hispanic, and 8 % other students of color) and 26 % were White. About 60 % of these students were considered low income, and 10 % of students' first language was not English. The school was founded in partnership with Expeditionary Learning and received additional funding for professional development from the Bill & Melinda Gates Foundation.

Project and Culminating Products/Performances. In a 1-year-long environmental science class, 200 students across two subsequent academic years (100 10th graders in 2008–2009, 100 9th graders in 2009–2010) engaged in a learning expedition called "Powering the 21st Century." Embedded within the expedition was an exploration of energy sources, carbon footprints, and energy consumption in Springfield's public buildings. In hopes of engaging students in community-based

Overarching Goal of the "Powering the 21st Century" learning expedition: Make recommendations for SYSTEMIC CHANGE of energy sources and energy conservation in buildings (heat and light)
Guiding Questions:
1. How are we going to power cities in 21st century?
2. Where do we get our energy? What are we using it for, where they are getting it from, and what are the possibilities?
3. What are sustainable choices Springfield can make?
Environmental Science Learning Targets:
1. I can demonstrate how feedback loops work in natural and impacted systems. *[skill target]*
2. I can differentiate between different energy practices and their impact on the earth systems. *[reasoning target]*
3. I can identify sustainable practices for buildings and make recommendations to the city of Springfield. *[knowledge target]*
4. I can cooperate with classmates to develop solutions to scientific problems. *[character target]*

Fig. 9.1 Yearlong guiding questions for the "Powering the 21st Century" learning expedition

problems, science teacher Aurora Kushner approached the facilities engineer for the City of Springfield to plan a project that would be mutually beneficial: Students would do much-needed research on energy conservation in Springfield's public buildings, and the work would meet the Massachusetts curriculum frameworks.

Figure 9.1 shows the project's broad academic goals.

The expedition began by studying energy and energy conversions, laws of thermodynamics, energy sources, environmental impact, and carbon footprints. Students conducted fieldwork in four public school buildings, investigating eight schools over 2 years. Fieldwork consisted of a walk-through with the facilities engineer, which resulted in the production of an energy audit for each school building and recommendations for Energy Conservation Measures. After thoroughly evaluating energy-related problems, students picked two key issues for each building and generated possible solutions. Students in each class then created a Request for Proposals (a formal process matching that of professional energy auditors) which the city needed to solicit bids for completion of the Energy Conservation Measures.

Under the supervision of the facilities engineer, students collected and analyzed the bids, calculating the potential savings for the city. They worked within the city's legislative guidelines for a maximum 5-year payback for all energy improvements. Students calculated costs for the whole project and for individual elements at each school, analyzing data and soliciting feedback from Springfield's facilities engineer.

In both years, students submitted a *Greenprint* to Springfield's mayor and city council as both a formal presentation and as a written document. The sample below, taken from the conclusion of one of the Greenprints, summarizes the sentiments captured in these communications:

> Global climate change is a serious issue facing the world today. The time for planning the prevention of this issue is far behind us. Now is the time to take action. We all need to be the generation that instills change in the world's lifestyle. A change in Springfield can cause a trickle up effect, where other towns emulate our work…Although some cities have made progress in green initiatives, many have not…If Springfield takes the road suggested in this Greenprint, then we will see enormous benefits to our city…we can become a smarter, cleaner, nicer place to live. These benefits are both economic and environmental. We will have the potential to receive national attention as a "green city," helping to boost our image and attract green-thinking residents.

These comprehensive reports also contained the students' research findings and outlined the economic reasons for the city to finance their energy proposals. Students also included other specific recommendations for "green"-related projects, such as bike trails.

The following samples illustrate the disciplinary knowledge required to produce the Greenprints.

Student work sample #1: An excerpt from the 2008–2009 Greenprint, showing one focus area from one school

Kennedy EMC #1: Gym Lighting Replacements

Existing Conditions:
The existing gym lights are (36) 400-watt Lithonia Lighting fixtures.

Proposed System:
We would like to install (24) energy efficient T8 florescent lighting fixtures and (8) occupancy sensors to the gym.

Benefits:
If we install these new light fixtures, the school's energy consumption will be reduced by 69%. Lamp CRI will increase from 62% to 82%. Also, maintenance will become easier and less disruptive because of the longer life span of the fixtures. In addition, we will make sure installation work is scheduled so that it will not interrupt regular school day activities.

Energy Savings: **Annual Costs:**
2,600 X 11.244 (kwh/hrs.) X $0.20 = $5,847.00

Cost Savings Analysis

24- 6 lamp 28 watt fluorescent fixture cost	$ 3,720.00
4 sensors	$ 900.00
Wire guard cost	$ 864.00
Hangers	$ 204.00
Installation cost	$ 5,552.00
Sub Total cost	$11,240.00
WMEC Rebate	-$ 1,200.00
Total	$10,040.00
Annual Savings	$ 5,847.00
Payback/Year	1.72 yrs.

Student work sample #2: An excerpt from the 2009–2010 Greenprint, showing again one focus area from one school

Estimated Energy Savings

Oil Reduction: 2,300 gallons @ $2.00/gallon = $4,600

Electrical:

Media Center AHU 2 -3hp motor @ 4.222kw X $0.20/kwh X 2,555 hrs= $2,157

East Quad AHU 2 -3hp motor @ 4.222kw X $0.20/kwh X 2,555 hrs= $2,157

West Quad AHU 2 -3hp motor @ 4.222kw X $0.20/kwh X 2,555 hrs= $2,157

Gym AHU 1- 5hp motor @ 3.060kw X $0.20/kwh X 2,555 hrs = $1,564

Natural Gas	$4,600
Electricity	$8,035
Total Energy Saving	$12,635
Payback in Years	4.5 years

Tangible results. After students' presentation to the mayor in the spring of 2009, the city decided to fund seven Energy Conservation Measures and to retrofit four school buildings—for a total cost of $157,347. After completing the retrofits and analyzing the first year of savings according to industry standards, the students' work saved the city $83,824 between energy savings and rebates offered by the energy companies. This trajectory far exceeds the city's required 5-year payback. The second year of student research was poised to achieve even greater success, a hopeful sign that the city will continue to fund students' retrofits.

The students' work also had an ongoing, yet unexpected, impact. First, after presenting to the mayor, students were invited to present to the city's Green Commission, a citizen-based group whose mission is to discuss and promote sustainability. Second, Springfield's city council made a formal written proclamation recognizing the students for their work. Third, the project was featured in a 30-min public television program called *Eco Exchange*, which aired on May

27, 2009. Students also continued to publicly promote their Greenprint to other civic groups.

Students were impacted academically, professionally, and personally. As the school's principal said, the learning expedition helped make scientific thinking accessible to students, thereby demystifying the role of science in human affairs. Students were tremendously proud of their work, finding real satisfaction in their tangible accomplishments. Finally, students benefited from communicating disciplinary knowledge both to the public and in more formal scientific reports.

In the end, Aurora, the science teacher, stated that she never could have predicted the ways in which student work in this expedition would impact Springfield—economically, socially, and environmentally. Students reported that they did not originally envision how much their work would matter to people, both in the content and quality of their work as well as the impression they made as young citizens of Springfield.

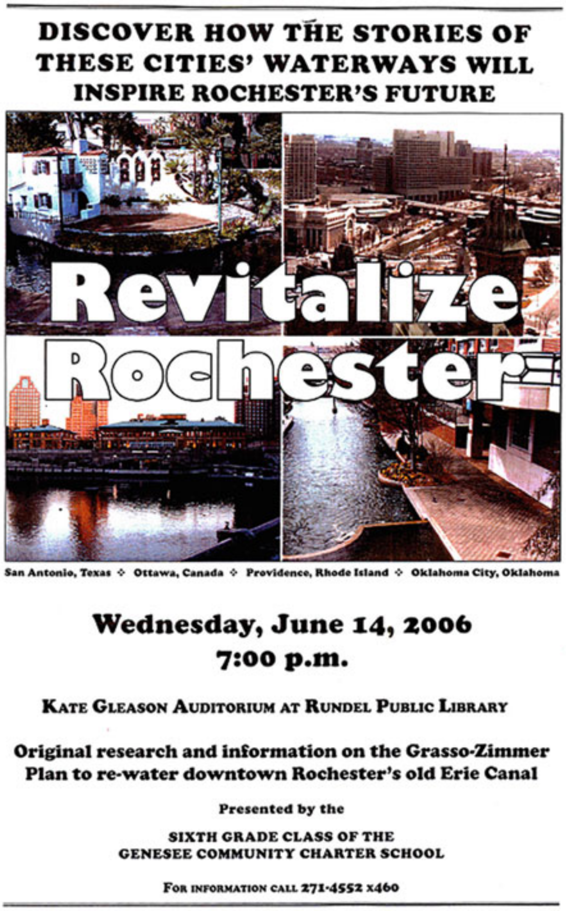
Case #2—Revitalizing and Reshaping Rochester

Setting. Started in 2001, the Genesee Community Charter School (GCCS), in Rochester, New York, is a K-6 charter school located at the Rochester Museum and Science Center. The population of approximately 210 students at GCCS is comprised of students from Rochester as well as surrounding suburban districts. Sixty-six percent of students are White, 24 % are African American, and 9 % are other students of color (Latino, Asian, multiracial). Approximately 22 % of students receive free and reduced lunch.[2] At the GCCS, students' final year is an expedition that fosters in-depth work with the local community, blending responsibility and activism: 6th graders become deeply engaged in research that contributes to the social, economic, and environmental well-being of Rochester.

[2]Like other public charter schools in the USA, the GCCS may tend to draw children whose parents are more involved in their education—a crucial resource for individual success. And, like others, this makes its demographics dissimilar from surrounding public schools (Ravitch 2010). We include this example not to compare it with district schools (this could be an unfair comparison), but to acknowledge the popularity of charter schools and to show how this kind of work is possible in different settings given current policy emphases.

Project and Culminating Products/Performances

Student work sample #3: Students created this poster informing the public about an upcoming presentation of their research findings. It originally was poster-sized, printed on glossy paper



In the 2005–2006 and 2006–2007 school years, students explored restoring the Erie Canal waterway and the possibility of establishing a surrounding commercial district in downtown Rochester. The Erie Canal, once a central part of Rochester's thriving urban core, became a symbol of the city's decline. Now empty, the dry canal bed was considered to be a dangerously derelict scar at the city's center. The original idea for this project came from conversations between GCCS's administrators, 6th-grade teachers, and people involved in efforts to restore the canal. It was an ideal opportunity for students to become advocates and researchers within their own community and to work on a local problem that supported the New York curriculum frameworks.

If We Build It, Will You Come? What A Center City Canal Could Do To Renew Rochester
A Sixth Grade Exploration of the "Re-watering the Canal" Proposal for Rochester

Engineering and Economics of the World's Canals August - November	The Rise of Civilization December - March	Imagining a New Rochester April - June
• **Posing the problem with Tom Grasso's and The 2006 Sixth Grade's Charge** - defining issues facing Rochester - setting purpose for year's study • **Participating in the World Canals Conference and Investigating the Fund For Teachers Fellowship Research Artifacts** - *World Canals* o why canals were built o economic, social, technological and environmental causes for the changing uses of canals o economic, social, and environmental effects of changing canal uses o preservation, restoration, and historical interpretation of world canals - *Canal Structures* o engineering waterways o how structures work: aqueducts, moving bridges, flood prevention, Falkirk wheel, inclined planes, locks o Archimedes' contributions to our understanding of physics	• **The Study of Ancient Mesopotamia Through the Lens of the First Settlements Near Water** - *The Evolution of Cities* o where people settled o advances that made settlement possible - *The Characteristics of Civilizations* o settlement in cities o labor specialization o government and public works o surplus production and trade o class structure o writing, mathematics, science - *The Components of Cities* o concentration of people o government - *Challenges Cities Face* o transportation o sanitation o food and water o public health o crime	• **The Grasso-Zimmer Plan** • **Travel to Ottawa's Winterlude and Investigate City Government Through Guest Experts** - *City Decision-Making* o who's who in city government o process of making municipal projects happen o issues of economics and historic preservation - *Elements of a New Rochester* o housing o recreation o retail o historic preservation o transportation o events • **Spreading the Word About the Grasso-Zimmer Plan – Community Surveying, Data Analysis, 5K, Presentation to Deputy Mayor** - *Citizens' Roles and Responsibilities* o community activism o formation of associations/societies/grass roots organizations o working with city government - *Gathering Community Input and Disseminating Information* o gathering community input o analyzing qualitative and quantitative data o principles of marketing

Fig. 9.2 Overview of the yearlong learning expedition

Work on the Erie Canal was embedded in a larger, full-year framework with guiding questions focused on three topics: Why do people historically settle near water? What is the science of canals? What is the potential to revitalize Rochester's dry Erie Canal bed? Figure 9.2 offers an overview for the entire year.

The first year involved investigating the potential benefits of re-watering the canal. Students researched information from other cities in the USA and Canada that had engaged in successful waterway revitalization projects, beginning with studying the *Grasso-Zimmer Plan* (a comprehensive economic and structural proposal for restoring the waterway that had not yet found broad support) with its authors—two local professionals keen to restore the dry canal bed. Students also raised some of the funds needed to travel in small groups to four cities that had completed successful waterway revitalization projects. They interviewed mayors, city engineers, city councilor members, business owners, and citizens. Upon returning from these trips, students shared information with their class, combining forces to write a document that presented the value of the project from economic, environmental, and recreational perspectives. Although they worked collaboratively on each stage of the project, individual students were responsible for writing different sections of the report.

Below is an excerpt from the introduction to *Revitalize Rochester*, the culminating written product of students' research the first year:

> We've grown up here and we want our children and grandchildren to be proud to call Rochester "home." But for us to see Rochester as a thriving community, we have to resolve some problems. Rochester's economy is declining. There has been urban flight and Rochester is losing its younger citizens. Crime continues to be a problem in this city. Major employers are downsizing and the unemployment rate continues to concern our families. Rochester needs revitalization! We need more jobs and a reason for businesses and people to come to the downtown area. We need a reason to stay!

In addition to this written document, students presented their findings to city officials, including the mayor. Students also presented their work to the public—as shown in the poster above—in an event attended by over 100 people.

The next year's class extended this research by studying whether or not people from the community actually supported the ideas in the Grasso-Zimmer Plan. They designed and implemented a survey, learning about polling strategies and statistics from outside experts. Students' research found overwhelming support for the initiative. Once again, they presented their findings to city officials, which shaped the city's next steps on the initiative.

Tangible results. Based on students' work, Rochester city officials reconsidered the re-watering plan. A scaled-back version of the original Grasso-Zimmer plan is now moving forward, with millions of dollars dedicated to renovation work slated for late 2010. Just before the work commenced, the mayor of Rochester commented:

> After 4 ½ years we are very close to encumbering all of the funds for phase one…the work would not have been possible without the great work and research of these outstanding young men and women…as I said after their meeting I would have hired any of them to be my planners for the city…I want to make it very clear that the work that this class did impact me both personally and professionally in being a big supporter of this project… (Excerpt, delivered as part of the key note address at the Expeditionary Learning Schools 2010 Conference)

Students were similarly impacted: Recently, five 10th-grade students, who as 6th graders participated in the first year of this learning expedition, presented at a national conference to over 800 educators. When reflecting on their experience, they commented:

- "I'm not sure we truly understood the magnitude of our efforts…We didn't expect that our work would have the major impact on the city that it had …It has taken four years for us to truly understand the significance that a bunch of twelve year olds could shape the city's future."
- "I've gotten involved in government and grass-root movements outside of school in order to satisfy my desire to be an involved citizen…I branched out and joined Rochester's Student Leadership Council and the Mayor's Youth Advisory Council. I also pioneered with my father a green movement. [Through this expedition] I learned how to think critically, speak effectively, act professionally and work with community."

- At the end of the collaborative presentation, a student said, “We now pass the torch on to you. We encourage you to give your students the same tremendous opportunity for community involvement work and for purposeful work…Giving students a chance to make their work matter and to recognize their potential to serve as a catalyst of change is the truest definition of education that we know.”

Accountability. These two cases serve as examples of enlarged indicators of accountability, along quantitative and qualitative dimensions. But they also reveal key philosophical issues that underpin this chapter. Readers are reminded that test scores in these schools surpass those of comparators, indicating that conventional measures of success were not sacrificed to community student engagement. We particularly highlighted the schools’ tangible evidence as a way to set the stage for our discussion of how schools become accountable for providing opportunities to enhance economic, social, and environmental well-being—over and above gains in test scores.

Discussion/indicators of quality. Before applying an analytic framework to our cases, we highlight several structural and cultural features common to both projects that undergirded students’ engagement in civically oriented science. Table 9.1 summarizes these elements.

Table 9.1 Elements supporting engaged science

Design elements		
Fieldwork:	*Community partnerships*:	*Audience:*
Expeditions centered on allowing students to do original, hands-on research outside of school	Students (and teachers) developed partnerships with local experts and other individuals from the community who assisted with academic tasks and disciplinary content	Both projects surpassed a typical notion of *sharing* work with outside audiences; work was specifically *geared for* these audiences. By crafting products and performances to address community economic, social, and environmental concerns and by building well-researched arguments, students pointedly impacted key issues
Structural supports/local policy environment		
Meeting standards flexibly:	*Additional support*:	*Whole-school partnerships*:
The schools allowed teachers to meet standards in unconventional ways, in contrast to schools that require teachers to strictly follow monthly, weekly, or even daily curriculum maps *Flexible schedules:* Both schools had flexible schedules that allowed for fieldwork and intensive periods of in-depth academic work	Teachers’ work was supported by grade-level teams or other teachers, providing extra resources at critical times. Additional personnel were often available to students, whether another teacher, administrator, student teacher, or parent	Each school established partnerships to help students and teachers identify with institutions beyond the physical walls of the school, GCCS with the Rochester Museum of Science and both schools’ affiliation with Expeditionary Learning

(continued)

Table 9.1 (continued)

Cultural supports		
Learning expeditions, case studies, and projects as core elements of curriculum: Students engaged in extended, research-based projects in all aspects of their school. Also, at the GCCS, students prepared for their capstone 6th-grade year in each previous K-5 year, establishing purposeful, multi-year scaffolding	*Culture of persistence:* Both schools had a culture of persistence and striving for excellence that pervaded all academic work	*Trust between staff and administrators:* The relationship among administrators and teachers was characterized by deep trust—for the way that teachers went about their work and for their ability to help students reach academic outcomes

Many of the design elements—the structural and cultural supports—exemplify a realignment of schools and communities, coupled with expanded notions of accountability. First, because the expeditions were collaboratively designed by teachers and community professionals, only those problems that truly needed solutions were tackled. Second, community members witnessed firsthand the tangible results of students' hard work, which qualitatively changed their understanding of what rigorous academic engagement looks like. This enabled people to see beyond test results as the only credible indicator of academic achievement. Third, the cases provided powerful alternatives for conceiving of student work. Students throughout the expeditions were deeply engaged in civic endeavors—so much so, in fact, that it became impossible to draw clear distinctions between doing school and doing citizen science. While students certainly were completing school-based requirements, they were also doing legitimate work that mattered to them and to their community.

Analysis: The Power of Assessment

Our cases demonstrate how expanded indicators of school quality serve to reconsider school accountability. Now, we outline a conceptual framework that underscores the importance of assessment while pointing toward several general implications for policy. We present assessment as a social practice and discuss the related notions of "ecological validity" and "boundary objects" as a way of understanding how examples of high-quality student work serve to deeply engage students in the work of scientific literacy.

Broadening Assessment: The Role of Teachers, Students, and Community Experts

Our two cases were shaped profoundly by multiple forms of assessment occurring regularly throughout the expeditions. In both cases, assessment strategies were tailored to support students' learning as it happened—using assessment *for* learning rather than being solely focused on the end result—as a post hoc indicator *of* learning (see Black and Wiliam 1998 for a discussion). Assessment practices included the following:

- Extensive editing of student writing, including multiple drafts based on self, peer, and teacher critiques
- Interview rubrics to help students prepare for their in-person surveying
- Individual letter writing outlining one "green" initiative that students thought the city should adopt, which assessed student's understanding of the science content and the ability to write a persuasive letter
- Tests and quizzes
- Expedition vocabulary assessment
- "On-demand" assessments

Although teachers were ultimately responsible for assigning grades, students themselves were heavily involved in critiquing their own and each other's work; students thus became stakeholders in a different way than what is typical in classrooms. For example, students critiqued their peers' writing and provided extensive feedback to each other during rehearsals of their presentations. Not only did the work itself matter—students' own evolving judgment about *what quality looks like* was given serious consideration in each round of feedback.

In addition to the teachers and students, experts outside the school were involved in evaluating student work and providing valuable feedback: External stakeholders were reading, assessing, and potentially using the work, which qualitatively changed the students' investment in what they produced. Springfield's facilities engineer, for example, was a constant yet constructive critic. Outside experts provided crucial support for Rochester students as they developed the survey to determine public support for the Erie Canal revitalization plan. At final presentations and culminating events, people such as the mayor and city council members provided honest evaluations for student work. Students had to legitimately ask themselves: *Will our proposals for Energy Conservation Measures be accepted? Will the city reconsider the revitalization plan?* The projects' successful evaluation by outside experts—sometimes surpassing work previously done by paid consultants—demonstrates the effectiveness of this approach. The schools' high test scores indicate that tangible results do not necessarily come at the expense of academic rigor. Rather, our focal cases give reason to believe that the production of tangible results can enhance it.

Assessment as a Social Practice: Sociocultural Perspectives

As evidenced in our cases, assessment played a much larger role than solely determining individual student outcomes. Instead, it was an integral social practice within the learning expeditions. By *social practice*, we mean a mode of conduct that shapes individual and collective work toward a common goal, an essential feature of any highly functioning organization or team (Wenger 1998). Highlighting assessment as a social practice rather than as a solitary event helps move the focus off of conventional assessment metrics, while still admitting that conventional assessment metrics have some value. It helps avoid the dichotomous views that sometimes exist between tests and other forms of assessment and offers, instead, a way to understand how assessment shapes students' development of scientific literacy and civic involvement on an ongoing basis.

In a social practice framework, assessment becomes recognized as a routine part of everyday interactions; humans continually assess whether or not their actions realize their goals (Jordan and Putz 2004). By deliberately thinking about it this way, assessment expands to include not just what is directed by a teacher but also other types of evaluation that happen continuously within and outside of schools. The projects we highlighted above used assessment in this way, as a key component of moment-to-moment decision-making that helped focus on quality, not as a typical classroom summary "one and you're done" testing event.

Further, seeing assessment as a social practice provides a way to think about the *ecological validity* (Roth 1998) of student products. As stated earlier, responses to test questions serve no purpose other than to evaluate students on narrowly prescribed metrics. Given the rarity of this kind of event in life, assessment is disconnected from the larger ecology of human activities. *Ecologically valid* assessment evaluates progress according to one's concrete contribution toward some meaningful goal—in our cases, effective community planning and budgeting. Ecologically valid assessment is planned to be spatially and temporally close to learning, occurring as an integral part of ongoing activities and not as a series of separate, summary events. Although these tenets seem logical—they are, for instance, how small children and adults learn almost everything they know (Lave 1990; Rogoff 1993)—they do not figure prominently in most classrooms, where students mostly produce things with little value other than a grade. Our cases consisted of many examples of ecologically valid assessment—ones that teachers, students, and community members had stakes in: *Were the proposed Energy Conservation Measures adopted? Did the changes save the city money? What was the Mayor's and City Councils' reaction to the presentation? Did community views on the project change as the result of our work?* In both of our cases, meaningful student work was central to the ecologically valid assessment that occurred throughout the learning expeditions.

Finally, school assessment as a social practice also means envisioning how change in audience and/or stakeholders alters the nature of student effort. Testing has an unknowable audience: An electronic bubble-sheet reader? Someone 500 miles away grading a stack of essays written by anonymous children? The student cannot know—whereas ecologically valid assessment has a definite audience to which one is immediately accountable.

Boundary Objects

Viewing assessment as a social practice also raises the significance of *boundary objects*, a term coined by Star and Griesemer (1989) to refer to the concrete materials people create and use as they work together—often, across substantial differences in institutional priorities. Boundary objects help people negotiate their differences not only for establishing common ground, but also to enhance their unique goals. Schools function differently from municipal governments in their goals and their domains of expertise. Boundary objects—common objects of work—can help reconcile these differences to further progress. Boundary objects thus enable substantive work on shared local issues along with a shared understanding of accountability. Viewing student work as boundary objects makes it easier to understand how disparate organizations can do mutually beneficial work and achieve more than either could alone. The better the quality of the work, the more effective it is at advancing both individual and shared goals. Ironically, test data can have just the opposite effect, dividing rather than unifying schools and community stakeholders, and test data quite often fail to serve as an effective boundary object.

A sociocultural perspective of assessment reminds us to look beyond individual performances on tests to consider the social and cultural relationship between students and their surroundings (Moss et al. 2008). The principles of ecologically valid assessment and boundary objects remind us to seek to understand how rigor can be applied to assessment practices that may appear unconventional to those preoccupied with test data. Seeing assessment as a social practice foregrounds students' successful participation in civically engaged science that produces tangible results. The relevant question in this framework is not *What is it that students know and are able to do?* But rather, *what constitutes skilled participation in meaningful work that contributes to addressing social problems?* Through this lens, the importance of testing diminishes. Knowledge is a valuable resource in this framework, but it is not an individual property. Accordingly, "neither learning nor development is an individual accomplishment" (Holzman 2006, p. 8). In our cases, then, achievement involves the successful application of scientific methods and concepts to advancing the economic, social, and environmental priorities of local communities. *Accountability* in this context implies the need to go beyond test scores (which are important), to look for other quantitative and qualitative metrics.

Implications for School Policy

Expanding accountability beyond test scores helps to imagine how student work that looks unconventional or irrelevant in a testing-only framework becomes a crucial indicator of school quality. On top of high test scores, our focal schools are meeting additional standards based on the extent to which they provide students with opportunities to produce work with real social, economic, and environmental value. Our evidence includes the number and quality of relationships with community experts, the successful completion of externally judged products, and quantitative indicators such as shifts in community sentiment toward economic revitalization projects or dollars saved through energy retrofits. Such tangible results have tremendous local significance and, along with strong test scores, significantly expand what school quality signifies. The principles we highlighted in Table 9.1 can be extended to other sites by attending to two school policy dimensions in particular: encouraging expanded notions of accountability and assessment and providing structural support for students' engaged participation in meaningful scientific practice.

Ultimately, policy can help schools hold themselves accountable for expanded indicators of academic achievement—those focused on *quality* and *tangible results*—along with the usual suite of test data. It is difficult to overestimate the transformation that would result if indicators of educational quality included other easily quantifiable data: improved air or water quality, reductions in energy use, municipal cost savings, expanded access to recreational or commercial opportunities, reduction of obesity and other health indicators, and so on. Qualitative indicators could evidence the preservation of community traditions, knowledge of local ecosystems, and dispelling of racial stereotypes. We are not proposing that schools should be held directly responsible for producing results in these areas—this could result in "burden shifting" to already strapped schools—but we are asking readers to imagine the potential benefits to student learning that would arise should such indicators be admitted. The fact that test scores are higher for our focal schools than for comparative schools suggests that standardized metrics already are confirming the benefits.

As Ravitch (2010) points out, our current notion of accountability—so dominated by market-based thinking—is a similarly grand experiment with no historical precedent to guide it. Policymakers wary of such grand experiments are encouraged to consider the ways American education has historically been relied upon to serve national interests alongside state and local interests. What is shared across local, state, and national levels, and what recent events such as the Deepwater Horizon spill demonstrate, is that engaged scientific literacy is essential to America's social, economic, and environmental well-being. Policymakers need to take the lead in cultivating scientific literacy by encouraging the use of expanded indicators of educational quality that concretely demonstrate key dimensions, produced by students themselves.

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Chapter 10
The View from the Top of the Plateau

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Introduction

When we began this inquiry, we had assumed that the School of Environmental Studies, the object of the study, was a very successful and innovative school. Nothing that we learned challenges that assumption. The consistent stories provided by all who we interviewed indicate that the school has been incredibly successful. The intent of our inquiry was to learn what circumstances and factors led to the school climbing to the top of the plateau and what the view from the top looked like to the teachers. We expected to see that, over the years, the school might have largely given up its initial vision due to complacency, changing external conditions (e.g., state testing and standards or declining budget resources) and changes in staff, etc. Another possibility was that the school had stagnated, such that it was no longer engaging students as it once had. We also expected that the school at the top of the plateau might be isolated on the plateau and not looking toward climbing to the next plateau. We made these less-than-optimistic assumptions because sustaining successful innovations is known to be incredibly difficult.

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The School and Setting

The School of Environmental Studies opened in 1994; it serves around 400 juniors and seniors and has approximately 24 teachers. The diversity of students in the district and School of Environmental Studies features are, respectively, 14 and 8 % in Special Education; 14 and 7 % on free and reduced lunch; 8 and 5 %, Asian; 9 and 3 %, Black; and 6 and 2 %, Hispanic. The school is located on 12 acres of land, on which is a small wooded area surrounding a pond. It is adjacent to the Minnesota Zoo and across the street from a well-wooded regional park.

The school is organized into houses—two junior houses and two senior houses—each with approximately 100 students. The students in each house meet for three hours each day and are taught by a team of three teachers—one each from science, social studies, and English. Other junior- and senior-level courses and electives (mathematics, physics, chemistry, art, careers, and languages) are taught during the rest of the day. The larger extracurricular programs, such as sports and music, are taught at the other high schools; the students return to those schools for those activities.

The details of the innovations that have shaped the school will become evident in what the teachers told us. However, the innovations can be summarized by saying that students were to become self-directed learners, engaged in their community, and environmentally responsible citizens of the world. They were to do so by learning about natural and social environments in an integrated way and by learning the knowledge and skills that are necessary to live in the real world, whether that be that the world of continuing studies or of work.

Approach

Our approach to the study was to view the school as a case that might reveal how a successful innovation comes about, what occurs as the innovation continues through time, what factors contribute to its being sustained, and what factors challenge the innovation. The inquiry was not a full-scale case study, in that we did not interview all stakeholders, or engage in extensive observations of meetings and classrooms, or exhaustively search documents associated with the school. Rather, we investigated selected teachers' views of their school in-depth, in order to reveal the practitioners' views from the plateau. We met with those whom we thought would know the school best. The teachers were selected to represent those who founded the school, those who joined the school within two years after the school was founded, and those who joined the school after it had been in operation for several years. No one who we interviewed had been there fewer than seven years. Truly, new teachers are not part of the school because of layoffs due to budget cuts. The teachers who we selected represented different subject matters (science, social science, and English) and were from the different houses. Those who teach other courses in the school, such as mathematics, languages, physics, or art, were not included, because they are not as directly involved in the innovative portions of the program. To complete the picture, we also examined the original founding documents and current program descriptions.

We interviewed six teachers and the school principal for approximately 1 hour each. The interview was designed to seek the teachers' perceptions of the context, overall goals, curriculum (what was to be taught), instruction (how the teaching was to be done), and assessments of the students and of the school overall. The teachers were questioned in these areas with respect to the past, present, and future. The depth and breadth of their responses to the questions was remarkable; the responses were very passionate, coherent, insightful, and reflective. If one had in some way "mapped" each person's responses, each point on the map would have been intricately related to many other points. We wish that all who read this chapter could listen to these interviews and hear for themselves the breadth and depth of the participants' understanding of their practices, why they do what they do, and why they do not or cannot do more. Perhaps we can give some voice to these consummate professionals and learn from their knowledge and wisdom. Here is the story we were told. It is presented as a compilation of their perceptions and perspectives with regard to the context of the school's development, goals, curriculum, instruction, and assessment.

The Context of Development

The context of development—the circumstances at the time the school was formed—matters even today. The initial key players were the superintendent and the curriculum director from the district, the director of the zoo, an educator on the zoo staff, two or three teachers in the district, and the mayor of Apple Valley, Minnesota, all of whom were innovators seeking opportunities for collaboration. The district wanted connections with the community and space for expected increasing numbers of students. The school district recognized that the cost of a large comprehensive school was much greater than the cost associated with creating one or more small schools. The zoo wanted buildings and an outlet for its educational programs. The politics of the community at the time favored innovation. The mayor and city council were willing to float 20-year bonds to build a smaller school as part of its response to community concerns about the building of a new comprehensive high school; they also were ready to act out of a sense that promoting educational innovation was part of their responsibility. Five options were considered for small high schools. These options were related to business, the humanities, health sciences, human services, and the environment. The original plan was to build more than one school. Each option required a real and substantial community partner.

The most real and substantive partner was the zoo, with which the district had an ongoing programmatic relationship. The SES probably would not have been built if it had not been so well supported by so many players or if it had not been first on the list. Ultimately, the district built only one small school. A new superintendent opposed the building of smaller schools, favoring instead the development of a comprehensive high school, which was in fact eventually constructed. What saved the SES was the fact that its development was already well on the way when the new superintendent arrived: it was just too late to stop.

Clearly, economics, demographics, available and engaged personnel, and community opinions were all major factors in the development of the School of Environmental Studies. However, the school probably would not have been built if these factors had not been accompanied by commitment both to innovation and to a complex of ideas that people thought would be good for children. Originally, the school was based on the ideas that were derived from then-emerging research concerning effective school size and essential schools. The commitment to basing the school on current research and expertise from the University of Minnesota was substantive.

The importance of the research base is most evident in the teachers' and the principal's discussions during the planning process. That process involved an extensive examination of relevant research literature, consultations with educational researchers and architects, visits to innovative schools, and self-study. The process also involved many hours of what Schwab would have called practical deliberations: the eclectic use of good ideas from many sources about many facets of a complex undertaking that are formed into a coherent and integrated plan. The plan consisted of many details, but some areas were of necessity left open. What was critical was the emergence of a set of what we call a *goal network of mid-level principles*: principles that could be used to guide specific decisions and plans for both the short term and the long term.

A reasonable interpretation of the interviews is that the school was designed and built because of a complex of practical contextual matters operating in conjunction with good, research-based ideas and knowledge of best practices. Another reasonable interpretation would be that the school would not have been built and would not have been successful or sustained without the synergies resulting from the interactions of the above factors, which resulted in the goals network of mid-level principles.

When the teachers and the principal were asked about today's context and the future, most of the comments were about changes in the current context. The most common concern was that there is no time to talk to each other within houses, across houses at the same grade level, or across the two grade levels. The teachers expressed a genuine yearning to be able to have facilitated conversations to review their goals, coordinate and update the curriculum, and redesign some of their instruction, especially in the area of using technology to teach. Some remembered the experience of having real and substantial time to study and plan on behalf of the school. Others who were not involved in the initial planning had heard of the value of the experience and recognized its value by coming into a situation that was thoughtfully designed. There was a sense that they were losing track of the goals and that the direction of the school was drifting onto an unplanned course. There were also questions about whether or not the nature of the students had changed and if the school had been responsive enough to such changes. A part of this concern was a sense that the students who were enrolling in the school had many more unmet needs of increasing severity.

For our part, and as best we could see, the school program continues to be driven by the original goals. The curriculum also remains reasonably well coordinated, but the coordination could be refined. We also recognized the teachers' sense that their knowledge and use of the goals, the coordination and currency of the curriculum, their instructional methods, and their own understanding of recent research and best practices are slipping.

It would be wise to heed teachers' concerns, we suspect, by creating substantial opportunities for them to examine their goals, the curriculum, and the instruction, especially since, as we will show, the time allocated during the development of the school has served the institution, students, and community so long and so well.

A second area of concern relates to staffing. Some of the original founding members have retired and others are nearing retirement. With the retirements comes the loss of intuitional memory and wisdom. Current hiring and within-district transfer practices are seen as working against finding new teachers who truly want to work in this unique school and who have the knowledge, skill, temperament, and commitment required to sustain the vision. More specifically, the concerns were that new teachers would not be willing to "stand in the rain at the pond," collaborate within and across teams, deal with the fact that every day is "choreographed a little differently," provide guidance and coaching in lieu of direct instruction, create and maintain community connections, or plan and conduct intensive intersession courses.

A third concern is that schools must now advertise and compete for students, not only against other public schools but against private schools. This is expensive and time consuming, but essential when the decreasing numbers of school-age students is coupled with declining state and local per-student aid. If enrollments drop, funds decrease, class sizes increase, and fewer teachers are available to carry out the innovative features of the school. The impact on smaller schools, such as the School of Environmental Studies, is proportionately greater than it is on larger schools.

Goals

We had thought that there might be one overriding goal, as is sometimes the case for schools. However, the School of Environmental Sciences has a set of highly interrelated goals. Taken together, we came to describe this aspect of the school as a goals network. One essential goal in the network was to create a school that provided an alternative learning environment for all students, including those whose needs could be better met outside of the standard "listen to the teacher, do what you are told, take the test" version of the secondary school. Two teachers described the goal as creating a rigorous "middle school for big kids." The idea was to create an environment in which the students felt welcome and encouraged. A second essential goal from the network is that the school would be interdisciplinary, to the point where the students do not see the teachers in their house in terms of their subject-matter specialties. As one teacher said, "The students should and I think do see us just as one of their teachers. They come to any of us regardless of what their work is requiring." The theme that guided the students' and teachers' interdisciplinary work was environmental. This theme is that students should come to understand the development of the social and natural environments in which they live and in which they will live. A related goal is that the students would be engaged in their local community and even in the communities of the world. Another essential goal is that students are to become independent, self-directed learners who are capable of finding and using resources to do real-world tasks. A corollary to this is the goal of having the teachers be "guides on the sides" rather than "sages on the stage" or in another word, "coaches." A final critical goal was that the assessments would be real world, in that they would be professional and work-related tasks and in that the assessments would be presented in community-based contexts.

Perhaps, if we attempted to write one overall goal, it would be to have the students, teachers, and community work together to become self-directed, successful, and environmentally responsible citizens. However, as can be seen above, this statement seems too vacuous, or at least overly general. The contrast between reading about the network of goals and this overly general statement is substantial. In fact, we would claim that one of the findings of this inquiry is that one of the reasons for the school's success is that the originators avoided vacuous feel-good goals in favor of a network of mid-level goals that could be translated into practices. The strongest evidence for this claim is that when asked about the current goals, the teachers and principal were universal in saying the original goals were still successfully in play. Founding teachers and newer teachers all said the same. Further, when asked about future goals, the statements were all about better ways to use the original goals and ways to protect against "drift" or "slippage."

As for future goals, teachers expressed the concern that the goals were becoming "less clear" and that they needed to be revisited. That said, there was strong support for the existing goals and no clear statements of new goals that should be considered.

Curriculum

The interviews did not reveal as much about the subject-matter specifics of the school curriculum as we had expected. This was interesting, because teachers elsewhere usually focus on discussing the discipline-specific knowledge and skills they teach. The School of Environmental Studies teachers thought about their curriculum differently and in terms of the goal network. This is not to say that the teachers thought their subject matters were unimportant, quite the opposite, in fact. Each teacher expressed his/her belief that his/her subject was essential to the larger goals.

One expression of the use of broader educational goals can be seen in an English teacher's view of her curriculum. She indicated that in the first trimester of the Grade 11 house, students learned about the relationships between living organisms and water—first ponds, then rivers, then oceans. She said students were asked "What is your role in society and what is your relationship to the earth?" She went on to say that the students were learning how people have looked at the world in the past and how things ought to be. She said that from the science side, the idea was to have students learn an evolutionary perspective of how life came to be. From English and social studies, the students were to learn how certain societies have been affected by imperialism. Imperialism was studied by learning about pre- and post-colonial Congo, India, and South America, through reading literature such as the *Heart of Darkness*. She also indicated that students studied philosophy through books like *Sophie's World*, and by reading the works of environmental philosophers such as John Muir, Teddy Roosevelt and Gary Snyder, to learn how humans have come to think about ourselves as we do. She saw this work as related to the primary project of the year, which was having the students create their environmental philosophy. She also pointed out that this junior-level curriculum about how we got to be like we are leads into the senior year, when students are asked "What is your role as a citizen in the world?"

A second expression of the teachers' use of the goals network to determine their curriculum is that they wanted time and opportunity to revisit the ways in which their subject matters contributed to the larger goals and worked together. For example, the topic of imperialism has been used for a long time, and the instructional materials and books for this topic have not been revised recently. However, the teachers are considering, as best their limited time allows, changing this topic to globalization as an alternative. They are thinking that the world has changed due to new communications technologies, more open access to other countries, and global transnational corporations, and they believe that Globalization would better serve the goals network. Making a change from using imperialism to globalization, when all other aspects of the curriculum are interrelated with the study of imperialism, would be a daunting task. Many of the instructional resources would need to be changed; new purchases of books, videos, and some equipment and materials would be required; new field experiences would have to planned; most of the instructional materials would have to be rewritten; and most of the assessments would have to be modified. About the only thing that would not have to be changed is the goals network. In fact, this change is being seriously considered and slowly tested because the idea of globalization is likely to serve students better.

The teachers thought about curriculum differently from what we expected in one other way. At least some teachers used cross-disciplinary principles when discussing what they teach. For example, one social studies teacher said he teaches "Complexity […] there are no easy problems, there are only problems that might look like they are easy – there are definitely no easy solutions […] whenever you think you have one, there are unintended consequences. Try to look at everything for all its component parts and that those parts are interrelated and it is not a linear progression." He then cited the example of having students "Reading critically and writing critically [about a complex issue] to challenge what students have been taught since day one." He had students read an article titled "Recycling is Garbage" that makes the case that much of what has been taught about recycling is bogus. "Many [students] go get new information and find the book may be right about economic gain but that [recycling] will done anyway because it makes us feel good and serves something in our soul. Other students say that all the numbers are wrong and the author is wrong." The teacher then went on to say that what he is teaching is the critical analysis of a complex matter and that it is being accomplished along with meeting the school goals and state standards. A science teacher has also indicated his use of the complexity theme.

The curriculum is very rigorous and sophisticated, as can be seen in what students are asked to read, write, and present. The critical point is that teachers seem to be well aware of, and guided by, the mid-level goals network and perhaps themes when selecting what to teach from their own fields. One contextual factor related to the teachers developing their sophisticated curricula needs to be mentioned. We noticed that the teachers seldom referenced using state standards as the primary source of their curriculum. Instead, teachers used the school goals and said they felt "free from" or "unthreatened by" the standards. This sense of freedom from state standards seems unusual in this day and age. However, the "freedom" is understandable given the context. Most of the state testing has occurred before the students come to the School of Environmental Studies, so the teachers are only minimally concerned about the standards. All that remains for some students is passing the state mathematics, reading, and writing tests, and these are seldom problematic.

At first, one might think that the limited explicit attention given to the standards is "bad." But we think the opposite is the case. The academic work the students are asked to complete encompasses and exceeds the standards. We think that the curriculum is better than what would be developed directly from the standards, in that the curriculum is integrated across the house subjects. Students get to experience the complementarity and synergy of the ideas and skills from various disciplines as they are applied to real-world problems and tasks.

Another function of the freedom from standards is that the teachers can use their own deep knowledge, rich experiences, and community-based opportunities to develop a curriculum that is sophisticated and creative. As one teacher said,

> Not having the state tests is good news because it gives us freedom – we do not have the pressure—we can use other innovative ways of doing the assessments and innovative excursions to relevant topics. Tests are very restrictive. We do not have time to deal with relevant topics. I am cynical about education now. I feel like we are going back to the dark ages in education. Legislatures want a teacher standing in front of room saying what students need to pass test. No creativity is allowed.

Perhaps an unintended consequence of our current penchant for employing inflexible standards comes at the expense of having teachers being able to create rigorous curricula that serve powerful, integrated educational goals as well as the specific disciplines that are taught.

When asked about the future, the teachers expressed several concerns about the curriculum. The primary concern was about staying current with respect to environmental knowledge, skills, and problems at a time when we are learning so much so fast. Another concern was that of figuring out how the non-house subjects, such as chemistry, physics, mathematics, and art, could be more integrated into the house-based curriculum. A part of this concern was that they realized it was already difficult to coordinate and team teach three subjects; they wondered if there is a limit to how much of this could be done. The final concern was that the demands for advanced placement, like courses in both the house and non-house subjects, were going to intrude on the existing goal set, most particularly, the interdisciplinary nature of the house-based curriculum.

Instruction

The instruction is what might be expected from the goals network. It is student-centered, highly organized, project-based, and varied. The teachers design the activities, make the off-campus arrangements, teach the content and skills, and guide the students through the final project presentations.

Each trimester, the students complete a large primary project as well as smaller tasks. The larger projects are done by groups of 8–10 students. Within the large groups, individuals and small groups are assigned primary responsibilities for specific aspects of their study. Ultimately, all students are responsible for, and must know, all aspects of the study. The most frequently referenced example of a primary project is a pond study the students complete during the first trimester of their junior year. This project requires that students study a pond in the community in terms of the biology and chemistry of the pond and in terms of the interactions between the pond and the local community. The ponds that are studied are selected by the city or a state agency and are actually part of a larger research program in the community. The students learn broad ecological principles, scientific research methods, and about the nature of science in the process of conducting the study. They report the results of their studies to the city or state agency. This project has been ongoing for many years. Over time, the city's ability to actually use the data has diminished somewhat due to the changes in the requirements of the grants funding the studies, changes in city personnel, abilities of the students to reliably use progressively more sophisticated research techniques, changes in the schedules for the studies versus the school schedules, etc. Even so, the city remains committed and involved in this school-based project.

An interesting feature of the project is that it is also used for assessing the students. For example, the assessment of the pond study is stated as "Prepare a historical, (geological), biological, and geographic profile of a local pond for a city government planning agency." The student's inquiries are guided by a primary question and a set of additional key questions:

How do Humans and Other Organisms Adapt to Ponds and Lakes?

- What are the characteristics of wetlands?
- What are the physical and chemical characteristics of water?
- What are the characteristics of lentic freshwater ecosystems, including ponds and lakes?

- What is the psychological and spiritual impact of lentic waters on humans?
- What is the principle flora and fauna of lentic freshwater systems and what are their adaptations?
- What are watersheds and what is the human impact on them?
- What is the geologic and human history of a given water body?

These key questions are then followed by what is called *Components of the Investigation*, which is a set of even more specific questions such as “In what different ways do flora and fauna adapt to life in wetlands?” and “What are the physical and topographical characteristics of wetlands and how are they formed?”

The study is supported by direct instruction and readings from books, articles, and field guides. The direct instruction is typical lecture and discussion. The readings are from books (not textbooks), articles, and technical documents. Students are also directed to use the internet to find the information they need. The internet sites are often the actual locations of state data and maps. A large part of the instruction occurs in the context of modeling a pond study that is carried out under the close guidance of the teachers. During that process, students learn to use field guides to identify organisms; paraphrase and summarize written documents; use microscopes and field equipment; collect, organize, and interpret data; interpret and create maps; interpret technical documents; research local history; and write technical, descriptive documents and reflections.

This somewhat elaborated description is provided to assure that the readers of this chapter can see the depth, breadth, and sophistication of the projects. The project process is rigorous, demanding, and intricate, and the project reports approach professional quality. The project reports are actually submitted to and read by professionals, who have been complimentary. The data have been used in the community. The idea of having students report to their communities is powerful. It raises the students’ expectations for quality work and increases the status of “school work.”

The roles of the teachers in developing the projects are critical. They are willing to give up some of their sense of control of the learning so that the students’ learning is “their own.” The teams of teachers also are patient and persistent so that they can see that “we had a break through day. The students are starting to see how tough this is and learn that they can do it on their own.” They also have to “[use] instructional practices [that] are more sustained, take longer and involve deeper engagement,” “spend more time with the students and instruction (even if it) seems slower,” ask lots of questions and make lots of suggestions, facilitate and guide, and be comfortable with “less predetermined outcomes.” As one teacher summarized the effects of this approach, “When you see something the students have generated that is new for them, that is beautiful.”

In addition to instruction that is based on large and small projects like the one above, the teachers provide what are called intensive theme courses and field experiences. These courses last from a few days to more than 2 weeks. The instruction engages the students deeply in specific experiences and subjects. The intensive theme courses are taught near or at the end of each trimester. The range of topics is amazing: human medicine, veterinary med, animal care and occupations, Earth Day, wilderness winter camping, sampler courses on careers, art, and fishing and boating. Many of these intensive theme courses involve the associated community and service learning when possible. Field studies have taken students to Denmark to participate in international climate-change discussions, to Costa Rica to study eco-tourism impacts on rain forests, to Baffin Island to see impacts of global warming on indigenous peoples, to Alaska to investigate land use management, and to South Florida to study the flow of water from Lake Okeechobee to Florida Bay. All students participate in these courses or field experiences. Sometimes there are fees for the more distant experiences; students who cannot afford them are often supported by the School of Environmental Studies Foundation.

Two features of these courses and field experiences are especially noteworthy. The first is that they are entirely consistent with and driven by the goals network. The transcripts of the teachers' interviews make this clear. More specifically, the theme courses address involvement in communities and becoming responsible worldwide citizens. The second feature is that the teachers report that, in journals and other assignments, students often state that the experiences are life changing.

When asked about instruction in the future, teachers' thoughts were clear and direct. They hope to maintain and extend what they are currently doing. They find great value in, and take great pride in, the student-centered, project-based, community-based, experiential education. They hope to create new projects and experiences, bring in many more speakers and community members and agencies, provide students more "real" audiences, and do more service learning. They are especially anxious to have the necessary time to engage the community. The time it takes to maintain and modify current relationships with the community is huge, especially in the face of increasing responsibilities, decreasing budgets, more regulation, and changing personnel at the agencies with which they work. Teachers long to create new connections to the community but are hampered because time away from their classrooms is unavailable.

One other related goal is to create a "culture where the students seek out and initiate their own opportunities." This is a phenomenal idea and it would be a terrific extension of the instructional goals. At first glance, this might seem like a "simple" way to increase engagement with the community, until one considers how much teaching needs to be done to prepare students, how much groundwork would have to be completed with the community, and how much mentoring of both the students and of the community would be required.

Despite the engaging instruction, or perhaps because of it, the teachers and principal worry. They worry about how budget cuts will eliminate teachers and thus make it impossible to engage the students as much as is needed. They worry about the slow drift toward more traditional instruction due to administrative decisions and political pressures. They worry about losing their ability to team teach and communicate across team and grade levels with fewer teachers, less financial support, more and more imposed state and district required tasks, and greater expectations for instantaneous communications with students, parents, and administrators via electronic media.

Finally, there is an emerging recognition that the instruction has to be enhanced by the use of more technology. As one teacher stated,

> [We] need more technology because that is students' language. As an older teacher I need to learn this. I am [left] out of all that. Students do not read books – I do – they use a Kindle. The [have and] need instant access to information – some is good some is not – how do they sift through this and get the real story and valid information? They need to be responsible consumers and we need to help.

Other teachers alluded to the need to enhance their own skills and to incorporate more and more sophisticated uses of technology into the instructional plans and into their daily, moment-to-moment teaching.

All of the above can be summarized by one teacher's stated hope and fears, "We must keep growing and exploring. We will not be an alternative [school] if we go back!"

Assessment

Two kinds of assessments were discussed by the teachers during the interviews. One was the assessment of the students; the other was the assessment of the overall effectiveness of the school.

As indicated in the goals network, the intention of the planners was that students be assessed in terms of the quality of their projects. By and large, this occurs. For example, one project is to write a paper about personal and public health, with the question being "Are there significant and credible environmental factors impacting the rate and severity of some disease in the human population?" Another example is the final assessment for the fall of the senior year, which consists of one question: "Can we manage for what we value?" For this work, students are expected to "pull pieces from what they have done and read and present how their understanding of the natural and social world has changed. [Their effort is to be based on] portfolios that are created along the way." Typically, students are directed to submit various parts of their projects as they develop them. The idea is that the teacher's "reading the final paper is to be done without a pen—and after grammar, structure, etc. are all taken care of along the way." In the end the students are evaluated on the academic quality of their understanding of the subject matters included in their investigation and on their writing skill. The writing evaluation includes everything from commenting on the forms of argument they use to the structure and organization of the paper to the grammar. In addition to the projects, students write journals, laboratory and field reports, and literary criticisms. Great emphasis is placed on the students learning to write well as one of the essential life skills.

In addition, students are also evaluated on the quality of their many oral presentations to the other students, teachers, parents, and community members. The senior students have eight to nine public speaking requirements. These presentations are often a part of their group's work. A critical idea behind the presentations is that "our students have to have an audience." One venue for the presentations is a model conference in which students can make a featured individual presentation or a special-interest presentation with a partner, or serve on a panel, or present a poster. The students select what they want to do, depending on their comfort levels and preferences. At the end of the year, presentations are made in the evening to an audience the students invite—parents, a boss, a coach, a pastor, and a past favorite teacher—any adult whom they think should hear what they have to say. “This is a great night – there will be someone from the student’s field and the kids get to shine and show what they know and care about and be supported and lifted up.” Debates and theater-like performances also are used. One debate was modeled after an 1800s parliamentary debate in England about the colonization of the Congo. Theater-like performances range from using readings to presenting characters with roles to play. Great emphasis is placed on public speaking as another essential life skill.

Along the way the teachers also provide other, more typical tests. They do so for two reasons. The first is that the tests provide the teachers some insight as to how well the students are doing. The second is that the teachers came to realize that the students would face many typical kinds of tests in their future schooling or work and thus would benefit from some test-taking practice.

The way in which the school’s performance is assessed overall surprised us. The usual standardized testing of students for college admissions or state standards has either been completed or occurred before the school has had time to have much of an impact on students’ scores. When comparing schools in terms of student achievement, ACT scores are often used. School of Environmental Studies students do quite well in comparison to students in other schools, but there is no formal evaluation of School of Environmental Studies or any other school in the district. As one teacher put it, “This is a hole in the whole plan.”

The school depends on amazing amounts of anecdotal evidence and stories. We cannot begin to recount the variety, breadth, and depth of this evidence: several examples and comments will have to suffice. We found their evidence of school success to be convincing.

One example is the change in the parents’ conversations with the teachers. Parents are uncertain about the school and come to the first-year meetings with questions about everything the teachers do. During the senior year, the conversations with parents are about the positive academic and personal growth of their sons and daughters. The parents send their students’ siblings to the school. As one teacher said, “We seldom miss a sibling.” In addition, the parents tell the teachers about “their student’s successes all the time.”

The students communicate their success and dedication to the school in multiple ways, as well. “While students are here we see them – we see that they were not engaged and are now showing up and we see them working hard all the time.” “We see their work and journals and their growth and happiness.” In a year-end survey mostly related to social matters, the students report they feel safe—physically, emotionally, and academically. The students report that they like the small school, knowing their teachers and the other students, working together, and the style of the teaching. Cliques do not seem to be prevalent.

Finally, the students come back in large numbers. The teachers report that they hear back from students frequently, especially when they are home on breaks. They come back to talk to the teachers and the current students. “They tell us how well they are prepared for college and their pursuits of careers in the world.” According to one teacher,

> Students come back and tell their stories – students never came back at other schools – some come back to teach with us – they tell us what they are doing in the world – they bring their journals and pictures that are part of their lives—we have an (active) alumni network that they run – students come back and help listen to presentations – mock trials – serve as judges etc.

A recent assembly day held before a holiday break had well over a hundred students return.

These stories matter to the teachers and to the community. However, teachers and the principal also expressed a strong desire to have a more formal evaluation and evaluation plan. External assessments were requested to help them see what they are doing and to help them think about what could be done better. They are concerned about whether or not they are continuing to meet the needs of their students. They hope for an external assessment of their work as a prompt and a basis for conducting internal deliberations about their school. They also want an evaluation that would allow them to report their successes and needs to the school district and community. They are somewhat perplexed by the fact that they are not as well recognized in the immediate community as they think is needed and warranted. We concur that it would be beneficial to conduct a thoughtful external assessment that involves past and current administrators and school planners, alumni and current students, parents, and community members and encourage them to critique the current goals and practices in the light of recent research and best practices.

Lessons Learned

An inquiry like this would be of little value without some statement of lessons learned. The following are presented for consideration, with full awareness that the inquiry was limited in scope. Even so, the views of the people who were interviewed matter, and the consistency of their views along with the absence of statements that contradicted what each said lends credibility to the lessons learned. What matters is context, time and resources, a network of goals, research, people, freedom, flexibility, community connections, accounting for complexity, and respect, with all of these factors being in play concurrently and continuously.

The context matters. The interactions among the practical needs of the school system, the zoo, the city, and the community provided the environment that allowed the school to be developed.

Providing substantial time and resources to the initial studies and planning matters. The goals network was created with these resources and became shared community property during the planning process.

A sustained network of goals matters. Nearly everything the teachers and principal said was related to the network of goals. The statements were about how the goals were being used, what aspects of the school needed to be improved in the light of the goals, or what goals might need to be improved or changed in the future.

Research matters. In this case, research means the combined investigations of academic studies, best practices, the school system, and the community. Research generated the ideas and the foundation for the goal network.

People matter. The leadership from several sectors—the director of the zoo; the superintendent, other district administrators such as the curriculum director, the principal, and board members of the school district; the mayor and city council members; and especially the teachers who did the studies and made the plans—all of these people were essential. The hiring of teachers dedicated to the network of goals was also essential because without them the curriculum, instruction, and assessments would never have been developed.

Freedom matters. The teachers and principal all referenced the academic and political freedom they had to use what they knew about education. This freedom to plan an innovative school and the continuation of that freedom allowed them to elaborate and sustain their plans.

Flexibility matters. The school architecture and schedule allows teachers and students to interact in productive ways on a daily basis and in response to changing economic and political trends and to specific local, national and international events. Flexibility was especially important in allowing the teachers to collaborate and cooperate as they taught.

Connections to the community matter. The connections to the community provided real-world experiences and interactions with adults other than teachers and raised the standards and status of the students' work.

Accounting for complexity matters. Accounting for complexity means the teachers used many different ideas and skills to allow interactions among people and practices to inform decision making at the school. The network of goals was essential because it provided stability to their thinking as the particulars changed and adjustments were made.

Respect for a diversity of ideas matters. The above sections do not provide direct evidence of this, but the interviews are replete with references to the deep respect that all in the school have for each other's ideas and skills. Mutual respect allowed for a level of sharing of ideas about what is best for the children that was remarkable.

When taken one by one, many of the lessons we learned are neither unique nor surprising. What is unique, though, is that the specifics of what matters are highly interdependent. In our view, this school was built, was successful, and was sustained only because all the above factors were present.

The View from the Top of the Plateau

We expected to find that the use of the original mission of the school had diminished over time. We expected to see complacency, given that the school was on top of the plateau. We expected to see little in the way of concerns for the future of the school.

But we found little evidence that any of this was the case. Instead, we found that the school remains dedicated to the original goal network and uses it every day to plan and carry out the curriculum, instruction, and assessments. It continues to deeply engage students in their educations. The school also uses the goal network to make adjustments to the current circumstances on a regular basis. We wish you could hear the passion and dedication in the voices and comments of these teachers related to the goals.

We also wish you could hear the tinges of fear that they will not be able to do what they do because of a changing political climate, state requirements including accelerating demands for high-stakes, test-based accountability, administrative intrusions, and budget cuts. Their greatest fear is the loss of the time they need to think about and plan and coordinate what they can do for children.

If we wish to have innovations that will benefit our children and future citizens, perhaps listening to the voices from the top of this particular plateau would be useful.

Chapter 11
Benefits of Elementary Environmental Education

Ryan J. Brock and David T. Crowther

This chapter discusses the benefits of nature, provides insights for how research and organizations have developed to help people reconnect with the natural world, and concludes with an exploration of a nature club for fourth graders. This chapter intends to inform policy and effective program development for increasing *environmental identity* (E.I.) as a category that could be assessed in elementary-aged children where this development is critical.

Introduction

The natural world has provided humans with food, shelter, and tools over the past tens of thousands of years. Experiences with nature can reduce sicknesses and stress and can help calm patients before and after surgeries (Kahn 1999). Nature can also help children develop a broad sense of values, from humanistic, moralistic, and naturalistic values to scientific, symbolic, and aesthetic ones (Kellert 2002). Nature also can increase children's self-esteem and sense of self (Taylor and Kuo 2006). Simply watching a child play in nature invokes a sense of curiosity. Science education research has also shown that a person's ability to identify and connect with the natural environment can influence whether there is later efforts that go into protecting it (Kahn 2002; Schultz et al. 2004).

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Elementary Environmental Education Research

Several scales and tests are available for determining the effects of programs designed to strengthen environmental identity. Among those considered were the Connectedness to Nature Scale (Mayer and Frantz 2004) and the Nature Relatedness Scale (Nisbet et al. 2009). Such scales, and several others, usually ask participants to rate themselves in a "Likert-type fashion" with a number system that ranges from "strongly disagree" to "strongly agree." While these scales show positive results of environmental programs in some cases, most of these scales target young adult and adult audiences, neglecting elementary-aged children (Brock and Crowther 2011). Here, we suggest the need to further develop environmental identity scales that are more closely aligned with science education, so as to better take into consideration the developmental and age-appropriate needs of younger students. It should be noted that the research we will discuss in this chapter comes from a larger study involving children in grades 3–5.

Developing Environmental Identities

In addition to general education regarding content instruction, schools also can be a central arena for health promotion and intervention services. These activities can help children develop a healthy identity regarding who they are and who they want to become (Roser et al. 2000). The science education literature suggests that when a person can identify with the natural world, s/he is more apt to preserve and protect it. Conversely, without a sense of place and community, people are more likely to disrespect or destroy their environment and are at risk of losing their sense of themselves and their identity (Kriesberg 1999).

It is because of the importance of identity that terms such as "ecological identity" and "environmental identity" have surfaced when discussing environmental education. Ecological identity refers to the different ways a person interprets his/her relationship with the earth, from values, actions, sense of self, and personality (Thomashow 1995). We define *environmental identity* simply as "how we see ourselves in relation to nature" (Opotow and Brook 2003, p. 250).

Regardless of what term is applied to how one sees his/her connection with nature, such connections have become a popular subject of recent research in science education and schooling. In understanding how one constructs and changes their identity in relation to the natural world, curriculum specialists and educators potentially have one of the most valuable roles in helping children connect to the local environment. In this regard, special considerations ought to be made when working with children in elementary school and creating outdoor curricula, experiences, and assessments that are appropriate and significant.

A Study of Fourth Graders in a Nature Club

Brock (2010) adapted Clayton's (2003) Environmental Identity (EID) Scale so it could be used with fourth graders to determine the impacts of an after-school nature club. With the school residing in a large city, making frequent visits to nature difficult, the study investigated the effectiveness of combining learning in nature alongside the use of natural artifacts in the formal classroom setting. The nine-week club was designed to create experiences for students to investigate and learn about the natural world, with emphasis on local mammals, birds, and the environment. Nine club meeting took place in an after-school classroom; three outdoor sessions were held on Saturdays, spread out between the classroom meetings. The outdoor sessions allowed students to participate in nature hikes, make first-hand observations of nature, set up decoys and call in ducks and geese. Families were encouraged to participate in the experiences as well.

After-school nature clubs provide appropriate and significant opportunities to incorporate authentic investigations that afford opportunities for students to "reconnect" with nature (themselves).

A variety of sources can be tapped to ensure that such activities are grounded in science content. Sources of information for this purpose include the internet, local pamphlets, local sportsmen organizations, the school's adopted textbook, and the local fish and wildlife service. In many science classrooms today, these kinds of resources are used largely for developing factual knowledge; however, a nature club can be used to explore these concepts more fully.

A Look Inside My Nature Club

Ryan, the first author of this chapter and the teacher of nature club, is a long supporter of encouraging children who live in the city to experience and take in the outdoors; he has spent the past nine years developing after-school nature clubs at his elementary school in Reno, Nevada. Ryan uses a combination of bringing nature into the classroom as well as taking children into nature as a way of blending typical school day and extracurricular educational milieu.

Ryan's Nature Club

The student, and perhaps a friend or two, along with other fourth graders that may not know each other well, enter Ryan's classroom after school. As they sit down at a desk, they can't help but look at the items at the front of the room: antlers, hides, a skull, and various other treasures of nature. After completing an initial EID survey, which Ryan will use to see environmental identity change from pre- to post-survey, students are asked to wander around the room and observe the items that have been placed at six stations.

Each student is given a nature notebook to use over the next nine weeks, and upon inspecting the items, they record their observations and questions inside it. The students are encouraged to smell, touch, poke, and magnify items with a hand lens. Unknown to the students, Ryan's goal is to use their observations and questions (after initial exploration time) to guide the lesson on the topic of elk—an animal that lives in Nevada. As students begin discussing their observations, Ryan leads them into deeper understandings of how elk survive. Concepts include learning about the differences between antlers and horns, the anatomy of an elk skull, and the reason that elk hairs are "hollow." Ryan points out the evolution of elk's ivory teeth and gives each student an opportunity to take in the smell of an elk, using a purchased "elk scent" fraguent bar. Each concept is initiated by a student observation and Ryan simply expands upon their discovery. A map created by the Nevada State Division of Wildlife is explored as students learn where the different elk herds reside in their state. The culminating experience of the first session is learning how to produce the sounds of the elk using a diaphragm call.

This first club session, as all other sessions, ends with journaling. Students are instructed to find the next blank page in their nature notebook and glue in the journal topic, which is handed to them on a piece of paper. They spend the next ten minutes engrossed in writing on that topic followed by a five minutes student-led conversation about their nature journal entries.

The next eight classroom meetings allow the students to experience nature in a similar manner. (With the difficulty of transporting students out of the city to spend time in nature during the after-school club, natural artifacts are often brought to them.)

A week later, during the second meeting, Ryan's goal is to get the students to begin thinking about nature inside their city limits. Nature photography is used for this purpose. Students are encouraged to bring in their own digital camera, or one is provided to use for the next several months. The students are instructed to take their camera to the playground, look beyond the concrete walkways and human-created structures to find nature, and document it with their camera. When they return to the classroom, Ryan encourages discussion about what natural items were observed and photographed. Students agree that nature, living plants, and animals are seen all over their own school grounds. Ryan challenges the students to take nature photos with their camera of these critters and email their best two or three to him before the next meeting. The next several meetings begin by allowing students to share these photos on the digital projector. Ryan's secondary goal of this learning experience is to get the students to think about nature more than just during a nature club.

The third meeting arrives. Students are encouraged to focus on small mammals living around them. Ryan unpacks a large bin of mammalian items: skulls, hides, replicate animal scat and tracks, and more. As before, Ryan encourages the students to investigate the items. Their observations help guide the discussions and learning of content knowledge, contribute to an understanding of how these animals interplay with humans, and more importantly, begin to be a vehicle that allows children from the city to identify with a world they may not know. Toward the end of this session, students learn how to use an elk diaphragm call to produce coyote sounds.

In the next meeting, students collaborate as they pretend that scissors, tweezers, or spoon is a beak. They learn which beak works best for certain foods. Ryan presents them with photos of different bird beaks and asks them to guess what type of foods each eats. Near the end of the session, the students move about the room analyzing mounted bird heads and feet. They discuss and write observations about the uniqueness of each beak and foot structure, and how the bird probably uses them. Again, students lead a discussion based on their observations.

A favorite activity is engaging students in a mock town hall meeting to discuss the imaginary issue of a possible local reintroduction of elk. Ryan explains all the roles in this simulation activity that students might play: wildlife biologist, business person in town, worker for the department of transportation, hunter, and so forth. After selecting their role, the students spend time researching relevant background. When all of the students are ready, the town hall meeting begins. A debate occurs for the rest of the session. Ryan likes students to take on a role that contrasts their own perspective. He does this so that students can better evaluate multiple sides of issues facing the community and environment. When Ryan tries to stop the discussion, students urge to go on, because they are so intrigued by the different positions and opportunity to analyze them.

The next two sessions focus on local birds. The first of these two sessions engages students with turkey artifacts. The second engages students with duck artifacts. In both sessions, the students learn about the animal and nature by observing wings, feet, and hearing stories from Ryan and classmates. Ryan provides various turkey calls for the students to evaluate. Then, they build their own turkey call from string, a plastic cup, and a sponge. During the duck session, a parent of a club member demonstrates on the playground how to set up a spread of duck decoys and provides an opportunity for the students to sit in his duck blind. The parent volunteer demonstrates the retrieval skills of his dog. Upon returning to the classroom, Ryan gives a duck call to each student and encourages them to mimic the sounds he teaches them.

Near the end of the year, Ryan brings in a variety of local rocks and minerals. The students investigate these using a combination of measurements: they determine the name of the minerals based upon their characteristics and use a map to see where they are located near their city. Ryan challenges students to bring in any interesting rocks they collect on their own and encourages them to start a rock collection. Nevada is a treasure trove of rocks after all.

During the final classroom meeting, the students develop a deeper understanding of how humans use items from nature. After participating in a discussion of the many items humans have and continue to use from nature, each student receives a wing feather from a turkey. They use it to create a quill feather pen, which they use by dipping into watered-down black paint. As they write in their notebook with it, a nature contract is passed around to each student that has been developed by one of their peers with her quill pen. She encourages each student to sign it with the quill pen. Ryan can't help but smile as the students excitedly sign this document that encourages them to continue to be a part of nature.

Although students enjoy and learn a great deal from the more formal classroom meetings of nature club, they gain as much from the three outdoor meetings. The three outdoor meetings are different in that the students visit natural environments instead of examining artifacts from nature in the classroom. Each outdoor session lasts about four hours and the students meet at a different location outside of Reno.

The first outdoor meeting is held at Galena Creek, a regional park at the base of Sierra Nevada Mountains. Being just a short drive away, the area contains a variety of pine trees, hiking trails, a creek, and a fishing pond. Ryan believes this first outdoor experience for the club needs to be a big success to encourage the participation of future outings. The students show up with their digital cameras, ready to take nature photos. As the club members hike along one of the nature trails, they take photos, until they come to an area where Ryan has hidden four secret nature caches. The students learn how to use a GPS and then head into the woods in small groups. When they arrive at the nature cache, they open the box and are given a task to complete. Tasks involve observing pinecones eaten by squirrels, comparing the leaves on different plants, and smelling pine bark to distinguish among different species of pine.

The second activity is a nature hike along the creek. Every four or five minutes, Ryan stops and has the students focus on a specific item near the trail. They learn various things during this short hike. One of the highlights is when students watch brook trout in a creek and follow a snake that darts in and out of bushes along the creek. For several students, this is the first snake they have ever seen in the wild! As families are encouraged to travel on these excursions, parents and siblings become as excited as the club member. They often come back to visit these sites later.

The second outdoor trip is to Washoe Lake, a local, yet infrequently used, Nevada State Park. The goal is to let students experience wetland ecology. During this trip, however, most of the wetlands are dry. Despite that students may have been discouraged, the dry wetlands provide unique learning experiences where we talk about how animals adapt to dry situations, especially in the high-desert environment, where this park is located. The group walks around on some dikes, discovering coyote scat, deer tracks, and other interesting items. The students use their keen observation skills to search out and find camouflaged wildlife artifacts. After exploring the dry wetlands, the group then departs this area and heads up the road to spend several hours hiking to a scenic overlook of the valley. Much time is spent learning about the local plants and discussing the remnants of a fire that came through this area in the recent past. When the group arrives at a scenic overlook, they are encouraged to stop exploring for a few minutes to eat lunch. During this time, Ryan offers a brief history of the area, including a discussion of the early people and tribes who once lived here. Before heading down, club members pose for a photo with the valley behind them.

The final outing involves using the duck-calling skills that the students learned in a prior session. Ryan's club partners with a local sportsman group, and this group helps students gain access to a local wetland. Some students show up in camouflage, and for the students who don't own this clothing, a pile of camouflage jackets are pulled from a truck to borrow. Ryan leads the students and parents away from the cars and has them pause to observe a small pond of aquatic life. A minnow trap is baited and thrown into the pond. It will be checked on the return trip back to the vehicles. The group continues the walk toward the much larger pond. Students sneak ahead of their parents and the instructor and crawl over the ridge to see a dozen or so ducks on the pond. Excitement builds for everyone, but eventually the ducks fly away. Over the next 30 minutes, the students put their skills to the test: they tell adults how to set up a decoy spread in the water. Once set, everyone hides in the tall, yellow tule brush. The students begin blowing their duck calls; they watch as a few ducks fly overhead.

Nature Club Experiences

Now we want to introduce you to another side of the nature club—a side that students know is taking place in the background, but soon realize doesn't matter to them—the research component. For nine years, Ryan has been running nature clubs with elementary students and he has always been fascinated with how many students stay an additional hour or more after school to learn about nature and wildlife. Thus, Ryan began collecting information on which components of the club seem to bring the students closer to nature. The following discusses this research.

In seeking to understand which components of the club help to strengthen environmental identity, multiple sources of data are collected during the club events. These include student's nature notebooks, photos taken by students, conversations in class, multiple interviews of participants (before the club began, halfway through, and after the final meeting), a pre- and post-EID (Environmental Identity Scale), and video recordings of each session that are later transcribed. Ryan learns that connections to the natural world are developed by students who participate in this nature club. Their weekly nature reflections, comments from class, interviews, and posttest results all evidence an increase in their environmental identification with nature.

In looking at the results of the Environmental Identity Scale for the entire club, the pretest results displayed an overall mean score of 5.7 points per item out of a possible 7.0. The posttest scores increased to 6.3. The initial EID served the purpose of identifying low, average, and high environmental identity students based upon this group's scores. Students were then selected from each category to follow more in-depth through qualitative measures. The lowest environmental identity students for this club scored a pretest mean of 4.5–5.0, average students scored 5.8–6.2, and the highest students scored 6.6–6.7.

No matter how strong the child's prior connections with nature were when entering nature club, contact and experiences with nature and natural objects help to broaden, deepen, or strengthen each child's environmental identity. According to some of the children's interviews and nature notebook entries, it is the Saturday learning experiences, where they spent several hours engrossed in natural settings. One child, who entered with low environmental identity according to the EID pre-survey, reflected in her notebook that the Saturday experiences created a place to "learn about nature by being in it." Correspondingly, the students with average environmental identity upon entering the club also gained much from the experiences according to their interviews, reflections, and entries in their science notebooks. One student wrote that she enjoyed the direct experiences with the natural world because they allowed her to "feel the breeze" and "see it actually with my eyes."

The implication for curriculum designers and policymakers is that learning experiences need to be developed appropriately and measured, both in the classroom and outside its four walls, to allow students to construct their own meaning of the world around them. A teacher must design experiences for children to learn from nature, as one way children construct knowledge of reality is through their physical interactions (Singer and Revenson 1997). By creating learning experiences where children from the club might interact with objects both inside the classroom as well as during outdoor trips, Ryan's children came to understand nature at a deeper level according to their notebook entries, interviews, and pre- and post-EID results.

The learning process that occurred in a nature club is easy to see. For example, while analyzing a mounted turkey, one child notices a feature on the turkey's leg that is unfamiliar to him. He searches through his memories to help him understand what a spur is. Unable to access any prior knowledge, he begins to think more deeply about spurs. He talks with a classmate who raised chickens when she was younger. Although having no knowledge of turkeys, her prior experiences were different from the boy's and she only had to modify an existing assumption of spurs. She is able to use this prior life experience to think about how chickens have similar looking "things" on them that they use for protection. The idea of being in a place or community to witness a mounted turkey triggers a shared learning experience for her and other students.

In designing environmental curriculum, we provide opportunities for learners to construct their own knowledge of the world around them. Future curriculum planners and classroom teachers need to be prepared for these outcomes, the challenges that come with a lack of funding for outdoor experiences, to be able to create experiences where children interact with their learning both literally and cognitively. An effective experience may require more time for preparation, funding, and better classroom management than lessons where a teacher lectures or has students read from a textbook. The depth of knowledge gained and deeper understanding is well worth the time.

Experiential Learning on Values

Another outcome of the nature club was that it helped students develop positive values about nature. Earlier, it was mentioned that through interactions with nature, students were better able to construct an understanding of the different topics presented. Unfortunately, in many school districts today, the standardized testing of general knowledge has become the basis of determining the outcomes of student learning. As important as tested knowledge is, it isn't the only characteristic that is learned in science classrooms, and definitely not the only attribute of a person that makes them a complete person. The affective side is also what makes us human which is just as important, perhaps more so, when it comes to taking care and loving others, both people and places.

Students with average to high environmental identities in the club made great strides toward strengthening their values of taking care of the environment. Through interviews, Ryan found they all entered the club wanting to take care of the environment. This was also apparent in their notebook entries during the first four weeks. (Yet each student in the study initially only expressed shallow ways of doing so.) Their textbook type recall reflected their prior learning about taking care of the world around them. Answers ranged from "If something happens that is big all the humans can die…trees produce oxygen, so maybe humans would die too" to another student's response, "We can plant lots of trees and stop cutting down trees for paper…because then we can't breathe that well." One student spoke with a passion about protecting the many places she had read about and learned about from passive measures. She said during one interview, we need to protect "all the tropical land and all the trees in the forest…putting things in the ocean from sharks and animals eating them may die…don't litter all the time." However, when asked what she could do right now, in her high-desert environment, she couldn't come up with a way to help her local community or environment.

Unfortunately, students' prior experiences of "protecting" the environment often come from passive experiences instead of direct encounters with the outdoor environment. Without this direct experience, fourth graders are not necessarily able to apply knowledge learned in science class to their local environment. Without direct experiences to help students develop their affective aptitude, they initially recite the broad concepts but are unable to articulate how to apply them to their everyday lives. Classrooms today, where learning is only focused on preparing learners to memorize factual information for a standardized test, lack in producing citizens who truly relate with the content on the affective side. We have to move American education away from emphasizing learning through lectures and books exclusively (Coyle 2005).

Nature club allows students to interact with nature and artifacts from it, increasing club member's affective values by the end of the nine weeks. According to qualitative data from midpoint interviews, notebook entries, and conversations in nature club, not much change is seen until after four weeks, indicating that single occurrences will not make much impact and students need to have encounters over longer periods of time to truly feel a connection and part of the natural world. Examples heard during the midpoint interview echoed those from the preinterview: “don’t litter because the animals don’t have anywhere to live,” “It is good to take care of the environment because it can help you survive and stuff like global warming,” “Stop cutting down trees for paper and our breathing, because then we can’t breathe that well.” Students also continued to reference where they obtained these ideas from, which included *Times for Kids*, a magazine they read in class, TV, and prior lessons from school. However, during their final interviews, the way students described taking care of the environment changed. One student stated, “There are sometimes two sides to a story” when dealing with environmental issues. Three other students had very similar discussions, understanding that there are complex issues in how one values nature. None of their conversations revolved around simple answers as before. They had begun to talk about their personal actions that they could easily control and begin with, versus through saving the rainforest campaigns. One mentioned he had started recycling at home. Another spoke of the battles that had started in her head when her actions went against her beliefs, such as using her family’s boat: She enjoyed being on it but realized that it released amounts of oil into the water.

In the research literature, there is inconsistency in the length of time a program needed to be conducted to have an impact on environmental identity for children. This particular study may guide policy and program development in that it took a minimum of four weeks to detect only the beginning of a change in some of these students with higher E.I. scores. For the lower E.I. scoring participants, it truly took the entire nine weeks in combination with the classroom and fieldtrip settings to see a change in E.I. both through the scores on their surveys and the qualitative measures.

The following table displays student mean scores from the environmental identity scale pretest and posttest, followed by their increase in score. Although all students increased their scores after the nine-week club, those students in each category (high, average, low) increased similarly. Students who entered the club with low environmental identity through direct and indirect experiences with nature increased the most. According to their post-interviews, these students believed the outdoor experiences in nature were the most fun and were the one component that helped develop connections with nature. One student mentioned, “I could learn about nature by being in it and having fun at the same time.” Concomitantly, the students who entered with high environmental identity, who had many prior experiences in the natural world, benefited from the personal reflections. One student with high environmental identity said during her last interview, “I think the journaling…make me think so much more about what I was actually doing and what we were talking about.”

High	Average	Low
6.7–6.9 (.2 increase)	5.8–6.4 (.6 increase)	5.0–6.2 (1.2 increase)
6.6–6.7 (.1 increase)	6.2–6.7 (.5 increase)	4.5–5.7 (1.2 increase)

The social components of a nature club seem to impact affective development as well. With activities designed to include social interaction, students learn from each other. Students with high environmental identity become leaders who share their knowledge and beliefs about the natural world. Examples of students with higher environmental identity model and discuss their views of nature with lower environmental identity students, evident from week one. This is integral to the E.I. growth for these children. Students with lower environmental identities especially benefit and often learn to take on the values of their peers through simple conversations and tasks. One such example took place while walking back from calling ducks. A student with low E.I. told another student with average E.I. how he wished he could shoot all the ducks flying overhead. The response to this was, "You can't shoot them here you know. So that's good. Because ducks need a habitat." The child with low E.I. thought about the statement and replied, "You can't shoot them here, but you can shoot them everywhere else." The other child responded, "No you can't." A conversation then began about hunting regulations, limits, and seasons and why those are important to conservation. Those with higher E.I. were leaders and mentors to those with lower E.I.

Often overlooked is how traditional teaching (which typically is directed by the teacher) allows students little access to the ideas and thoughts of their peers. A benefit of creating a community of social inquiry is the awareness of what other students are thinking about the topic at hand (Splitter 2000). Program and policy developers are encouraged to take this into consideration so that the entire range of children with different levels of E.I. may benefit from the social experience.

Newfound Hobbies

Ryan's Nature Club provides an enrichment opportunity for the students who attend. Unfortunately, during a normal school day, instruction is often directed by curriculum choices outside of Ryan's control. Since high-stakes policies were put into place, many enrichment activities have been cut or reduced to allow more instructional time for the content that is assessed to measure a school's Adequate Yearly Progress. Many principals and teachers now focus on math and literacy and deemphasize, or even totally remove the time spent on elementary science (Marx and Harris 2006). Science isn't the only subject to suffer, as physical education, arts, and social studies have also taken similar hits. With the emphasis on math and literacy, our high-stakes policies appear to be slowly changing the emphasis of investigation and inquiry to more rote memorization of facts. Activities that used to be seen in classrooms which helped enrich students' lives and encourage inquiry are disappearing. This is not the case in Ryan's nature club.

Participants recalled how the nature club had helped them find new passions in life. A few students became more interested in hunting. One child even encouraged his father to get back into his old hobby of hunting. Nature photography became a newfound passion for one young lady. Rock collecting was picked up by two boys halfway through the nature club because of one lesson focusing on local rocks of the area. One boy, whose family had no real interest in the outdoors, aspired to explore nature more often, leading to family hikes around Nevada. Even a year later, this child's father talked about the impression the club had on his son. Another child's parent sent an email to Ryan stating that the child and "her dad were practicing their duck calls last night and she is getting pretty good. I see her hunting with her dad in the next couple years." Both of these students entered Ryan's Nature Club with low environmental identity. The nine weeks of a nature club, with only an hour or so a week of classroom learning, combined with three Saturday excursions results in much needed enrichment for the students, so much so, that parents witnessed incredible changes in their children. The significance of both more funded in- and out-of-school learning experiences cannot be overstated.

Implications for Science Education

In this era of high-stakes policies, the increased science content, both factual knowledge and conceptual understanding that students walk away with from a nature club, is worthwhile. The club piggybacks upon the standard based content that is introduced during the normal school day and allows students to get more personal with it and construct deeper understandings. Ryan's study also reveals that students develop other skills that are equally significant in fostering scientific understandings and environmental identity. First, many students walked away with a newfound hobby, such as rock collecting, hunting, fishing, and nature photography. Of the six students followed in-depth through qualitative means, four began new hobbies. One other student believed he "liked to identify plants" but wasn't sure if this was considered a hobby.

Another concept which emerges from this research is the strengthening of social identity, especially for the two students with lowest environmental identity. Both of these students made specific references to the social aspects of the club during their mid- and post-interview. For these students, who lack prior experiences with nature (according to their interviews and notebook entries), the social components where students complete activities collaboratively and learn from each other through conversations and discussions are uniquely evident and a critical aspect of the club. These two students shared more with their peers as the club progressed and noted that one of the top three things they enjoyed about the club was making new friends.

A third unintentional outcome is the development of process skills. Many fourth graders in the club talk extensively about how nature club increased their observational skills, especially with respect to noticing more details in nature. Of those students intently followed, three of the six made specific references to having a more keen sense of observation. This was also apparent in each of the six student's nature notebooks, where more details began appearing in later entries as well as during the last two Saturday outings. It is during these last nature experiences outdoors where most every student kept Ryan busy, showing them a variety of items they discovered. Students were eager to present their findings and inquire what a plant, track, or other item is or to share their discovery and relate it to a prior nature club experience.

Designing Curriculum Appropriately and Significantly

This study was conducted after school, and although it combined formal components of classroom learning, it also used out-of-school educational aspects. However, lessons learned from this study could easily be transferred to the formal realm of education.

Children benefit from direct experiences with their learning (Kahn 2002). Lectures and textbook reading alone do not fully develop the cognitive aspects of learning. Additionally, in order for elementary children to develop values about nature, it is best that they come from direct experiences and encounters, as "the formation of values typically move from relatively concrete and direct perceptions to more abstract levels of experiencing and thinking" (Kellert 2002, p. 132). These experiences may require more time in the classroom, as a high-quality field experience or science lab requires time to allow student interaction with the content. Teachers who reduce such experiences and succumb instead to fast-paced, textbook-led instruction may provide a less well-rounded education for their students.

Students need time to develop affectively and intellectually. In looking at a classroom scenario, where most classes are unable to provide experience upon experience of in-depth nature study in an outdoor setting, understanding the minimum length of time for direct and high-quality indirect experiences for students to increase their environmental identity is appropriate and significant. For students with lower environmental identity, this study found that longer lengths of time, seven to nine weeks of direct and indirect experiences with nature, are required. Students with higher environmental identity strengthen their connections to the natural world more rapidly still require a minimum of four to five weeks of both indirect and at least one direct experience with nature.

Curriculum developers and teachers alike need to reassess the current school curriculum to ensure that social learning components are present, as these allow children to develop a sense of reinforcement, peer interaction, modeling, and belonging.

The teacher's background in science, nature and creating appropriate activities for 3rd–5th graders, is very important at the elementary level because it creates the foundation for effective pedagogy. Teachers who have a passion for science often move to the middle school or high school level where they can teach it throughout the day. At the elementary level, teachers that have strong content knowledge in science are relatively uncommon. This problem emphasizes the need for well-rounded training for instructors of elementary curriculum and programs or the need for collaborations with content experts and teaching specialists to create optimal learning situations and curriculum for students.

The Ideal Situation

What would the ideal learning situation look like for elementary students? First, the state and national priorities for science curriculum would need to be reexamined to include more focus on environmental sciences at the elementary level. Second, educators will need to understand both the science content and developmental implications of implementing the curriculum that best reaches the needs of the students that they work with. Teachers must learn to allow students to value nature through experiences lived and intimacy felt, rather than on acquiring additional facts (Kahn 1999).

If students are to value nature through their experiences, they need to have learning experiences in nature. This means dedicating some financial resources to permit field trips to natural areas.

It is our opinion that every child should experience an overnight trip in a natural setting at least once during their elementary years. This is occasionally made a reality when an energetic teacher within a school makes it possible. Most elementary teachers don't appear to want to take on the extra burden of such intense planning, preparation, and responsibility. There are very few rewards, such as merit pay, available for teachers who do these things. Other times, local organizations, led by specialists in outdoor education, search from school to school to find a teacher who is willing to give the overnight experience a try, with additional assistance and expertise from the organization. In our area, organizations such as Sierra Nevada Journeys and Great Basin Outdoor School offer excellent experiences for classes, with associated costs.

In our district, which houses 64 elementary schools, the cost for funding an overnight experience for every student in a particular grade is somewhat difficult to calculate. The following is based upon a one-night camping trip for fourth graders at Ryan's school, where a teacher has developed the trip and only district busing and campground fees for the 75 students and 20 parents are calculated. Meals are excluded, as student groups plan and provide their own food. Total cost for the annual trip might run about $1,000. With only one campground within 60 miles to hold this large of group, the school is limited in campground choices. This means a minimum of $64,000 for the school district for every fourth grader to experience such a trip. This price tag pales in comparison to what districts spend on textbooks, classroom resources, and the standardized exams.

Although the costs for outdoor experiences and overnight camping are expensive, there are ways to alleviate these costs such as through some of the tactics used in Ryan's school. The fifth-grade class at this school has been able to make an annual trip only because of partnering with a different sportsman's groups each year, which help cover the majority of the cost. It has been a lot of work for the teacher who leads this trip to seek out organizations with the same mission of getting kids into nature, presenting at their board meetings, and writing follow-up reports. Although cumbersome, the process has formed good collaborations between the organizations and the school. Hiring a motivated coordinator for the school district to build these relationships and enable every fifth grader to attend this natural experience would be ideal. Why are teachers not compensated for their participation? Should merit pay be linked in some way with building partnership?

Parent involvement is another key element in environmental education and outdoor experiences. Having experiences that allow parents to get involved with their child is important. When parents see the value, then opportunities arise outside the school day where families begin to develop identities with nature.

Having checkout nature kits that elementary teachers can use within their districts will help increase some hands-on learning experiences dealing with nature. It is unrealistic to learn about nature 100 % of the time outdoors, unfortunately. However, like Ryan's Nature Club, nature can be brought to the students through artifacts and so forth. While elementary teachers are generally hesitant to teach science due to lack of science content and pedagogical science content knowledge, these kits could help increase both of these (Appleton 2008). The hands-on nature materials will help the teacher instruct outside of a textbook while at the same time allow students to investigate nature through real objects from their state.

Being an ideal situation, as mentioned above, we wish more consideration would take place regarding the building of new elementary schools. It is easy to get jealous when reading articles or books describing school context and teaching experiences embedded with a nearby stream, wooded vacant land, a forest, or even a wetland. They simply walk out their classroom door and engage the students with their natural environment in minutes—no buses needed. Including in the design, areas near the building will drastically increase the amount of time teachers take their students outside. Incorporating science, writing, research, and more can take place around such communities.

Creating more high-quality environmental education or outdoor programs will greatly benefit environmental identity and student connections with nature. In Ryan's school district, he has seen after-school cooking clubs, science clubs, language clubs, and just about anything else you can think of. Currently, Ryan is one of the few teachers in the district offering nature clubs, elk clubs, duck clubs, and turkey clubs. Students flock to them and fill them up in a day or two—(he has to limit numbers). Children are passionate and curious about nature. We simply need to create more opportunities that allow them time to investigate it.

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Chapter 12
Teaching Earth Smarts: Equipping the Next Generation with the Capacity to Adapt

Bryan H. Nichols

What if we could equip the next generation – Generation R – with the capacity to adapt to their changing world? Isn't it our responsibility to give them the ability to face local and global environmental challenges and improve, or at least maintain, the quality of life that many of us presently enjoy? This chapter will suggest that education should be about giving our kids "earth smarts," a kind of street smarts writ large. Instead of churning out workers for declining industries or training children to take endless batteries of tests, we should be teaching them how to build vibrant, healthy, and resilient communities, even in challenging conditions. This chapter will introduce earth smarts as an educational construct, a tool that can help policymakers, educators, and researchers produce citizens and communities that can creatively and justly adapt to environmental challenges. I will examine the main components of earth smarts and how they were derived.

Why Earth Smarts?

Humanity is in the midst of two important changes that are relevant to this chapter. The first is an unprecedented loss of first-hand ecological knowledge, brought on by our dazzling technological achievements and our migration into cities. For the first time in the 200,000 years that modern humans have walked the Earth, more than half of us now live in cities, and that ratio is increasing (United Nations 2006). Urban living and modern technology insulate us from the natural systems we rely on. Millions of people now have no idea where their food, water, or energy comes from. This ignorance would have quickly killed our ancestors – now, it contributes to decisions that jeopardize our well-being.

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The second change is happening to our environment itself – the evidence is piling up that our increasing numbers and consumption are altering the world on a global scale, trigging changes that may take us out of the conditions that our civilizations have thrived in (e.g., Hansen et al. 2006). Yet even though scientists are becoming increasingly good at recognizing and even predicting such changes, in many countries, particularly the United States, there is a growing disconnect between what scientists predict and what the public believes.

Education is at the heart of both of these issues. Our education systems are failing to address our unprecedented loss of ecological knowledge, and they are failing to equip citizens with the ability to adequately consider scientific claims and evidence. Simply training more students to do well on high-stakes exams is not enough. Earth smarts is an educational construct that embodies the qualities we will need to adapt – more specifically, to justly maintain or improve our quality of life in a changing world. It was designed as a practical, nonpartisan tool that can help educators, administrators, researchers, and policymakers better understand and impart the cognitive and affective qualities we need to live well. Grounded clearly in justice and quality of life, earth smarts offers an answer to those who wonder what the point of education is or what we are supposed to be sustaining when we talk about sustainability. It consists of four domains (concepts, competencies, values, sense of place), each with its own components, providing solid guidance that is specific enough to work in modern, standards-based educational settings, but flexible enough to encourage cultural and bioregional localization by creative educators. The components, which include affective and moral elements, should encourage educators to design more meaningful assessments that incorporate these complex but essential qualities.

Ensuring a healthy environment is about more than just preserving someone's idea of what nature should be. Societies that can sustain healthy environments are more resilient and secure – one of the themes that emerged from the Third National Conference on Science, Policy and the Environment was that "Simultaneously protecting the environment and providing for economic and personal well-being is the path to human security and the foundation, in the long-term, for global security" (Blockstein and Greene 2003, p. 18).

Three Key Concepts

There are three potentially confusing concepts I'll need to clarify before examining the components of earth smarts.

Educational Construct

In education, constructs are concepts for which there is no direct, physical referent –things like literacy, happiness, or intelligence. Defining educational constructs can be helpful as it allows everyone to speak the same language, making it easier to create appropriate curricula and assessments. Literacies (e.g., media, earth, ocean, science, financial) are particularly popular constructs now, as they attempt to encompass more than simple memorization of facts. Earth smarts, or socioecological literacy, is related to environmental literacy, which many states are presently creating plans for.

Quality of Life

Maintaining or improving quality of life (or well-being) is the goal of earth smarts, but to be universal, our definition has to avoid specifics like chickens in every pot or home theater systems in every media room. Here, quality of life will mean clean air; sufficient, safe, and nutritious food; sufficient clean water; and adequate shelter from the elements. That will keep our bodies healthy – for our minds, quality of life will also include freedom from violence and crime, opportunity, and input into one's governance (e.g., a sense of participation, living in a democracy). The role of the latter three is complex but important – examining the issue from a psychological perspective, Diener and Seligman (2004) note that traditional economic measures such as GDP are not adequate for measuring well-being once basic needs have been met, and much better measures are needed. It is important to note that many people will uproot themselves and move, often enduring huge risks and costs, if they are missing any of the mind or body components, so our definition of quality of life plays an important role in geopolitics and security.

Transdisciplinary

The sense of transdisciplinary I am using is adapted from Godemann (2008), who uses it to examine the importance of knowledge integration. In this sense, transdisciplinary research deals with real-world problems and crosses disciplines; it integrates different types of knowledge and develops practical solutions. Polk and Knutsson (2008) include a variety of nonacademic stakeholders and organizations in transdisciplinary knowledge production and make the point that understanding and balancing the different value rationalities that stakeholders may have is also essential. Earth smarts isn't a static, top-down construct conceived entirely in government offices or ivory towers – it is an adaptable set of qualities designed to remain temporally, culturally, and ecologically relevant. Earth smarts is maintained with Creative Commons licensing and open-source software, because for many environmental issues like clean air and water, everyone is a stakeholder, and stakeholder input is key to success (Reed 2008).

Building a Better Construct

Earth smarts emerged from an extensive construct analysis, a technique Krathwohl (1993) described to help "clear the fuzz" from constructs that people use in different and potentially confusing ways. Figure 12.1 shows the transdisciplinary sources it drew from.

There were dozens of concepts and hundreds of components involved in deriving earth smarts, so a full reference list is beyond the scope of this chapter. However, it is worth highlighting some of the key documents, academic and otherwise, that were used in the analysis – they appear in Table 12.1.

Earth smarts (*Nichols 2010 proquest link forthcoming*) was derived using a mixed methods, two-stage methodology set in the context of theory-building, spiraling research (Berg 2007). The initial stage began with an intensive, wide-ranging literature review using a purposeful, stratified approach to gathering ideas by deliberately seeking review papers and top journals from a variety of academic disciplines and professional organizations. The results (over 80 related concepts) were used in the construct analysis (Krathwohl 1993), assisted by theoretical techniques including

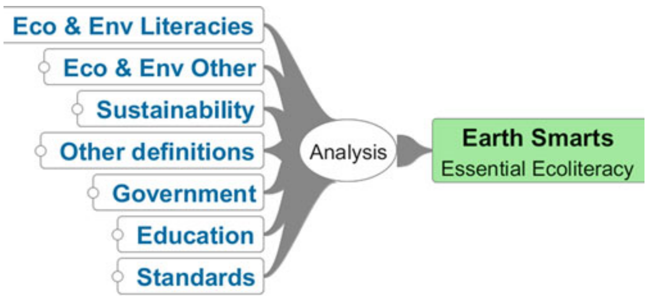

Fig. 12.1 The sources of information that went into the earth smarts construct analysis. *Eco* is short for ecological; *Env* is short for environmental

Table 12.1 Key influences on earth smarts

Item	Disciplinary source	Key reference
Environmental literacy	Environmental education	NAAEE (2004)
Ecological literacy	Ecological science	Jordan et al. (2009)
Science literacy	Science education	Roberts (2007)
Ecological naturalism	Philosophy	Code (2006)
Sustainability	Nongovernmental organization	Second Nature (n.d.)
Bioregionalism	Transition movement	Hathaway and Boff (2009)
Ecological economics	Economics	Daly and Farley (2010)
Historical ecology	History and anthropology	Crumley (2007)
Earth Charter	International council	Earth Charter Initiative (2000)
Science standards	Professional/government	National Research Council (1995)

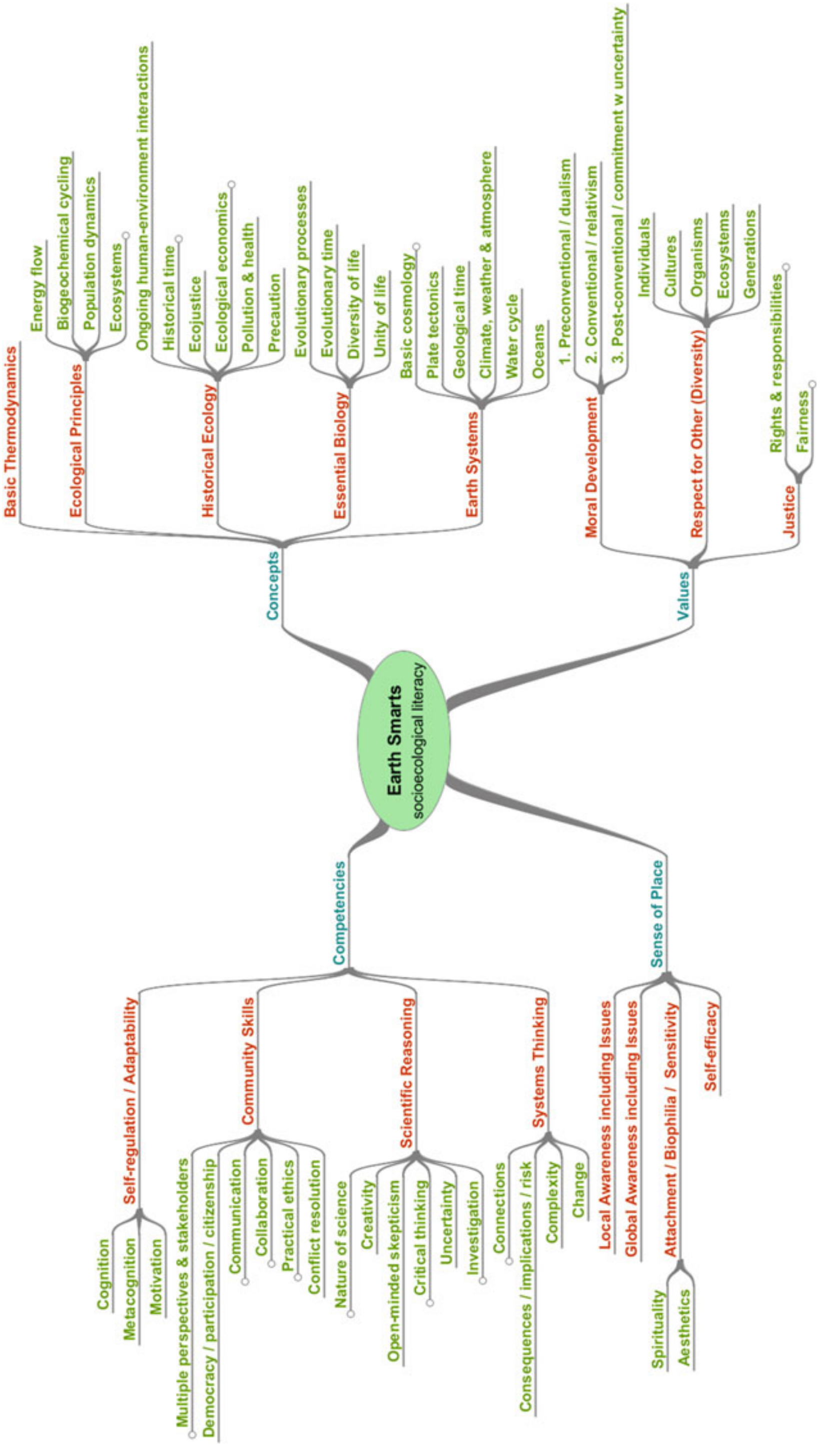

Fig. 12.2 The domains and primary and secondary components of earth smarts (Creative Commons Attribution 3.0)

the graphical mind mapping of essential elements, a component analysis table, and a set of systems analysis matrices (Nadler 1981). The domains and components that emerged from these analyses were used to solicit qualitative and quantitative input from experts and practitioners, primarily in the form of interviews and surveys. This ongoing input helps build and validate earth smarts and its components but also provides examples of localization, highlighting how the construct can be useful in a variety of ecological, social, and cultural contexts.

Earth Smarts: A Better, Happier You

So what makes someone earth smart? What qualities emerged from the large collection of constructs and components that went into the analysis? Figure 12.2 displays the four primary domains along with first and second level components, in the form of a hierarchical mind map. How do you measure up – how many of the components are you comfortable with? What about your children – how much of this are they learning in school, at home, in church, or at camp? Questions such as these highlight one of the benefits of an educational construct – as an individual, you can fill in your personal gaps, while institutions and communities can consider gaps or focus on strengths.

Concepts (Knowledge, Awareness)

Two domains that will look familiar to educators are concepts (knowledge) and competencies (skills or abilities) – traditional public education focuses almost exclusively on these. A basic understanding of how our world works is critical – particularly when our role in it is carefully considered. Earth smarts includes basic knowledge of thermodynamics and, true to its roots in environmental literacy, some essential ecological principles such as biogeochemical cycling, population dynamics, and food webs. In-depth, highly specialized understandings are not the point – awareness and a more holistic grasp of the concepts is key. For example, some critical earth science is important – understanding the basics of such things as the water cycle, climate, and plate tectonics helps us put events in perspective.

The concepts domain also includes a sense of time in three important dimensions: (1) geologic, which gives us the big picture; (2) evolutionary, which provides insight into the processes that continue to shape life; and (3) historical. Archaeologists and historians are discovering humanity has a rich and complex past that has much to teach us, particularly when examined from the viewpoint of historical ecology, which focuses on such things as our use of common resources, how the environment has affected our health, and other factors that have made the longevity, success, and well-being of some societies far greater than that of others.

Competencies (Skills, Abilities)

Competencies, which can also be considered abilities or skills, are another common feature in traditional education, although earth smarts incorporates some that are seldom taught well, if at all. It is worth remembering that skills, including cognitive skills, cannot be memorized – they must be practiced, and practiced in a variety of situations, to become effective. Competencies also often involve attitudes that must be nurtured along with them. Perhaps the most important skill is learning itself – earth smarts requires something cognitive scientists call self-regulation, what educators might consider lifelong learning, and what ecologists consider a type of adaptability. We need to learn new things, quickly and effectively, in order to deal with new challenges. This complex combination of attitude and skill is something that can be encouraged and practiced, in school and out.

Earth smarts also includes employment-friendly skills such as critical thinking, communication, and investigation. It incorporates new research on the nature of science by including creativity, open-minded skepticism, and a better understanding of uncertainty and risk. Other competencies may seem familiar from a twenty-first-century skills standpoint – grouped here under community skills, they include a raft of sociopolitical skills that make action, both collective and individual, possible and effective. Again, these aren't just helpful for improving your life or your community – employers consistently ask for graduates that possess them. As you can see in Fig. 12.2, community skills in earth smarts include (1) the ability to consider multiple perspectives, which is especially important when dealing with diverse stakeholders; (2) democratic participation; (3) communication; (4) collaboration, as there are many challenges we cannot solve alone; (5) argumentation and persuasion; (6) practical ethics, which offer techniques to effectively deal with the thorny moral issues that often arise when societies face environmental challenges; and (7) conflict resolution, as resorting to wars can be very hard on both the environment and our well-being.

A final set of competencies involves systems thinking. The disciplinary, increasingly specialized nature of our educational institutions has impaired our ability to think more holistically in terms of complex systems, something we need to change (Gabriel 1996). We need to better understand the world and our place in it in terms of connections, interactions, consequences, and implications – not in the linear sense that has dominated much of western thought, but in the interconnected cycles and webs that are familiar analogies from the science of ecology. Thinking in terms of complex systems will help us grapple with the complexity of the changes we face and take more appropriate and effective actions. Our education systems, at all levels, need to challenge students to use and improve all of these competencies – they will need them.

Attitudes, Values, and Other Topics Tricky to Teach

Ongoing research in human cognition and learning suggests that a "just the facts" approach to science education has serious limitations (Alsop 2005). Furthermore, many people agree that some form of character education is important in public schools, but what sort, exactly? Enter earth smarts. Education and awareness are often not enough for people to effectively respond to environmental issues (Kollmuss and Agyeman 2002). That is why earth smarts includes two domains that explicitly incorporate affective (emotional) and moral components. Addressing these is more challenging than teaching concepts or practicing skills, especially when it comes to assessment, but we know values and attitudes play important roles in many aspects of learning.

Beyond the pedagogical difficulties, teaching specific values can be politically or culturally controversial, and earth smarts acknowledges that different societies will have different ideas about what is right and proper. However, inflexible religious or cultural dogmas have helped doom societies in the past (Diamond 2005). On the other hand, relativism and its politically correct extremes are no answer – Bowers (2008) has written extensively about the potential conflict between modern critical theory and traditional lifestyles. It is important to note that for our purposes, a high quality of life is not apocalyptic paranoia inside heavily guarded compounds, nor is it some sort of unattainable utopia of equality. To help navigate the moral waters, earth smarts is grounded in respect and justice, especially justice as fairness (Rawls and Kelly 2001).

Human beings can be remarkably crafty, creative, and resilient. If we manage to move past shortsightedness and greed, we can and have made the world a better place for many. Many people believe our unique intelligence and increasingly global impact impart a moral responsibility for the well-being of our own communities, as well as respect for those living justly in other societies and cultures. A sense of justice also requires that we maintain our own quality of life without needlessly compromising the well-being of other species and future generations.

As we will see, however, earth smarts does not prescribe behavior. Instead, the values domain includes three components. The first is moral development – due to the complexity of the world and its challenges, we need to move beyond simple dualism (right or wrong), or what psychologists consider the preconventional stage (Kohlberg et al. 1983). To accept and cope with the uncertainty spawned by a changing, complex world, we need to move from dualism through relativism towards a post-conventional state that allows us to cautiously commit to ethical decisions. The second component of the values domain is respect for a range of “others”: other people, cultures, species, ecosystems, and generations. This is important in a just world, but it also acknowledges that there is rarely a single right way to do things, and different people and cultures may face their challenges in different ways. As engineers and ecologists are happy to remind us, diversity is important to the resilience of a system, so respect for others is also important because the resilience of your community in the face of change could depend on its diversity.

The third component of values in earth smarts is an awareness of the tension that exists between individual rights and community responsibilities. Different individuals and cultures deal with this tension in different ways – earth smarts requires us to consider it carefully, but it’s worth remembering that this tension has existed for millennia, and philosophers as lofty as Rawls and Kant have failed to settle it. The tension shows up in several aspects of earth smarts, highlighting the interrelated nature of the components.

Sense of Place in a Modern, Mobile World

One of the biggest challenges to achieving earth smarts in the twenty-first century is our unprecedented disconnection from nature. Cement and glass insulate us from some very important things – how many city dwellers are aware of where their water, food, or power actually comes from? This loss of critical knowledge contributes to needlessly unsustainable decisions, and most of our schools are doing a poor job of addressing it. Awareness of your local environment and the issues associated with it are an important part of the sense of place domain – our ancestors really were much more locally earth smart than we are, because their immediate survival depended on it.

On the other hand, science and technology have allowed some societies to achieve remarkable feats and learn vast amounts about how the world works in the process. Our ancestors might have known approximately when to plant their crops, but they didn't have the satellites and supercomputers that can predict potentially devastating hurricanes or El Niño conditions. We have learned a lot about the world, and even the best local knowledge is no longer enough, as it does not prepare communities for changes on larger scales, either geographically or temporally.

Another important aspect of sense of place is understanding your role in your world – how it affects you and how you affect it. Many people, especially in the face of global level challenges, feel powerless – despair and helplessness are not conducive to well-being. Self-efficacy is a concept some psychologists use to describe the belief that our actions have an effect on the environment. Such effects can be negative from our perspective, such as using chemicals in spray cans that degrade the protective ozone layer, or positive, such as halting the use of those chemicals so the ozone layer can replenish itself. Whether the effects are positive or negative, self-efficacy is critical – with it, rather than lapsing into despair, we can recognize our effects, minimize the negatives, and maximize the positives.

Finally, our sense of place needs to involve some sort of connection to the land, both locally and globally. In the past, this was easy – we spent a lot of time directly involved with our surroundings, and bonding with them spiritually and aesthetically is part of human nature. Unfortunately, this is far more challenging in the twenty-first century – not only do most of us live in cities that were not designed to enhance any sort of connection to the land (to put it charitably), we have become a much more mobile society, and newcomers to an area are typically less connected to it. To make matters worse, a culture of blame and litigation has cut off many teachers and their students from nature or any other experiences outside of the classroom. This extinction of experience (Pyle 2001) may be contributing to what is popularly known as nature-deficit disorder (Louv 2008), something the proposed No Child Left Inside legislation seeks to reduce. Children are not the only ones at risk – evidence suggests we are all spending less time outdoors (Pergams and Zaradic 2008). This is not just an environmental issue – theology and the humanities, as well as the natural and social sciences, can all help. Archbishops, architects, and artists must all play a role in connecting us to our places in more meaningful ways.

Place-based education (Sobel 2004) represents a collection of related efforts to restore and nurture our connection to the cultures and environments we inhabit. Whatever our affective connection to place is called, whether it is spiritual, religious, aesthetic, or some combination thereof, we need to become much better at nurturing it, within and beyond formal education, if we are to avoid not just ecological ignorance but apathy and alienation. Cultural context is obviously essential to how we develop this sensitivity to our places, but urban planning and green design for schools, parks, and other spaces will play a critical role as more of us spend more of our lives in cities.

Values, attitudes, and emotions are critical to achieving earth smarts, but as parents, Sunday school teachers, and advertisers well know, attitudes and values have always been tricky to transmit. In education, they are decidedly more difficult to assess than concepts and have therefore been deemphasized in the rush to accountability in public schools. However, when good teachers are given time and support, they can both model and teach the apolitical, justice-based values and sense of place that earth smarts requires, and these values can be supported by other individuals and institutions in a community. Other chapters in this book offer numerous ideas on how to achieve these challenging but essential goals.

The Perils of Telling People What to Do

Many iterations of environmental literacy specify behavior or action of some sort. Sometimes, environmental solutions seem to simply involve specific changes in behavior – don't eat this, flush that, or buy those, and things will get better. Unfortunately, there are several problems associated with "teaching" behavior.

In a dictatorship, the leaders decide what the best course of action is and command their subjects to do it. If they're right, things work out well – if not, well, history suggests that dictators are often incorrect. People starve, heads roll, and societies collapse. In a democracy, telling people what to do is more difficult, particularly a democracy like the United States, where individual rights and freedoms are usually taken very seriously. Legislating behavior can be difficult and often provokes backlash – the same issues occur in education. Telling people what to do, in a classroom or elsewhere, doesn't just rile up libertarians – it can run counter to democratic principles and degrade individual freedoms, once again highlighting the tension between rights and responsibilities.

A second concern about teaching behavior – that of assessment – is critical to education. As Ratcliffe and Grace (2003) note, in educational contexts, evaluating behavior in anything but contrived situations is difficult. This is especially true for controversial or complex issues, which environmental challenges often are. How does a teacher know if she has taught a behavior effectively, especially if it isn't something directly observable in the classroom?

A final, and perhaps greater, concern is that telling people how to behave only works if (1) you're right about causes and effects and (2) things don't change. Science has shown conclusively that the world changes, dramatically, and there is plenty of evidence to suggest it's doing so right now. Static world views and behavior patterns that are hopelessly mired in tradition are causing serious problems and will hinder future generations from adapting to the local and global changes they are facing.

The point of earth smarts isn't to teach people how to act or tell them what to do. The goal is to equip individuals and their communities with the capacity to adapt in ways that justly maintain their quality of life. Earth smarts cannot specify what actions to take, as those actions will often be culturally, temporally, and geographically different. Behavior or habits that work right now might not if a new virus wipes out your crops, if your rainfall is cut in half, or if your sea level rises. We need to educate our children to respond quickly, creatively, and effectively to challenges like these and ones we can't even imagine yet. That is what earth smarts can do for them.

All this is not to belittle the importance of behavior change. Many earth smarts competencies facilitate action in social contexts, and encouraging behavior change can be appropriate in specific situations. However, it is more helpful to consider activities with behavioral change as the primary goal as social marketing, rather than education, particularly when specific changes are sought.

Earth Smarts in Action

As a pragmatic educational construct based on a wide range of accumulated wisdom about ourselves and our world, earth smarts can be useful to examine policy, curricula, or research results. A few quick examples will illustrate how.

Individuals – Free access to the components of earth smarts will allow youth all over the world to take responsibility for their own education and capacities. This will be enhanced by open educational resources that help learners acquire the various concepts and skills.

Researchers – Much research is underway on ways to achieve various environmental and social literacies, but it can be difficult to generalize results, in part because different and even conflicting definitions are used, especially between academic disciplines. Earth smarts is transdisciplinary and freely available to all, so researchers could use it as theoretical common ground in interdisciplinary discussions.

Educators – As schools, colleges, and universities attempt to "green" their curricula, educators often wonder where to start. Designed as an educational construct that transcends disciplines, earth smarts can provide a theoretically robust guide that curriculum writers could localize and expand upon appropriately. Earth smarts also links knowledge and cognitive skills with affective and moral components that need to be supported beyond the classroom. As a result, its use should encourage pedagogies that include more learning in nature and society and provide a framework for assessment that moves beyond facts and low-level skills. In turn, place-based learning, citizen science, and social justice approaches could benefit by integrating their strengths with the components of earth smarts they don't cover well.

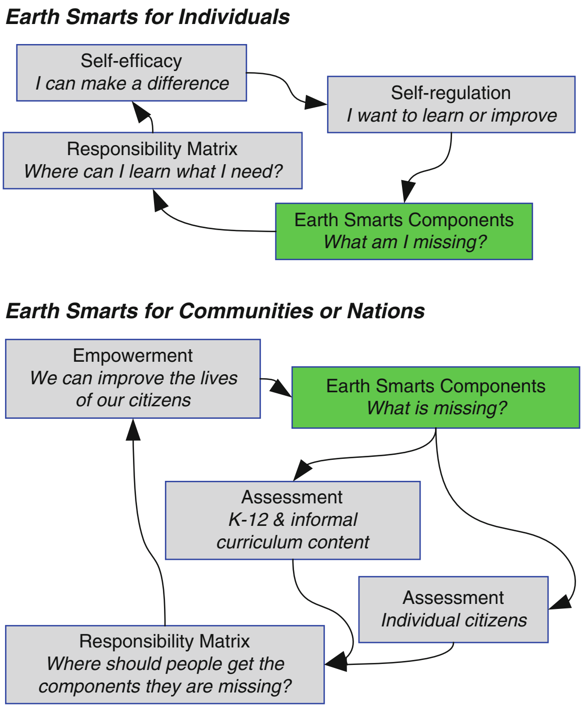

Fig. 12.3 A logic diagram highlighting that knowing the components of earth smarts, in conjunction with the use of a responsibility matrix, can be useful to individuals, communities, and nations

For example, a school might notice they were covering knowledge and skills well but having difficulties with character issues such as sense of place and values beyond the classroom. They could share their goals with local environmental and informal education organizations such as an aquarium, park, or youth group, which in turn could use the earth smarts framework to better integrate their activities with the students' classroom-based learning. Teachers could then use student performance and follow-up reporting on these activities to design more sophisticated assessments of their progress.

Policymakers – Civil servants and policymakers wondering how they can help their communities or nations meet the challenges of a changing world can use earth smarts as a road map to more resilient societies, improving their ability to learn, adapt, and thrive. Figure 12.3 illustrates how earth smarts can be used in conjunction with a systems analysis tool called a responsibility matrix, which examines which aspects of a system are responsible for others. For example, most of us would agree that formal education should be responsible for the concepts (knowledge) and competencies (skills) of earth smarts, but values and sense of place may need to originate, or at least be supported by, things such as family, informal education, or spiritual communities.

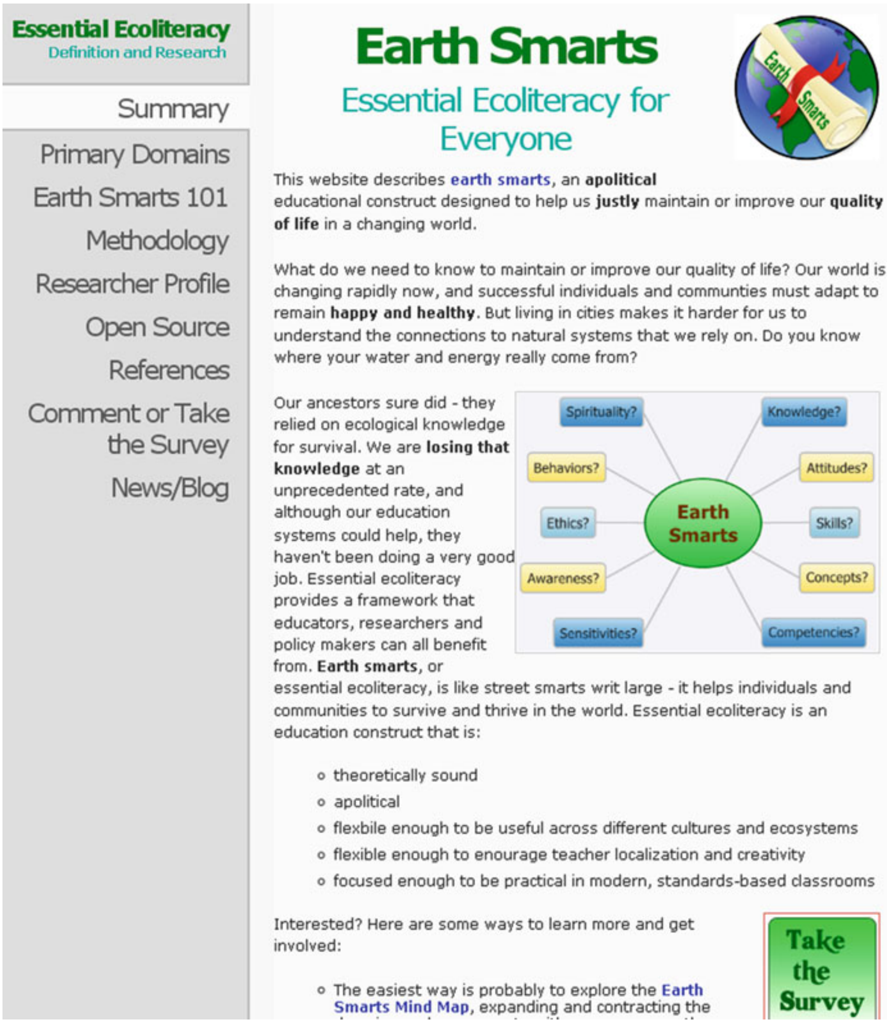

Fig. 12.4 The earth smarts website at www.earthsmarts.info, where the framework and details are freely available under Creative Commons licensing

Conclusion

Earth smarts is far from a panacea to the current and future socioenvironmental challenges that communities face. However, it highlights our considerable capacity to meet those challenges and is a useful tool for anyone who believes that education can play a crucial role. Synthesized from some of the best ideas that scientists and professionals from a wide range of disciplines have developed, it is a flexible, culturally adaptable framework for preparing individuals and communities to face environmental challenges in creative, just, and effective ways. Freely available in a variety of formats at www.earthsmarts.info (Fig. 12.4), policymakers, researchers, and educators from around the world are welcome to use it, add to it, and make it their own.

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Part III
Responsibility with Digital Technologies

Chapter 13
Digital Technologies and Assessment in the Twenty-First-Century Schooling

Jing Lei, Ji Shen, and Laurene Johnson

Introduction

The rapid development of information and communication technologies (ICT) has significantly changed the ways in which today's children entertain, socialize, and learn. The digital society in the twenty-first century requires a suite of cognitive and psychological abilities and perspectives that enable the individual to intelligently consume and creatively develop digital products, and ethically lead or participate in a world that has become increasingly mediated by technology. How can today's education help our students, the next generation of responsibility (Generation R), develop technological competencies for surviving and thriving in the twenty-first century?

In this chapter, we address this question by envisioning school assessments that focus on technological competencies. Our discussions center on the following aspects: the critical skills students need to equip with in terms of digital technology, assessment of student digital technology proficiencies, and the indicators of strong digital competencies. Specifically, we will first review the role of digital technologies in the twenty-first century. Second, we examine what technology proficiency is necessary for the Generation R to fully participate in the society in the twenty-first century. Third, we discuss how the concept and standards of digital proficiency have evolved over the last several decades, corresponding to the rapid development and adoption of modern digital technologies. And fourth, we investigate how student digital technology proficiency has been assessed and discuss what schools need to do to better prepare their students with proficient digital literacy.

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Workforce for the Digital Technologies in the Twenty-First Century

With the rapid development of modern technologies, it is reasonable to expect that today's students will need a whole new set of digital technology skills and abilities as they enter the workforce. Technology has penetrated all aspects of our everyday lives, creating a digital society. People entertain, socialize, do business, go to school, and participate in government in an ever-expanding digital universe (Horrigan 2008; Lamb 2006). In 2006, Americans spent approximately $227.6 billion online, a 9 % increase from the previous year (comScore 2011). Increasingly, the economy worldwide is driven by information and communication technologies (ICT) (Barlow et al. 2007; United National Conference on Trade and Development (UNCTAD) 2008). In 2006, ICT-producing and ICT-using industries contributed half of the acceleration in US economic growth (Jorgenson et al. 2005; Jorgenson 2005). The Bureau of Labor Statistics (BLS) estimates that ICT occupations will increase by 40 % between 2004 and 2014, a rate more than three times faster than the growth of the overall workforce, and most of the fastest-growing occupations require ICT skills (Hecker 2005). There is no doubt that our world will be further digitized (Livingstone and Kemp 2006; Prensky 2005). It is predicted that by the year 2020, virtual reality on the Internet will come to allow more productivity from most people in technologically-savvy communities than working in the "real world" (Anderson and Rainie 2006).

As pointed out by Zhao (2009), the technology-mediated world differs from the traditional world in fundamental ways, including the tools required for participation, the rules that govern activities, and the consequences of participation. Competent citizens of the digital economy need a sound understanding of the nature of the digital world, a positive attitude about its complexities, and the ability to create digital products and services in order to participate in and lead its activities. Schools need to prepare students to be contributing members and creative leaders in the digital era.

In the USA, the need to prepare students with the ability and skills needed to participate fully in the increasingly technological society has been a long-standing priority (U.S. Department of Education 2000). Since the early 1980s, reports on the needs and crises in education have explicitly addressed the need to prepare students to be part of a computer literate workforce (Urban-Lurain and Zhou 2004). *A Nation at Risk* frames the "risk" in the context of a workforce that may not be prepared to compete in a global economy that is driven by technology (The National Commission on Excellence in Education 1983). The US Department of Education has publicized three national technology plans, in 1996, 2000, and 2004, respectively. The need to improve student technology ability and skills is emphasized explicitly in all national technology plans. The first national information technology plan—Getting America's Students Ready for the 21st Century: Meeting the Technology Literacy Challenge (June 1996)—states

> Our economy is characterized by rapidly changing technologies and increasing international economic competition. And, our society is complex, diverse, and mobile. Success as a nation will depend substantially on our students' ability to acquire the skills and knowledge necessary for high-technology work and informed citizenship. (p. 00)

In the second technology plan, one of the five goals is "All students will have technology and information literacy skills" (p. 00). And the third national educational technology plan continues to stress:

> Over the next decade, the United States will face ever increasing competition in the global economy….To an overwhelming extent, this competition will involve the mastery and application of new technologies in virtually every field of human endeavor… It is the responsibility of this nation's educational enterprise– including policymakers – to help secure our economic future by ensuring that our young people are adequately prepared to meet these challenges. (U.S. Department of Education 2004)

How we might help students make full use of available information technologies and improve their technology proficiency has become a critical issue facing educators and educational researchers. In the last two decades, much attention has been paid to students' technology proficiency, especially that of K-12 school students, including investigation on current student technology use, conditions for student technology use, and the ways technology use might help improve student technology proficiency.

The Evolution of Student Digital Literacy

Student digital literacy has evolved greatly over the last several decades, tracking the rapid advance of digital technologies and the cultural, political, and economic changes in our society. By reviewing educational technology policy documents and national standards on student education technology proficiency, we examine how the requirement of student technology proficiency has changed over time.

Diverse Interpretation of Digital Literacy

What is deemed necessary for student technology abilities differs at varying stages of technology development. A review of research and policy documents reveals different terms related to technology proficiency, such as "information literacy," "computer literacy," "technology literacy," "information competence," and "media literacy." The following definitions are examples:

- "Technological literacy": computer skills and the ability to use computers and other technology to improve learning, productivity, and performance (U.S. Department of Education 1996).
- "Information literacy": the ability to know when there is a need for information and to be able to identify, locate, evaluate, and effectively use that information for the issue or problem at hand and as "a constellation of skills revolving around information research and use" (The National Forum on Information Literacy n.d., p. 00)

- "Information communication and technology (ICT) literacy": using digital technology, communication tools, and/or networks to access, manage, integrate, evaluate, and create information in order to function in a knowledge society (The Educational Testing Services 2002)
- "Digital literacy": the ability to find, evaluate, utilize, and create information using digital technology (Cornell University Digital Literacy Resources 2009)

Even for the same term, the definition has in cases evolved over the years, reflecting the changing expectations of technology proficiency. For example, the term "information literacy" has been interpreted differently:

> the skills of information problem solving. (Wisconsin Educational Media Association 1993, p. 00; c.f., the Associated Colleges of the South 1999)
>
> a new liberal art that extends from knowing how to use computers and access information to critical reflection on the nature of information itself, its technical infrastructure, and its social, cultural and even philosophical context and impact. (Shapiro and Hughes 1996, p. 00)
>
> the ability to locate, evaluate, and use information to become independent life-long learners. (Commission on Colleges, Southern Association of Colleges and Schools (SACS) 1996, p. 00)
>
> a wholistic, interactive learning process encompassing the skills of defining, locating, selecting, organizing, presenting, and evaluating information. (Steele and Stewart 1998, p. 00)
>
> the ability to search for, find, evaluate, and use information from a variety of sources. (Goad 2002, p.21)

Despite the alternate definitions developed by various educational institutions, professional organizations, and individuals, the term "information literacy" calls for individuals being "able to recognize when information is needed and have the ability to locate, evaluate and use effectively the needed information" (Presidential Committee on Information Literacy 1989, p. 1). We note that a piece of "information" in the digital era can be presented in various formats including print, visual, and computer-based network (Plotnick 1999).

In addition to defining digital technology proficiency from various perspectives, substantial effort has been devoted to clearly identify the essential digital technology skills and abilities. Below, we briefly summarize the essential components of digital literacy for students as stated in different standards and national documents published in the last two decades.

The Essential Components of Student Digital Literacy Before the Twenty-First Century

Much effort has gone into creating national technology standards for students. For example, in 1998, the American Association of School Librarians and Association for Educational Communications Technology (1998) published The Nine Information Literacy Standards for Student Learning, which defined nine information literacy standards in three categories: (1) information literacy, including three standards—to access information efficiently and effectively, to evaluate information critically and competently, and to use information accurately and creatively; (2) independent learning, including three standards—to pursue information related to personal interests, appreciate literature and other creative expressions of information, and strive for excellence in information seeking and knowledge generation; and (3) social responsibility, the student who contributes positively to the learning community and to society is information literate and recognizes the importance of information to a democratic society, practices ethical behavior in regard to information and information technology, and participates effectively in groups to pursue and generate information.

In 1998, the International Society for Technology in Education (ISTE) developed the first set of National Educational Technology Standards for Students (ISTE 1998). This document focuses specifically on technology as a tool for students. It suggested that a technologically literate student should master the following six classes of skills and abilities: (1) basic operations and concepts—students demonstrate a sound understanding of the nature and operation of technology systems; (2) social, ethical, and human issues—students understand the ethical, cultural, and societal issues related to technology; (3) technology productivity tools, students use technology tools to enhance learning, increase productivity, and promote creativity; (4) technology communication tools, students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences; (5) technology research tools, students use technology to locate, evaluate, and collect information from a variety of sources; and (6) technology problem-solving and decision-making tools, students use technology resources for solving problems and making informed decisions (ISTE 1998).

In 1999, the Committee on Information Technology Literacy of the US National Research Council (NRC) published a document entitled *Being Fluent with Information Technology*. This document outlined an information technology fluency framework that included three kinds of knowledge: (1) contemporary skills and ability to use today's computer applications to apply information technology immediately—skills provide a store of practical experience on which to build new competence; (2) foundational concepts, the basic principles and ideas of computers, networks, and information underpin the technology—concepts explain the how and why of information technology and give insight into technology's opportunities and limitations; and (3) intellectual capabilities to apply information technology in complex and sustained situations, ten specific skills/capabilities were also proposed for each kind of knowledge. These three kinds of knowledge prepare a person in different ways for FITness:

> FITness requires that persons understand information technology broadly enough to be able to apply it productively at work and in their everyday lives, to recognize when information technology would assist or impede the achievement of a goal, and to continually adapt to the changes in and advancement of information technology. FITness therefore requires a deeper, more essential understanding and mastery of information technology for information processing, communication, and problem solving than does computer literacy as traditionally defined. (p. 15)

In 2000, the second American national information technology plan (U.S. Department of Education 2000) included the following as necessary skills students should learn: task definition, information-seeking strategies, location and access, use of information, synthesis, and evaluation. In this context, evaluation focuses on how well the product meets the original task (effectiveness) and on how well students carried out the problem-solving process (efficiency).

In summary, a close examination of the technology standards in the last decade of the twentieth century reveals that these documents emphasize the ability of using information technology to find useful information, including searching, locating, and evaluating information; to use information to solve problems; to learn new technologies; and to understand the social and ethic issues related to technology use. The concepts and standards of digital technology proficiency in the 1990s mostly view students as information consumers and emphasize mostly the abilities and skills to use digital technologies.

The New Development of Student Digital Literacy in the Twenty-First Century

As we enter the twenty-first century, with the dramatic development of information technology and its unprecedented impact on society, focusing on technology skills seems insufficient. Instead, a more holistic view of student digital literacy has started to emerge, and this view includes how to prepare students not only how to be information consumers but information creators, as well. For example, the iSkills™, developed by researchers at the Educational Testing Services in 2007 (Katz 2007), proposed an ICT literacy framework which includes the following areas of abilities: (1) define, understand and articulate the scope of an information problem in order to facilitate the electronic search for information; (2) access, collect and/or retrieve information in digital environments; (3) evaluate, judge whether information satisfies an information problem by determining authority, bias, timeliness, relevance, and other aspects of materials; (4) manage, organize information to help you or others find it later; (5) interpret and represent information; (6) create—adapt, apply, design, or construct information in digital environments; and (7) communicate—disseminate information tailored to a particular audience in an effective digital format.

Similarly, in 2007, ISTE publicized the National Educational Technology Standards for Students. This set of standards also recommends six (but considerably different) areas of skills and abilities: (1) creativity and innovation—students demonstrate creative thinking, construct knowledge, and develop innovative products and processes using technology; (2) communication and collaboration, students use digital media and environments to communicate and work collaboratively, including at a distance, to support individual learning and contribute to the learning of others; (3) research and information fluency, students apply digital tools to gather, evaluate, and use information; (4) critical thinking, problem-solving, and decision-making—students use critical thinking skills to plan and conduct research, manage projects, solve problems, and make informed decisions using appropriate digital tools and resources; (5) digital citizenship, students understand human, cultural, and societal issues related to technology and practice legal and ethical behavior; (6) technology operations and concepts, students demonstrate a sound understanding of technology concepts, systems, and operations (ISTE 2007).

As Zhao and Lei (2009) note, the penetration of information technology into every aspect of society has created an increasingly digitalized world. They propose that competent citizens of the digital world and the digital economy need to have digital citizenship: (1) knowledge of the nature of the digital world, (2) ability to use different tools to participate in the digital world, (3) ability to create digital products and services and to lead in the digital world, and (4) positive attitude toward the digital world (Zhao 2009; Zhao and Lei 2009). They point out that digital technology abilities in the twenty-first century need to be expanded from being intelligent consumers to enhanced abilities of being creative and contributing members and effective leaders. Schools need to prepare students to actively participate in, create, and lead the coming digital society.

The KPCL Framework

From an extensive examination of the literature, especially on the digital competencies proposed by Zhao (2009), we summarized the Knowing, Participating, Creating, and Leading (KPCL) framework of digital technology literacy for the twenty-first century: (1) Knowing—having a sound understanding of the nature of the digital technologies and the social, cultural, legal, and political responsibilities of using digital technologies; (2) Participating—having the abilities to use digital technologies to actively participate in activities; (3) Creating, having the abilities to use digital technologies to create digital products and services; (4) Leading, assuming the leadership role in using and creating digital technologies to transform the social and natural environments. Table 13.1 identifies critical aspects of the framework and their associated specific indicators.

This new perspective extends the gap between how schools should evaluate student digital literacy and how schools usually do, a topic to which we now turn.

Assessing Student Digital Literacy

Although the importance of preparing students with digital literacy is widely accepted, both the research and practice on assessing digital literacy have been lagging. In the USA, as of 2005, only two states reported having a statewide assessment of students' technology skills, 11 states had a statewide assessment planned, and 13 states indicated that individual districts administered technology literacy assessments to students (Bakia et al. 2007). By 2009, 13 states reported having tested students' knowledge of technology (Hightower 2009). As more states and districts add student technology assessments, the question of how to accurately assess students' technology literacy becomes increasingly important. Our review of the literature on assessments of digital literacy revealed various methods for determining if students have the technology skills needed to be successful in an increasingly technological world.

Table 13.1 The Knowing, Participating, Creating, and Leading (KPCL) framework of digital technology literacy in the twenty-first century

Aspects of digital technology literacy	Specific indicators
Knowing: having a sound understanding of the nature of digital technologies and the social, cultural, legal and political responsibilities of using these technologies	Understand the variety of digital technologies and the nature of the digital technologies Understand the social, cultural, legal, and political responsibilities of using digital technologies
Participating: being able to use digital technologies to actively participate in activities of different communities	Use various digital technologies regularly Participate in the activities of different communities with the aid of digital technologies
Creating: being able to use digital technologies to create digital products and services and craft new ways of disseminating knowledge	Transform the traditional use of digital technologies Create new digital products and services Craft new ways of disseminating knowledge
Leading: assuming leadership roles in using and creating digital technologies to transform the social and natural environments	Lead the development of new technologies Lead the transformation of the social and natural environments using digital technologies

The various digital literacy assessments found in the literature fall into three main categories: (a) self-report questionnaires, (b) online skills assessments, and (c) portfolio-based assessments. Each category is summarized below, and examples are included to provide context for how these tools are being used with students.

Self-report questionnaires are instruments that ask students to rate their own competency on various computer applications and technology skills (Keengwe and Anyanwu 2007; Salaway et al. 2008). Such self-report instruments have been used primarily with university students or adults. For example, in the ECAR Study of Undergraduate Students and Information Technology (Salaway et al. 2008), the researchers used an online self-report questionnaire to assess the technology skills of over 27,000 undergraduate students. The assessment instrument requested students to rank their use of specific software applications (such as spreadsheets, presentation software, and Internet search engines) on a scale from *Not at all skilled* to *Expert* (p. 105). In addition to this type of measurement, the questionnaire included items on students' ownership and use of various technology tools and applications, as well as their preferences for technology use in learning environments. Similarly, McCoy (2010) required undergraduate students to rank their ability to complete tasks such as "sending and receiving electronic mail" and "browsing the Internet" using a 1–4 Likert scale (p. 1617). Morahan-Martin and Schumacher (2007) surveyed over 400 undergraduate students by having them rank their skills on a four-point scale, from poor to expert, on eight technology applications such as word processing, Internet use, and creating a web page.

Online skills assessments test students' technology literacy through a combination of performance-based tasks and multiple-choice questions. These online assessments are self-scoring and most such systems also store student data, so they provide an all-in-one solution for many states and schools (Roland 2006). Judson (2010) used data from the TechLiteracy Assessments™ (TLA) administered by Learning.com to analyze the technology literacy of 10,000 fourth-through seventh-grade students in Arizona. TLA is designed to measure students' actual skills rather than their perceptions or dispositions. The TLA assessment consists of a combination of multiple-choice knowledge-focused questions and performance questions requiring students to complete a technology-based task. Aligned with the International Society for Technology in Education (ISTE) National Educational Technology Standards for Students (NETS*S) (2011), this assessment measures digital literacy in seven categories: (1) system fundamentals, (2) social and ethical issues, (3) word processing, (4) spreadsheets, (5) multimedia presentation, (6) telecommunication, and (7) databases (Judson 2010, p. 276). The assessment is criterion referenced and has been validated with over 8,000 students nationwide (Judson 2010; Learning.com 2011). Other online skills assessments for K-12 students have similar features in that they contain a combination of multiple-choice and performance-based questions, are aligned with the ISTE NETS for students, are computer scored, and are designed to be completed in one class period, making administration easy for teachers and students (Atomic Learning 2011; Hohlfeld et al. 2010; InfoSource 2011; Roland 2006).

Portfolio-based assessments require students to complete a series of activities or projects to demonstrate their ability to use technology resources in various applications. Portfolios are completed over the course of months or even years and are designed to help students build and demonstrate competency (Boone 2009; U.S. Department of Education 2011). The state of West Virginia uses a statewide portfolio-based assessment system, called *techSteps*, to assist their students in building portfolios, showing student growth in digital literacy (Boone 2009; Tullis 2010). Aligned with both the NETS for Students and the West Virginia State technology standards, *techSteps* provides approximately six technology-based lessons per grade level that students complete over the course of the school year. During the lessons, the students create a technology artifact that is scored using rubrics that assess whether the student has demonstrated literacy in the specific areas addressed by the lesson (SchoolKit 2011). Artifacts and rubrics are kept in a student's "personal technology literacy profile" (Boone 2009, p. 69) which provides evidence of their technology literacy throughout their K-8 school career. While techSteps is a statewide initiative in West Virginia, the lessons and assessments must be implemented by teachers at the school level.

A similar portfolio-based system, TechYES, gives students the responsibility for their own technological literacy by creating meaningful projects that demonstrate their ability to use technological tools in real-world applications. TechYES is implemented at the school level, for it requires involvement of instructors working with TechYES students. Completed projects are assessed using rubrics and scores from multiple projects and establish a student's overall technology literacy score, which is then compared to a minimum proficiency cut score in order to determine if the student is digitally literate (Generation YES 2011). Like *techSteps* and TechYES, portfolio-based systems are often technology curriculum and technology assessment in one package (U.S. Department of Education 2011).

Although flexible strategies have been developed to assess student digital technology knowledge, skills, and abilities, additional efforts are needed to develop specific digital literacy instruments that are based on sound theories, designed using scientific assessment methods, and supported and validated by empirical research. One example is the iSkills™ assessment, developed by the Educational Testing Services (ETS) in partnership with a consortium of institutions of higher education. The iSkills™ assessment includes two subsets of assessment: the Core iSkills assessment that measures the ICT literacy skills of students who are making the transition from high school to the first year of postsecondary education and the Advanced iSkills assessment that measures the ICT literacy skills of students who are making the transition either from second-year postsecondary education to third year or the workforce.

In the report titled *Tech Tally: Approaches to Assessing Technological Literacy* published by the National Academy of Engineering, & National Research Council (2006), the committee identified 28 technology assessment instruments, most of which were aimed at K-12 students, and found that none of them provided an adequate measure of technological literacy. The committee offered the following suggestions for future assessments: assessment of digital literacy should (1) begin with a clear purpose in mind; (2) take into account research findings related to how children and adults learn, including how they learn about technology; (3) be based on rigorously developed learning standards, (4) provide information about all three dimensions of technological literacy—knowledge, capabilities, and critical thinking and decision-making; (5) be free of gender, culture, or socioeconomic bias; and (6) be accessible to people with mental or physical disabilities. They also provided recommendations in five categories: opportunities for assessment, research on learning, the use of innovative measurement techniques, framework development, and broadening the definition of technology (pp. 176–177).

What Schools Need to Do

Schools need to prepare students with skills for the digital economy. Today's children, the "digital natives" (Prensky 2001), are not necessarily competent digitally responsible citizens. However, adults, assuming the role of "digital immigrants," often leave children's technology exploration on their own (Livingstone 2008). Schools are not preparing students with the necessary skills, knowledge, and responsibilities to face the challenges and to live and work competently in the digital society. In fact, schools are falling behind their students in using technology (Education Week 2007; Hitlin and Rainie 2005: Levin and Arafeh 2002). More than half of parents and teachers who participated in the Speak Up 2006 survey said their schools are not doing a good job of preparing students to compete for jobs and careers of the twenty-first century (Project Tomorrow 2007).

Based on the KPCL framework, we suggest that schools can improve this situation from several aspects. First, schools should not mistake "access" to technology as digital literacy. The last two decades have witnessed strong advocacy and heavy investment in equipping schools with computers and Internet connection for all students (U.S. Department of Education 1996, 2000, 2004). However, access to technology does not necessarily lead to the actual use of technology or to development of KPCL abilities. Despite dramatically increased access to technology, in many schools, computers remain "oversold but underused" (Cuban 2001; Education Week 2005, 2007; U.S. Department of Education 2004). Schools need to make better use of available technologies, integrate technology into teaching and learning in meaningful ways, and help students take advantage of the opportunities afforded by digital technologies. For example, in the last a few years, the widespread use of social-networking websites, data-sharing websites, blogs, podcasting and wikis is making the Internet more important than ever. Schools can use the popularity of Web 2.0 technologies to strengthen teaching and learning. Teachers can use wiki web pages as a venue to have students collaborate on authentic learning tasks. Blogging can be used not only by teachers to reflect on their own teaching but also by students to reflect on their learning, voice their opinions on educational values, and communicate with their peers, friends, and teachers. Social-networking websites such as Bebo, MySpace, Facebook, and Twitter also provide new opportunities for creative teaching and learning and new ways to participating in schooling.

Second, schools need to go beyond traditional technology education practices and concepts such as "technology literacy," "information literacy," "computer literacy," and "computer education" that mainly focus on only using technology hardware and software or searching, selecting, and using information as information consumers (e.g., Goad 2002, p. 21). Instead, schools need to help students expand their understanding of the nature of technology and its role in the digital world (Campbell 1998; Yannie 2000) and to better prepare students for transitioning from being mere consumers of information to taking on multiple roles as "producers, collaborators, researchers and publishers" (Stead 2006).

Third, schools need to help students to build capabilities for coping with challenges in the digital world and for developing the responsibility to resolve such challenges. Without adequate preparation for the coming digital world, today's students face a number of challenges. Schools need to help bridge the gap between being technology savvy and being digitally literate. Today's children are much more technology savvy than previous generations (Prensky 2001; Rideout et al. 2005; Tapscott 1998). However, being able to use technology does not necessarily mean being able to use technology critically, wisely, or meaningfully. The digital generation often falls short in demonstrating the fundamental understanding of digital media (Heverly 2008). Children's superficially competent use of technology can conceal the narrow scope of the activities, the ineffectiveness of online searches, and the lack of in-depth exploration. Such use is often curtailed by the lack of interest in information and poor skills in searching and evaluating information (Livingstone 2008, pp. 103–106). Researchers find that students have difficulty in judging the legitimacy of information (Eastin et al. 2006). A recent report by the Educational Testing Service reveals that only 24 % of first-year community/technical college students and 39 % of 4-year college freshmen meet or exceed the core foundational level of ICT literacy skills, and only 27 % of these students meet or exceed the intermediate foundational ITC literacy skills (Tannenbaum and Kartz 2008). This finding calls for an urgent need to develop these skills from an earlier stage, especially among middle school students.

Fourth, schools need to prepare students to be responsible digital citizens who understand the social, cultural, and legal consequences of their digital behaviors. Researchers point out that risky behaviors that can happen in real life are also happening in the digital world (Irvine 2006; LeClaire 2006). Most parents and teachers are increasingly concerned with privacy and online safety issues associated with technology use (Project Tomorrow 2007). Among the issues are privacy, online victimization, security threats, and cyber crime. For example, despite the common use of filters and monitoring software in schools, more students are exposed to online pornography, harassment, and cyber bullying (eSchool News 2007; Wolak et al. 2006). Not realizing how much information they are revealing online (Irvine 2006), young people are easy targets of spoofing websites (Dhamija et al. 2006). Aside from becoming potential victims of cyber crime, young people also are at risk of getting involved in committing cyber crimes without an understanding of the consequences (McAfee 2006; Marks 2006). Schools need to help students develop a sound understanding of the good, the bad, and the ugly of the digital world; to understand the social, cultural, and legal consequences of their digital behaviors; and thus to act as responsible citizens in the digitalized world. Schools need to engage students as leaders of the digital world who can voice their thoughts, values, and concerns.

Conclusions

In this chapter, we reviewed the history of technology integration in schools, discussed the importance of digital technology proficiency in the twenty-first century, and examined the evolution of various concepts, definitions, and essential components of digital literacy, with an emphasis on digital literacy in the twenty-first century. We also examined how digital literacy is being assessed and discussed and what schools need to do to prepare students with digital technology abilities and skills needed to be effective in the twenty-first century. We conclude that, with the rapid development and adoption of modern digital technologies in society and among students, what is considered as essential technology skills and abilities has changed over the past several decades, evolving from emphasizing specific technology skills to focusing on a more holistic view of an integrated set of skills and abilities, ranging from using digital technology skills for various tasks to problem-solving abilities, critical thinking, and digital citizenship. Correspondingly, to prepare students with the necessary digital technology proficiency, schools need to go beyond technology education practices and concepts that mainly focus on only using technology hardware and software and on students' role as consumers of digital technology products and services, to emphasize a deeper understanding of the nature of technology and better prepare students to be responsible participants, active contributors, and effective leaders in a digital society. In terms of assessment, various flexible strategies have been developed to assess student digital technology knowledge, skills, and abilities. However, what is needed are specific digital literacy instruments that are based on sound theories, designed using scientific assessment methods, and supported and validated by empirical research. Future assessments must begin with a clear goal, assess all components of technological literacy, and be sensitive to how technology learning takes place. They also should be based on learning standards, be nonbiased, be accessible to all learners, and use multiple assessment methods to assess development over time.

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Chapter 14
New Interoperable Web Tools to Facilitate Decision-Making to Support Community Sustainability

Elizabeth R. Smith, Anne C. Neale, C. Richard Ziegler, and Laura E. Jackson

Introduction

Decisions made at multiple scales (ranging from communities to states, regions, or national policies and regulations) impact the quality of life at the community scale. Communities, regional-planning authorities, regulatory agencies, and other decision-making bodies currently lack adequate access to spatially explicit information crucial to making such decisions. Further, decisions also are influenced at multiple scales: individuals write letters and get involved, the media influences the public, science informs the public and policymakers, and voters influence politicians and, therefore, policymakers and regulators (Fig. 14.1). Better information is needed to support decision analysis at all of these scales, such that stakeholders can consider a full accounting of the costs, benefits, and trade-offs of alternative decisions.

Here, we summarize an effort to integrate two such decision-analysis platforms under development by the US Environmental Protection Agency's (EPA) Sustainable and Healthy Communities Research Program (SHCRP). These two platforms afford opportunities for stakeholders to review information that characterizes: the variations in biophysical characteristics that predispose communities towards a particular response to changes in conditions, the distribution of stressors that affect community sustainability, the distribution of both vulnerable resources and populations, and

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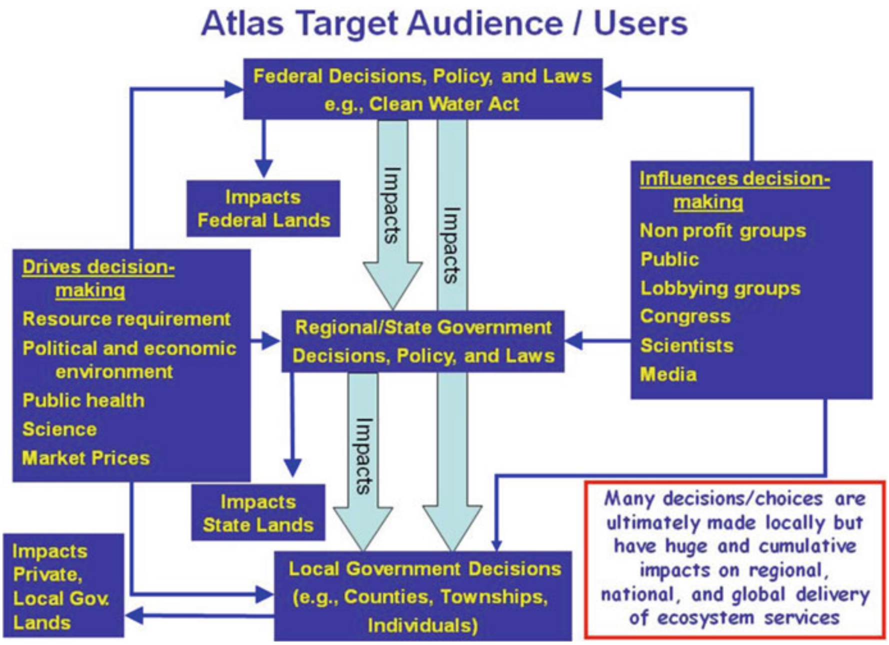

Fig. 14.1 How decisions relate across scales

opportunities for multiple benefits or unintended consequences associated with management actions. These decision-analysis platforms, referred to as the *Regional Vulnerability Assessment* (ReVA) and the *National Atlas of Ecosystem Services* (Atlas), are based on web-accessible statistical and GIS software with user-friendly interfaces and provide access to tremendous amounts of spatially explicit information and exploration and visualization capabilities. The integration of the two platforms will provide unparalleled resources for science education, in that it will establish a portal for accessing large amounts of data, information, and analysis capabilities to explore linkages between human health and well-being and changes in environmental conditions, at community, regional, and national spatial scales in a scientifically correct manner.

Good decision analysis attempts to consider all important factors. But good decision analysis often requires conducting a variety of interconnected and complex tasks—and all before decisions are made, money is spent, and improvements are seen. Therefore, investing considerable "up-front" time and resources on decision analysis may not seem favorable to stakeholders seeking immediate solutions to worsening environmental problems. Four key factors contribute to decision-analysis difficulties: (1) lack of information, (2) a traditional tendency to make decisions in a stove-piped fashion rather than considering the entire system, (3) inadequate representation of factors that contribute to desired goals, and (4) the lack of a transparent process for structuring and assessing the decision objectives. A community's decision processes vary by specific decision, community culture, the individual decision-maker, the ability to synthesize available pertinent information, and the degree of understanding of the linkages between actions and changes in community environmental, economic, and social health and well-being.

Increasingly, there are opportunities for schools, through active place-based science-education projects, to fit into their community's decision-analysis framework. Thus, the data and tools available in ReVA and the Atlas warrant attention, from the perspective of Generation R students and their teachers.

An effective decision-analysis system is one that permits a community to (1) fully identify and understand issues or problems, (2) assess sustainability, (3) enable future visioning and goal setting, (4) evaluate alternatives to enhance sustainability, (5) track progress towards goals, and (6) develop adaptive responses. Decision-analysis information and tools must be packaged in broadly accessible and easy-to-understand and use applications.

Information technologies available today for supporting effective decision analysis are unprecedented, and they continue to improve in leaps and bounds. It has only recently become possible to serve massive amounts of spatially explicit data (e.g., Google Earth, ArcGis.com) or to create mobile phone applications and web applications allowing large numbers of users to submit data easily to a large number of data-collection sites (e.g., Cornell University's eBird). It is this technology that will drive the development of web tools of the future—web tools that will help communities become more sustainable, leading to a higher quality of life.

One of the biggest issues with community decision-making is the lack of an adequate accounting of the goods and services provided by nature. This deficit has led to innumerable unintended consequences, such as loss of wetlands that help buffer against hurricanes and remove pollutants in runoff from agriculture lands, thus allowing disproportionate impacts of flooding and chemical pollutants on vulnerable populations. To date, there has been insufficient accounting for the more implicit, less easily quantified benefits we receive from nature, such as the value of green space for human health and well-being, or the cultural significance attributed to aspects of the natural environment by communities, tribes, and different ethnic populations. Today's technologies allow a more effective and accurate accounting of these kinds of diffuse natural benefits and, thus, have greatly advanced the development of a more robust decision-analysis system.

Example of Emerging Web Tools from Environmental Protection Agency Research

The US Environmental Protections Agency's (EPA) Sustainable and Healthy Communities Research Program (SHCRP) is developing web tools that (1) are interoperable (i.e., they work together and are able to exchange and use information); (2) use common data to the degree possible; (3) make use of emerging technologies in areas of information technology, visualization, and modeling; and (4) resonate with users, which triggers changes in behavior and new business-as-usual approaches. New metrics (i.e., a standard of measurement) and indicators (i.e., a metric that indicates the condition or level of something) are being developed not just for education! They also are being developed by SHCRP to reflect and communicate the linkages between human well-being and environmental changes and to measure progress towards communities' sustainability and quality-of-life goals. Communication and engagement of communities throughout the development of decision support is considered crucial—to ensure we are meeting communities' needs, effectively communicating the results of our EPA research, and ensuring ongoing use of the decision-analysis tools that we're developing.

EPA's SHCRP intends to improve access to information, tools, and decision frameworks that allow community decision-makers to understand how specific actions affect community well-being, weigh the full consequences of alternative management actions, track progress towards goals, and encourage creation of innovative solutions to community problems. It is also our goal to empower communities to effectively improve social equity and access to the full benefits of a sustainable future. This goal is being supported by EPA research that quantifies the supply and demand of ecosystem services (i.e., all the things humans receive from their natural environment, such as clean water and food) and the supply and demand of the services provided by our "developed" environment. Additional research in progress contributing to decision-analysis data and tools includes establishing linkages between human health and well-being and changes in environmental conditions, a better understanding of the processes that are used by decision-makers, and case studies of approaches that empower communities to move towards a more sustainable future. The suite of tools currently under development by the SHCRP will allow insights into the implications of alternative decisions on community resilience and quality of life and promote the creation of innovative solutions to problems faced by communities. One such benefit will be the use of created tools for assessing multiple positive outcomes of schools and teachers who act in relation to the communities in which their students will grow and make longer-term decisions for. Based on preliminary analyzes by EPA using the ReVA system, we believe other institutions such as schools, school policymakers, and those who guide the future directions that schools will go could substantially benefit from considering larger multilayered contexts to encourage student participation in real-world problem-solving.

The SHCRP is capitalizing on a vast amount of research that the EPA has already conducted on ecosystem services and on integrated assessments. Two of these efforts are the *Regional Vulnerability Assessment* (ReVA) and the *National Atlas of Ecosystem Services.* These two efforts, plus the ongoing visioning to combine them and to add to them in an interoperable platform, are of particular potential value to science educators and are described below.

EPA's Work in Integrated Assessment

Since 1998, EPA's Regional Vulnerability Assessment (ReVA) has been developing and demonstrating approaches for conducting integrated assessments (Fig. 14.2). Recognizing the importance of information at various spatial scales, ReVA was

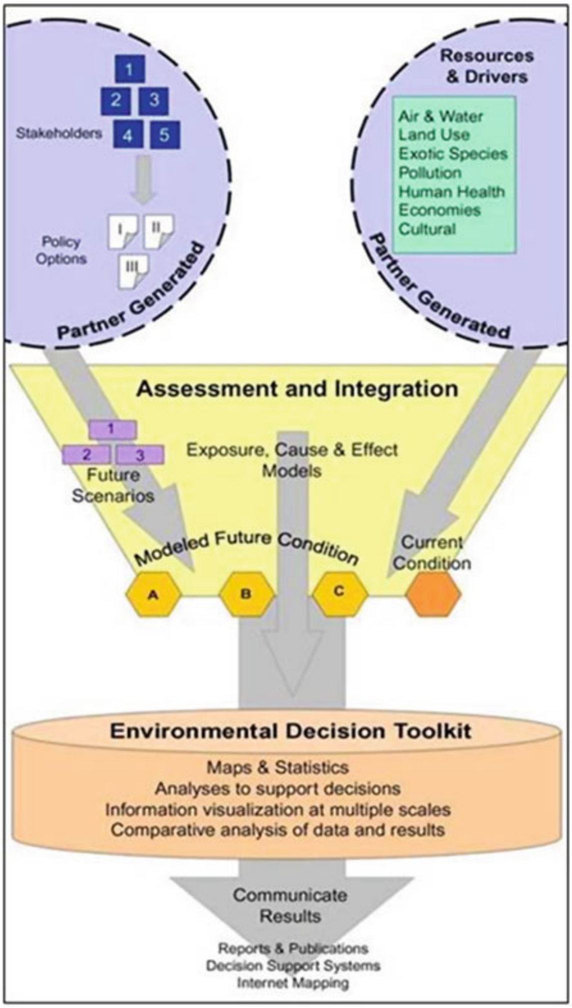

Fig. 14.2 Graphic depicting the Regional Vulnerability Assessment (ReVA) program process

designed to emphasize a broad spatial perspective while allowing thorough exploration of data from many perspectives, including changes in scale. Combining data that were collected for many different purposes can be problematic: as metric scales vary, distributions often don't meet statistical requirements (i.e., most statistical analyses require a normal, bell-shaped distribution of data), or data are unbalanced, meaning that there may be large amounts of data focused on specific areas, but lacking in others. Thus, much of the early research effort within the ReVA program focused on the invisible but difficult problem of how to integrate disparate data and model results into meaningful indices designed to address specific assessment questions posed by environmental decision-makers.

Today, many GIS-based applications allow users to overlay many different spatial coverages—a technique that allows the user to (for example) identify where

Region 4 population and health vulnerability data correlation matrix (partial)

1	NAME	MULT_RACE	HISPANIC	AGE_UNDER5	AGE_5_17	AGE_65_UP	Per_Pvty	HS_Diploma	Unemployed
8	MULT_RACE	1.0000	0.8791	0.9139	0.9233	0.8617	-0.1649	0.9301	0.9560
9	HISPANIC	0.8791	1.0000	0.6961	0.7158	0.6500	-0.0512	0.8111	0.8496
10	AGE_UNDER5	0.9139	0.6961	1.0000	0.9978	0.8865	-0.2652	0.9464	0.9322
11	AGE_5_17	0.9233	0.7158	0.9978	1.0000	0.9025	-0.2624	0.9582	0.9444
12	AGE_65_UP	0.8617	0.6500	0.8865	0.9025	1.0000	-0.2449	0.9209	0.8961
13	Per_Pvty	-0.1649	-0.0512	-0.2652	-0.2624	-0.2449	1.0000	-0.2192	-0.1594
14	HS_Diploma	0.9301	0.8111	0.9464	0.9582	0.9209	-0.2192	1.0000	0.9701
15	Unemployed	0.9560	0.8496	0.9322	0.9444	0.8961	-0.1594	0.9701	1.0000
16	Lead_NonAt	0.0672	0.0133	0.2257	0.2243	0.1240	-0.0112	0.1737	0.1599
17	Ozone_NonAt	0.1876	0.0579	0.3601	0.3474	0.2352	-0.2140	0.2656	0.2300
18	PM_NonAt	0.0350	0.0063	0.0852	0.0926	0.1017	-0.0310	0.0937	0.0596
19	NEI_COUNT	0.4178	0.2125	0.6318	0.6151	0.5142	-0.2842	0.5785	0.4723
20	EI_PNTDENS	0.2727	0.0868	0.4805	0.4582	0.3744	-0.3201	0.4201	0.3270
21	PPlaceExp	0.8315	0.6590	0.8780	0.8793	0.7986	-0.1728	0.8800	0.8550
22	RSEI_risk	0.3927	0.3447	0.4831	0.4877	0.4108	-0.1639	0.5218	0.4740
23	NATARiskCan	0.2545	0.1369	0.3774	0.3731	0.3160	-0.2343	0.3455	0.3083
24	NATAHQNeuro	0.0492	0.0245	0.0881	0.0869	0.0621	-0.0667	0.0785	0.0765
25	NATAHQResp	0.4308	0.2715	0.5210	0.5196	0.4601	-0.3301	0.4571	0.4324
26	CMortRMale	0.0720	0.0261	0.1211	0.1205	0.1074	-0.1530	0.1145	0.0992
27	CMortRFem	0.0639	0.0248	0.0992	0.0981	0.0892	-0.2138	0.0947	0.0836
28	CanMort05	0.9090	0.6823	0.9918	0.9936	0.9257	-0.2676	0.9545	0.9331
29	nCMortAgAj	-0.2370	-0.1375	-0.2810	-0.2863	-0.3519	0.4162	-0.2589	-0.2332
30	No_Uninsur	0.9692	0.8298	0.9717	0.9789	0.8982	-0.1938	0.9742	0.9778
31	Per_Unins	-0.0376	0.0374	-0.1253	-0.1258	-0.1350	0.8606	-0.1114	-0.0485
32	HPSA	-0.1232	-0.0598	-0.1826	-0.1838	-0.1715	0.2680	-0.1764	-0.1510
33	R_Drug_Use	0.9149	0.6942	0.9887	0.9929	0.9391	-0.2670	0.9632	0.9419

People within 10 km of a point source is 88% correlated with population under 5 years old. This means that 88% of the information you get from one coverage is redundant with the other. **Combining these 2 coverages effectively weights the common information by 1.88**.

Fig. 14.3 An example of a correlation matrix for human health vulnerability metrics for the Southeastern United States

high levels of pollutants come in contact with vulnerable ecosystems or populations. While this technique is satisfactory for screening data and identifying where things converge on the map, it is problematic if data are correlated and the user is trying to prioritize areas for management or protection. Simply put, data correlation means that two or more metrics change in value simultaneously: that is, a change in one metric is associated with a change in another metric. An example is population data from the census. Areas of high poverty often coincide with low education levels, with high levels of minority groups that could be linguistically isolated, and with poor access to health care. Yet it can be very difficult to determine how much one of these metrics influences the others. Another example of high levels of correlation among metrics includes data derived from satellite imagery, which are classified into different land-use or land cover classes (e.g., agricultural land versus urban land with high levels of impervious surface), and, likewise, the landscape metrics derived from these data (e.g., the degree to which forests are fragmented, or the amount of riparian buffer that is in natural cover). Clearly, for example, an increase in the amount of agricultural land must result in a decrease in other land-use classes: thus, the land-use metrics are correlated, and metrics derived from a single land-use land cover map are also correlated.

A high correlation among two metrics means that the variation in one metric is similar in some part to the variation that occurs in the other. Correlation matrices illustrate how much the change in one metric relates to another (Fig. 14.3). When the amount of correlation is given as 0.90, this means that 90 % of the information gained from looking at one metric is already covered by the correlated metric, so the new metric contains only 10 % new information. If GIS applications do overlays of

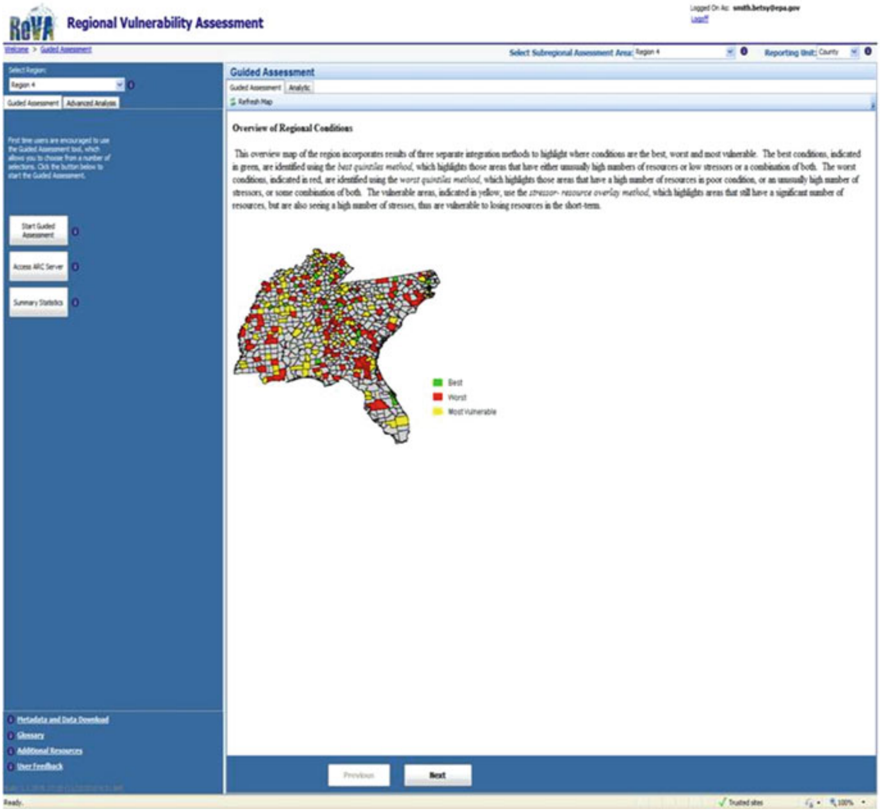

Fig. 14.4 Screenshot from the ReVA Environmental Decision Toolkit showing counties in the Southeast with the best (i.e., lots of resources in good condition with few stressors) and worst (i.e., lots of resources in poor condition and a high level of stressors) conditions and those that are most vulnerable to future changes (i.e., both high numbers of resources in relatively good condition and a high level of stressors that over time are likely to impact resources)

these metrics without considering the correlations among metrics, it introduces bias, because each metric is counted equally, even though subsequent metrics don't add as much new information. Thus, if two metrics correlate 90 %, yet they are mapped in GIS in an additive way, the result is basically weighted by 1.9, because information in common is effectively counted twice.

A powerful accomplishment of the ReVA program has been to develop a method that corrects for bias among metrics by weighting each metric according to the amount of correlation that each individual metric introduces (Tran et al. 2006). In the ReVA web-based *Environmental Decision Toolkit* (EDT) (Fig. 14.4), overcoming the metric-correlation problem allows the user to map how far away from an ideal reference watershed other watersheds in the region are. Similarly, for human population metrics, it is now possible to define a reference population as one without poverty, without disease, and with no linguistic isolation—and the ReVA user then can see how far away other counties or census blocks are from this ideal human population, without introducing bias from correlated metrics.

Another important result from early ReVA research has been to find different ways of combining data into indices to address community-sustainability questions. For example, the integration method described above (the Tran distance) can be used to look at overall conditions by comparing reporting units to the best or worst conditions found in the region, giving an overall ranking of each individual unit, compared to the reference. But other methods can be used, too, to identify reporting units that are the most vulnerable in terms of where conditions are likely to change for the worse in the shortest amount of time. In terms of potential losses, this can be accomplished by looking at areas that have both a combination of resources that society does not want to lose (e.g., clean water for recreation and drinking, habitat that supports diverse wildlife) and stressors that can harm these resources. As the numbers of these two things increase simultaneously across the map, so does the environmental vulnerability. This measure of vulnerability is illustrated by a two-dimensional matrix that has relative amount of stressors present as columns and the relative amount of valued resources by row (Fig. 14.5). Vulnerability increases along the diagonal as resources and stressors both increase.

A third major advance in ReVA methods is that of developing capabilities for "what-if" scenarios. These scenarios permit a ReVA user to inspect likely future changes in environmental vulnerabilities from anticipated regional changes in population growth, economic conditions, land use, transportation infrastructure, and so forth. ReVA can improve the environmental decision-making process by permitting more realistic inputs for school/environmental decision-making and by expressing results of multiple factors at a regional spatial scale. This scenario-exploration approach allows an evaluation of *net* change, so that the user can visualize how both positive and negative changes affect future conditions and vulnerabilities.

As its name implies, ReVA is based on vulnerability assessment. ReVA's web-based Environmental Decision Toolkit (EDT) allows users to examine a broad range of information across a region, and can help identify areas where as-yet-unidentified resources, ecosystems, or populations might be vulnerable. ReVA accomplishes this objective by applying environmental indicators (or descriptive metrics) to represent important changes in conditions and examines the co-occurrence of valued resources and stressors to represent vulnerability to potential harm. The techniques used to examine how stressors and resources combine can reveal threats that are often not clearly identifiable or quantifiable; this allows ReVA users opportunity to explore complex interdependencies of related issues.

The National Atlas of Ecosystem Services

The *National Atlas of Ecosystem Services* (Atlas), currently under development, is a comprehensive approach for quantifying and visualizing the current and future demand and provision of valued ecosystem services needed by communities to

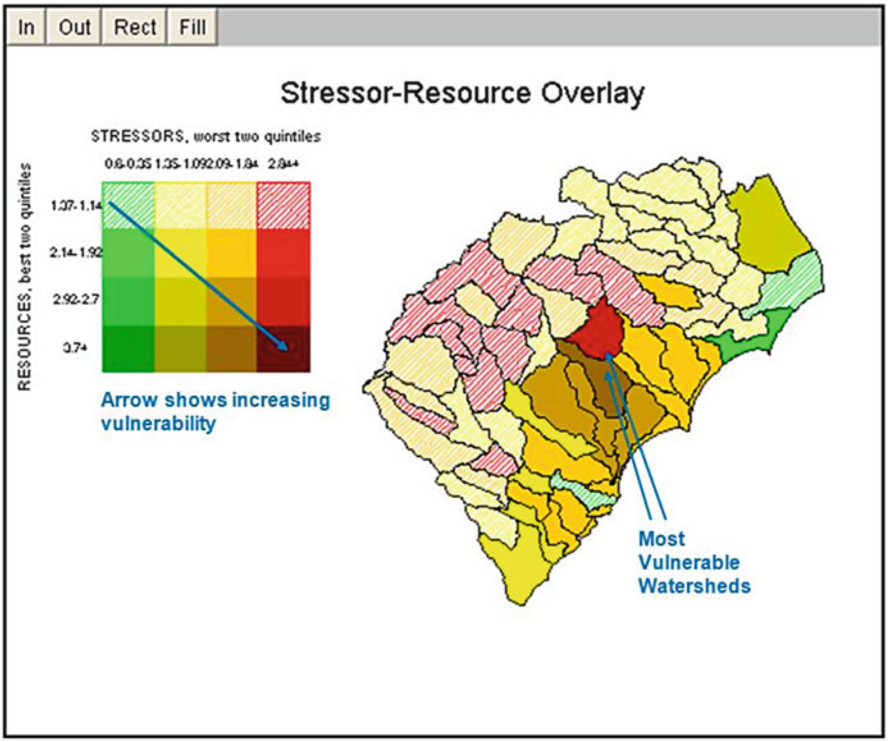

Fig. 14.5 Illustration of the stressor–resource overlay that identifies where the greatest urgency is to protect resources that are vulnerable. Watersheds that have few resources or low amounts of stressors are not considered as vulnerable as areas that have both high numbers of resources and high numbers of stressors present

sustain human life and well-being (Fig. 14.6). As an interactive, publicly available web tool, the Atlas will also show the distribution of drivers of change (e.g., population, multiple stressors, and climate changes) and forecast future trends for each of these drivers, with the associated changes in the supply of, and demand for, ecosystem services. In short, it will provide information about the implications for human health and well-being. Where feasible, the Atlas will provide information about the social and economic costs of various decisions, such as the trade-offs between gray (i.e., built items such as culverts and drains) and green infrastructure (i.e., using natural features). Data and model results also will be available at multiple scales: wall-to-wall summarized information will be at a relatively coarse scale (about 83,000 basins or catchments) for the conterminous USA, while the underlying national data layers are at a much finer scale (30 m^2). The Atlas also will contain very fine-scaled analyses for selected communities across the country. The multiple scales of information can be used in combination, which will allow decision-maker insights into issue *context*. For example, they can clarify the role of upstream watersheds for protection of community water quality and regional pollutant sources for

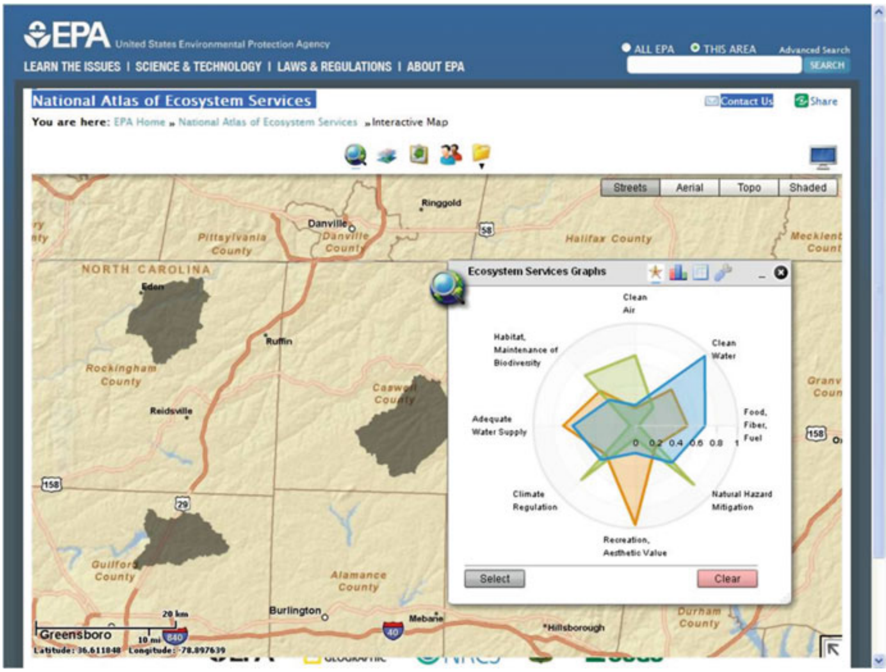

Fig. 14.6 Screenshot from the National Atlas of Ecosystem Services depicting the relative supply of ecosystem services (*inset graphic*) for three watersheds (*in gray*)

community air quality, as well as incorporate information relevant to regional and national policy alternatives.

Until very recently, the data that will be available in the Atlas were available only to users that had expert-level skills with *Geographical Information Systems* (GIS) and which had access to powerful computing resources. The Atlas, using the newest technology, allows users with no more than an internet browser and some healthy curiosity to access a wealth of spatially explicit data and analysis tools. The implications of the opening of this resource to students, science educators, and those involved in environmental decision-making at the community level will be huge. Schools that establish ReVA- or Atlas-based community-centered science projects might, for example, be able to count these activities as evidence of success, in lieu of efforts devoted to high-stakes testing.

The national scale data will allow users to easily view and analyze information such as the numbers of threatened and endangered species in each catchment, the number of harvestable species in a given catchment, point sources (e.g., sewage treatment plants, industries, animal operations) and nonpoint sources (e.g., runoff from agriculture, lawn runoff) of pollution in the catchments (upstream of drinking water intakes), and availability of recreation resources. Users also will be able to view how well connected naturally vegetated patches of land are, the condition of stream buffers, and the protection status of all lands contained within the USA. In isolation, each one of these pieces of information can help answer important questions about the use of resources: linked, in an easy-to-use tool, the Atlas creates an incredibly powerful means to enable better decision-making. Further, ready access to these data and tools affords a direct link from place-based studies, led by science teachers and their students, to community policymakers.

The fine-scaled community analyses (urban Atlas) in the Atlas will provide information linking human health and well-being to environmental conditions such as urban heat islands, near-road pollution, wise use of resources, access to recreation, drinking water quality, and other quality-of-life factors. In addition, the urban Atlas will facilitate the analysis of who pays and who benefits through characterization of populations that are disproportionately impacted due to limited access, low levels of opportunity, and lack of community empowerment to effect positive changes. The urban Atlas also will facilitate site-specific problem-solving and provide support to individual communities by allowing identification of places that are further along towards finding innovative solutions to sustainability challenges. The urban Atlas will rely heavily on foundational land cover data that will be characterized from aerial imagery at a 1–3-m pixel resolution. This high-resolution land cover classification will also be made available through the Atlas tool.

The categories of ecosystem services to be included in the Atlas include: clean water for drinking; clean water for recreation and to support aquatic habitat; recreation, cultural, and aesthetic amenities; clean air; flood protection; climate regulation; habitat and the maintenance of biodiversity; food, fiber, and fuels; and water supply and timing. Eventually, it is likely that the USA will adopt a *National Classification System* for ecosystem service. When this happens, the Atlas will change its framework to adopt that classification standard. The Atlas will include multiple tools to allow users to analyze the data from simple graphical analysis, to a tool to allow users to navigate up and downstream from any point on the map, to tools that will eventually allow complicated models to be run.

Future Visions

Information technology (IT) is moving more quickly than ever—where capability builds upon itself—requiring more agile approaches to doing business, even in schools. This is especially true for communities, where emerging IT could be harnessed to tremendous benefit on real-time, in situ sustainability planning. We plan to be creative in extending our outreach efforts and will engage in online social networking culture to achieve objectives as efficiently as possible. For data needs and integration of our existing and future tools, we plan to transition to a modular and interoperable IT business model, similar to the building block model involved in creating a Blackberry. For example, one block controls the camera, another converts pictures to .mpeg files, and another manages how such files are sent to other smartphones. The "block" analogy shares commonalities with several other business models, for example, those of Drupal.org and WordPress.org. Drupal programmers create building "blocks" that are interoperable (these are referred to as "modules"). Website developers then use those blocks to build websites (e.g., the Whitehouse site). One block includes the code for a "log-in" page, whereas another is a tool for viewing a gallery of images. Just as millions of people publish and peer-review *Wikipedia* articles, millions of programmers from around the world now publish and peer-review *Drupal* modules for free. We plan to extend this analogy to develop and maintain sustainability tools and the tools that build on one another. This approach involves using open-source software and harnessing a virtual workforce of programmers to help us develop and maintain the code necessary to help communities solve problems and achieve sustainability; however, sustainability is defined.

Integrating ReVA and Atlas

The Atlas will serve as a foundation for SHCRP decision-support tools and sustainability assessment capabilities, providing both basic landscape information (e.g., soils, land cover) and modeled output that represents the distribution of specific ecosystem services (e.g., water supply, air quality, agricultural yields, biodiversity) and human populations served. These data, both static (e.g., soils data) and modeled (e.g., estimated air pollution deposition), will inform analyses of what-if questions that are reflective of decision-maker needs at the individual, community, regional, and national scales. This will be accomplished through the development of empirical relationships that build on the vast information available from the Atlas and the spatial and temporal linkages among those factors that influence changes in environmental condition and human well-being. In addition, this research will be interfaced with research in other federal agencies including the US Geological Survey, National Oceanographic and Atmospheric Administration, and the National Aeronautics and Space Administration. By integrating the data and derived spatial coverage components of the Atlas with ReVA analytic capabilities, it is hoped that users will gain an improved understanding of the linkages between human well-being and environmental conditions and insights into choices and opportunities that allow communities to become more sustainable. The evolving integrated Atlas/ReVA application is moving towards system modularity where data from multiple sources can be accessed and integrated and where the interface itself is considered a service rather than traditional software.

Engaging Communities

SHCRP decision-support developers cannot physically meet with every community that has decision-support needs, yet we recognize the critical need for engaging communities in processes that foster good decisions. EPA's experience and history demonstrate that stakeholder involvement is proportionate to decision buy-in and, ultimately, to successful environmental outcomes. Further, multilateral dialog ensures that EPA receives feedback for ongoing development and improvement of useful tools. Several existing social media websites, such as *Facebook* and *LinkedIn*, offer examples that can inform our ability to engage stakeholders in environmental problem-solving and sustainability planning. We also plan to partner with universities, nonprofit organizations, and the private sector to harness the power of social media technology, framed by an online architecture that allows communities and stakeholders to participate in problem-solving processes.

Atlas and ReVA are being designed, minimally, to encourage users to provide critical feedback, but we anticipate developing mechanisms and governance standards by which users can incorporate their own data, share data and results, and embrace other benefits of social networking. Both tools are being designed to be interoperable with social media and networking functionality. This combination will allow users and communities to create living conversations with powerful geospatial information. Atlas and ReVA functionality will be made available to non-EPA organizations seeking to integrate spatial tools within their online communities (e.g., *Ecosystem Commons*, www.ecosystemcommons.org, a recently launched networking tool for ecosystem services practitioners and interested parties to exchange information). We at EPA also anticipate developing and evolving online platforms that harness the power of ReVA and Atlas' spatial information management in combination with emerging social media and networking technology.

Upcoming Steps

We expect to continue enhancing the ReVA tools over time, while providing updated information and analysis capabilities. Some of the planned enhancements include:

- Add ability to change broad environmental conditions (weather, buffers next to streams, the number and type of pollution point sources), so as to allow users to turn up and down these conditions and see implications for communities and human health and well-being.
- Add ability to delineate an area of land-use or land-management change, and evaluate resulting impacts over both the local and the broader regional areas.
- Add ability to identify where the user is on the map, and show how that area compares to other areas.
- Add automated reporting on conditions for various reporting areas, such as congressional districts and large watersheds.
- Add options for screening of areas, to identify communities that are disproportionately impacted by pollution, waste management problems, or lack of access to public transportation.
- Add ability to bring in real-time data (e.g., weather, land use, air pollutant levels), and map changes in things such as runoff and human health vulnerabilities.

- Add capability to answer the question "what can I do to…" to reduce impacts from environmental stressors such as air pollution.
- Allow users to query the system with a series of "what-if" questions, such as what is the benefit/cost of different activities for mitigating problems, restoring ecosystems or community resiliency, and protecting things people care about.

The EPA SHCRP intends these tools to be widely available and easily accessible in ways that continue to take advantage of new technologies and communication tools. We recommend checking EPA's website for updates on the SHCRP web tools (e.g., the website www.epa.gov/ecology) and will include links to these future tools, along with updates as to new features as they are added.

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Chapter 15
Is There an App for That? Connecting Local Knowledge with Scientific Literacy

George E. Glasson

Mobile digital technologies, including laptops, tablet PCs, and smartphones, are used increasingly in society for communication, social networking, navigation, research, and documenting everyday life events. Thousands of application software (i.e., Apps) can be downloaded on electronic devices to assist in performing specific tasks such as cooking, birding, blazing a trail, sailing, recording music, and so forth. An important challenge for educators is to explore ways for enhancing classroom instruction, student learning, and achievement through the use of these technologies. In the field of environmental education, there is an important trend towards connecting local community knowledge with scientific literacy. Is there an App for that?

Education that encompasses local community knowledge and culture is referred to as place-based education. According to Loveland (2003), place-based education "provides the context for learning, student work focuses on community needs and interests, and community members serve as resources and partners in every aspect of teaching and learning" (p. 1). This chapter explores environmental education projects that use emerging digital technologies and software applications to assist students from diverse cultures in connecting local knowledge and practices to scientific literacy. After discussing the goal of achieving scientific literacy for students in K-12 schools, I explain how the GLOBE Program and place-based education projects from my own work in Africa and Thailand demonstrate how digital technologies can be used to facilitate science learning, curriculum development, and authentic assessment.

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Scientific Literacy for All Students

For over two decades, scientific literacy for all students in the United States has been a goal for scientists, educators, and policy makers. Most notably, the book, *Science for All Americans*, published in 1990 by the American Association for the Advancement of Science (AAAS), is based on the premise that

> A science literate person is one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity and uses scientific knowledge and scientific ways of thinking for individual and social purposes. (1990, p. xvii)

Additionally, the authors advocate that all students develop scientific "habits of mind" in the process of learning science in schools. Scientific habits of mind involve learning how to apply scientific investigation skills to evaluate evidence and solve problems that may be applicable to daily life. This vision expands the borders and boundaries of students in the USA by emphasizing the importance of scientific literacy in understanding global environmental issues:

> There is more at stake, however, than individual self-fulfillment and immediate national interest of the United States. The most serious problems that humans now face are global: unchecked population growth in many parts of the world, acid rain, the shrinking of tropical rain forests and other great sources of species diversity, the pollution of the environment, disease, social strife, the extreme inequities in the distribution of the earth's wealth, the huge investment of human intellect and scarce resources in preparing for and conducting war, etc. (p. xiii)

Science teachers have an important role in helping students understand and critically evaluate scientific evidence that may be connected to important decisions affecting both local and global ecosystems. In rural Spain, for example, Dopico and Garcia-Vazquez (2011) document the learning of students who were investigating agricultural practices of farmers that are passed down for generations. The farmers utilize composting and organic methods of pest control while limiting excessive use of fertilizers and herbicides. The decisions of the rural farmers in Spain and elsewhere affect global ecosystems but are grounded in actions of individuals within the local communities (Glasson 2011).

The concept of scientific literacy for all students is formalized in US science classrooms through the adoption of the National Science Education Standards (NSES) (National Research Council 1996). The NSES identify the teaching, content, and assessment standards for K-12 science programs. Specifically, the authors advocate teaching science as a "human endeavor," and they identify unifying science concepts and science content that all students should learn. Additionally, the concept of scientific literacy is expanded to include standards for teaching science-as-inquiry, technology, social, and personal perspectives, and the history and nature of science. Interestingly, the standards for technology, which focus on scientific and engineering design applications, have not kept up with the pace of technological change since 1996. In 1996, the Internet was just beginning to expand, and mobile phones and laptops were not in widespread use.

Most recently, Mueller and Bentley (2009) emphasize the importance of connecting science literacy to everyday life choices as a means to facilitate students' understanding of sustainability issues:

> Science education purports to foster an understanding of how scientific inquiry helps to make everyday choices, referred to as *science literacy.* It logically follows that there might not be a declining environmental literacy among citizens in the United States if the natural sciences were taught in a way that serves to elicit citizens' fuller participation in choices that lessen human impacts on the world and contribute to sustaining everyday life. (2009, p. 55)

From my own work in Malawi and Thailand, teachers and students are involved in exploring scientific literacy that uses technology to connect problem solving and investigations to the daily life and agricultural practices of the local community. As I discuss below, a community-based definition of scientific literacy is particularly applicable to place-based education and meeting the needs of students from economically marginalized cultures.

Standardized Assessment of Scientific Literacy

Although a broad definition of scientific literacy is advocated for connecting scientific issues to local communities, the rationale and urgency for achieving scientific literacy for all students remain directly linked to the economic development and competitiveness of the USA. In response, the assessment of scientific literacy for US students is being been tracked by the Trends in International Mathematics and Science Study (TIMSS) and the Program for International Student Assessment (PISA). The TIMSS tests measure content knowledge in the biological, physical, and earth sciences (National Center for Educational Statistics 2007). The PISA test, sponsored by Organization for Economic Cooperation and Development (OECD), reportedly measures scientific literacy that is defined as "an individual's scientific knowledge, and use of that knowledge, to identify questions, acquire new knowledge, explain scientific phenomena and draw evidence- based conclusions about science-related issues" (OECD 2010a, p. 137).

Both international science tests document mediocre performance of US students when compared to other industrialized nations. In 2007, out of 47 countries, the average science scores of US eighth-grade students on the TIMSS test were lower than students in nine countries (located in Asia and Europe). In the PISA test of scientific literacy in 2006, 15-year-old US students ranked 21st out of 30 countries that were members of OECD; in 2009, US students ranked 17th out of 34 OECD members and 23rd out of all 65 countries.

In response to the performance of US students on these international tests, many politicians and government officials call for alarm and advocate more standardized testing and a reemphasis on K-12 STEM education. Comparing the scores of all US students to other countries, however, raises concerns because of the significant achievement gaps that occur within different subsets of the US student population. On the TIMSS test, student performance is linked to ethnicity and poverty as US eighth-grade students from White, Asian, or multiracial ethnicities score on average higher than Black or Hispanic students. Students of lower socioeconomic status (as identified as eligibility for free or reduced lunch) score lower on the TIMSS test than more affluent students. On the PISA test, socioeconomic factors are found to have a strong impact on student performance in the United States (OECD 2010b).

These international tests that measure scientific literacy are also problematic because rather than focusing on how science is connected to students' everyday lives, the tests measure standardized content that is presumably universal across cultures. Atkinson (2010) argues: "the 'achievement gap' occurs because standardized assessment robs the teachers and students of autonomy and creates a false impression of deficit-model thinking in science" (p. 440). Rather than assessing student strengths and understandings of scientific literacy within the context of their local culture and environment, students are considered deficient in their understanding of science if they "do not exhibit correct language, accept content knowledge without question, and reason using accepted multiple-choice answers to the corresponding standardized test question" (p. 441). Atkinson further challenges the assumption that standards-based curriculum and assessments prepare students to be global citizens; instead, she advocates focusing on diverse types of assessment and reducing inequalities in the educational systems.

Indeed, measuring science literacy that involves students in learning how to apply scientific investigation skills that may be applicable to daily life and social concerns presents a challenge for educators. The results on standardized international tests indicate that a new approach is needed for assessing the performance of students from minority ethnic groups or economically marginalized populations of students. This community-based approach requires educators to design science lessons and assessment systems in a way that encompasses students' local culture, language, and everyday lives.

Place-Based Education

Place-based education (e.g., Glasson et al. 2006) connects schooling to the local community, culture, and environment. Semken and Brandt (2010) explain the importance of a sense of place to learning in schools:

> In summary, places are where we sense and connect to our natural and cultural surroundings, and sense of place is a construct that usefully describes this connection. Place-based education is situated in pedagogically fruitful places and leverages the senses of place of students and teachers. It is highly relevant to environmental ethics, conservation, ecological integrity, and cultural sustainability, because all of these are also situated in places. (p. 289)

Place-based education is embedded in both literate and nonliterate oral traditions and is "fundamental to both individual and sociocultural identity" (Semken and Brandt 2010, p. 294). Place-based education includes the sources of intellectual and cultural capital in the local community, known as "funds of knowledge" (e.g., Gonzalez et al. 2005). These sources, for example, may include knowledge of sustainable farming, cooking, or the use of indigenous technologies. As placed-based education is linked to the natural and cultural environments, it may also be a "channel through which students act globally from their locality" (van Eijck 2010, p. 323).

Place-based education may require a different assessment system for students from marginalized cultures who do not traditionally perform well on standardized tests. Zandvliet (2010) explains: "our educational concern for local space (community in the broad sense) is sometimes overshadowed by both the discourse of accountability and by the discourse of economic competitiveness to which it is linked" (p. 309). This discourse of accountability presents a sense of "placelessness" where all students and cultures are considered standardized and science literacy is disconnected from local communities. As Zandvliet also noted, the omission of place-based education in our efforts to systematically reform science education presents a serious problem in helping students become scientifically literate.

Below I discuss three international projects that offer alternative and authentic means of assessment of scientific literacy that is connected to students' local communities. The projects all utilize digital technologies to help students access the funds of knowledge of the local community in the process of learning science. Subsequent discussion focuses on how a place-based education approach can encourage students from marginalized ethnic populations and socioeconomic groups to improve their own scientific literacy.

GLOBE Program: Connecting with Local Communities

The GLOBE Program (http://globe.gov/) is an example of a large-scale project that uses technology to connect local community knowledge with scientific literacy. The GLOBE Project reaches over 1.5 million students from over 111 countries, including the United States. The GLOBE Program focuses on investigating earth system science topics related to the atmosphere, hydrology, soils, and land cover. Using scientific instruments such as thermometers, wind vanes, and chemical test kits for water, students collect scientific data from their local schoolyards, rivers, playgrounds, and natural environments. The data are then uploaded to the GLOBE website and shared with other students and scientists around the world.

Students are using the GLOBE protocols and inquiry to answer questions relevant to local environmental issues. According to Dr. Deb Hemler, GLOBE facilitator and professor of Science Education at Fairmont State University in West Virginia, students use ozone protocols to look at sources of local emissions of coal power plants along the Ohio River (personal communication, Deb Hemler). Other students use *E. coli* testing along the Little Sandy River in West Virginia that flows through their town to determine whether it is safe for swimming. Students in Cameroon, Africa, implement GLOBE protocols to investigate the link between malaria and local environmental conditions.

The GLOBE Program provides many avenues for using digital technology to connect local environmental problems with global issues. Students connect to their local geography by creating maps and graphs using GLOBE data and Global Positioning System (GPS) devices. Students draw contour maps and diagrams of their local landscapes, use local sounds to produce music CDs, and incorporate digital photography of local ecosystems. Besides publishing results of their research projects on the GLOBE website, students also present what they learn about their local communities as part of the International Learning Expeditions conferences. Included in these reports are scientific data, information, and photos pertaining to their local cultures and ecosystems. In essence, students' scientific literacy begins at home, by collecting and analyzing data from their local environment. In the GLOBE Program, digital technology facilitates the expansion of students' knowledge and understandings of science from an international perspective.

Malawi

My work in curriculum development in Malawi uses the framework of place-based education to connect scientific literacy with local community knowledge (Glasson et al. 2006). Malawi is a sub-Saharan African country that is economically challenged with widespread poverty and serious ecological degradation. Unfortunately, most of the science taught in Malawi is didactic where teachers lecture and students take notes or recite answers. The science textbooks in Malawi lack examples or descriptions of the local culture and environment and instead are filled with examples from US or European countries. Unfortunately, rural villagers perceive science education as being largely disconnected from their everyday lives. But within the rural communities, there is a wealth of local indigenous knowledge and practices that relate to scientific literacy. Many of these forms of knowledge are essential for survival. These local practices include knowledge about organic farming, food preservation, and herbal medicines. Unfortunately, the local, intergenerational knowledge in Malawian society is becoming increasingly marginalized, and it is not included in the science curriculum.

To better understand how scientific literacy can be connected to the local funds of knowledge, we interviewed elders in the community on topics such as sustainable agriculture and food preservation (Glasson et al. 2010). The interviews, conducted in local languages, reveal that many farming practices, such as gravity-fed irrigation, composting leaves to fertilize the soil, or using organic means of pest control, are well entrenched in local community. These organic farming practices are a form of local scientific literacy that can be explained in terms of western science. For example, farmers bury the leaves of the *mzungu* tree (a particular acacia species) in the soil to hasten decomposition, thus providing a natural fertilizer (*chajila cha chilengedwe*) to improve crop yield. This knowledge has been passed down from elders (*kusunga misyungu ja achinangolo*). Another example of local knowledge is the preservation of vegetables (*timasunga masamba*). Because most rural Malawians do not have access to electricity and refrigerators, women preserve vegetables by boiling (*kwaphika*) and sun drying (*kuyanika)*. These vegetables are sold in the

Fig. 15.1 Mobile Malawi project website

market during the seasons before crops are harvested. These examples of scientific literacy could be used to provide a context for improving student learning. However, these types of knowledge are not part of the school science curriculum and are not found in textbooks.

In response to this lack of connection between the local funds of knowledge and scientific literacy, we developed the Mobile Malawi Curriculum (http://www.mmp.soe.vt.edu) as a pilot project (Glasson et al. 2008; Glasson 2010) (see Fig. 15.1).

A software application was developed for mobile smartphones to assist children in growing a sustainable garden by communicating with an organic farmer 300 miles away who had local knowledge and experience to share. The application, delivered by a mobile phone, contains lesson plans that involve children in growing gardens using gravity-fed irrigation, composting, and organic pest control. The application on the mobile phone also provides access to videotaped interviews with the farmer to learn about local organic agricultural practices. Using mobile phones, teachers and children document their progress and post photos of gardening projects on an Internet blog. The mobile phones are particularly important because the children have limited access to textbooks. The teacher is therefore able to log on to the Internet to access information from around the world pertaining to organic gardening or any other topic of interest.

Even though Malawi does not participate in TIMSS or PISA international assessments, students are tested after the 8th grade to determine whether they can continue on to secondary school. After secondary school, students must pass an examination in order to be one of the select few to be admitted to college. With this high-stakes testing, most students do not continue in school past the 8th grade. The vision to improve student achievement and understanding in science in countries or populations with widespread poverty requires a transformation of the curriculum to authentically connect scientific literacy with local culture and funds of knowledge in the community. Mobile phones, in such cases, facilitate communication and students' understanding of scientific literacy within their local community. Planning and successfully growing an organic garden with gravity-fed irrigation represents a form of authentic assessment that enables students to connect scientific literacy with their daily lives.

Thailand

In Bangkok, Thailand, primary school teachers and children study plants and the water cycle using a place-based education approach (Klecheya and Glasson 2011). Working in groups under the guidance of teachers, children engage in inquiry learning by growing plants in enclosed jars to observe evaporation and condensation, measuring the amount of water that various plants use, and observing transpiration. These efforts use locally available plants and materials. For example, when measuring the amount of water in plants, the children squeeze water out of local fruits (e.g., dragon fruit, pineapple, and watermelon).

Local community members, involved as guest speakers, include a parent who works at the weather center, a university botany student, and an expert on local plants. Class discussion focuses on the tradition of growing rice in the Thai culture, how long it takes to grow rice, and the importance of not wasting food at lunch. Children discuss the importance of water conservation at home and how to reuse wastewater for agriculture.

To better understand this place-based education project, I collaborate with Thai teachers and observe children in the classrooms using Skype, an Internet communication application. Over real-time video on the Internet, the children share their investigations and receive feedback via a translator. During a recent trip to Thailand, I observed teachers and students involved in an expanded place-based education project in Lampang Province in the northern part of the country. In this project, directed by Thai science educator Rojjana Klecheya, students are involved in investigating the water quality of local streams, adaptations of local plants, and the types of soils needed for growing rice.

The results of this place-based education project are highlighted in a YouTube video (http://www.youtube.com/watch?v=wzH8vSBV540) (Klecheya 2010). This video describes a community where 60 % of the population is indigenous Hill Tribe people where the main occupation is farming. In the schools, science is poorly integrated with community and surroundings, and there is a shortage of basic resources such as books and learning resources. Through a professional development program, teachers are involved in searching the Internet for background information and identifying local community members and resources for teaching about sustainability and water resources. Teachers collaborate to write place-based science curriculum and lesson plans that meet the national curriculum standards of Thailand.

This place-based curriculum is designed for students to learn about topics such as the cycle of life in rice fields, the advantages and disadvantages of biological and chemical fertilizers, and water pollution in the local rivers and irrigation channels. Through modeling of instruction, the teachers and students learn to measure the temperature, pH, phosphates, nitrates, and bacteria in local streams using water quality test kits. Throughout the project, the importance of healthy environment and caring for the community are emphasized as children learn how to prevent dengue fever by controlling mosquito populations. As a school project, students are recycling plastic bags and bottles and present recycled candles to monks in the temple. Students also design posters on creating sustainable environments and present their work to local community members on a science exhibition day. Parents, involved in creating a new herb garden and painting the library, are amazed at the ability of the students to talk about science and protecting the water resources in the community. This video exemplifies place-based education and how digital technology can be used to showcase the work of students from rural or marginalized cultures around the globe.

Authentic Assessment and Place-Based Education

Several assessment methods in these projects demonstrate how educators may document students' learning about scientific literacy in the local community. In the GLOBE Program, assessment connects students' ability to collect and analyze data that is relevant to issues in local communities. The students collect data using scientific instruments and enter their findings into a database on the Internet; thus, students' research is connected with other students from around the world. The investigations that students are engaged in, however, originate from local environmental issues. Students are able to create digital representations of learning that involve local art, music, and culture.

In Malawi, teachers and students learn about organic farming through a curriculum application that was delivered over a mobile smartphone, and students are assessed on the basis of their progress that is documented via the digital photos and information they post on an Internet website. The final assessment is not student scores on a multiple-choice test; rather, it is the students' success in growing an organic garden at the school site using scientific information about sustainable agriculture in their local community. Although digital technology is used for communication, accessing information, and dissemination of results, local indigenous resources and technologies are used in the school lessons and student activities.

In Thailand, students are also engaged in learning that connects scientific literacy with local environmental issues. Since the whole community is involved in the children's education, the local funds of knowledge provide a valuable resource for science learning. Assessment is measured by the students' ability to produce artifacts or products that represent their learning, such as posters with graphs, drawings, or descriptions of their investigations. Digital technologies are used to document and display student achievements and learning in the classroom and the local community via the Internet.

The place-based education projects described above are examples of how science literacy could be improved for all students in the United States, including students from economically marginalized populations such as urban ethnic groups, rural Appalachia, and Native Americans. Although standardized tests will continue to provide important comparative measures of scientific literacy, future research and longitudinal assessment studies need to document the progress of students engaged in place-based educational studies. If students are involved in place-based education that connects to their daily lives and local community, their understanding of scientific literacy will likely increase because they have a framework and context for understanding scientific concepts and processes. However, educators must also be sensitive to developing test items that assess scientific literacy that is culturally relevant.

Although place-based education may be an important strategy in reducing achievement gaps, state and national governments should also work hard to reduce any digital divide that may exist between affluent and less affluent communities. Reducing the digital divide by enhancing opportunities for all students to access digital technologies may improve the achievement of students from low socioeconomic and diverse ethnic populations. As more students become technologically savvy and are linked digitally to other students from around the world, students will have more opportunities to learn about other cultures and develop their scientific literacy that begins at home.

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Chapter 16
Developing Collective Decision-Making Through Future Learning Environments

Gillian H. Roehrig, David Groos, and S. Selcen Guzey

National reports such as *Rising Above the Gathering Storm* (National Academies 2006) and *Tough Choices or Tough Times: The Report of the New Commission on the Skills of the American Workforce* (National Center on Education and the Economy [NCEE] 2007) call for fundamental changes in the education system in the United States. In fact, the NCEE report categorically states that "the core problem is that our education and training systems were built for another era, an era in which most workers needed only a rudimentary education" (p. 8). The rapid evolution of technology in the twenty-first century is changing the needs for the workforce in general and more specifically in STEM fields; in turn, this changes the expectations for students entering this ever-changing workforce and the teachers who prepare them to do so. This is not only to develop the next generation of STEM workers but also to develop technological, or STEM, literacy for all. Hurd (1998) clearly indicates that current ways of teaching and learning "need to be reinvented to harmonize with changes in the practice of science/technology, an information age, and the quality of life" (p. 411).

Twenty-first-century knowledge and skills are garnering growing attention in the conversation about the transformation of schools for the current century. Proponents argue that within the context of core knowledge instruction, students must also learn the essential skills for success in today's world, such as critical thinking, problem solving, and communication. Central to the development of these skills is the ability to use twenty-first-century technology tools, such as information and communication technologies. Students of today are digital natives who live in a rapidly changing and developing technology and media-suffused environment with ready access to an abundance of information and collaborative and social-networking tools. Leveraging

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technology and new learning environments made possible through innovations in information and communication technology will be critical to develop the collaborative culture of problem solving needed for the schools of the future.

Visit almost any US school, you will still see the "700–900 square-foot classroom, superbly designed for a teacher to stand in front of a class of thirty students in neat rows, listening, taking notes, and doing worksheets" (Pearlman 2010, p.117). Even though today's classrooms have been equipped with many educational technology tools such as interactive whiteboards and computers, the vast majority of teachers are still using traditional teaching approaches (National Educational Association [NEA] 2008). This is surprising since one would intuitively expect that having easy access to the educational technology tools would promote learner-centered approaches to education. However, it has been documented that most teachers use computers to perform administrative tasks such as taking attendance (Becker 2001) or to replicate teacher-centered practices (NEA 2008). Unfortunately, very few teachers allow their students access to use educational technology tools to solve problems, analyze data, do research on the Internet, present information graphically, and participate in distance learning via Internet (US Department of Education 2003).

Billions of dollars have been spent to turn K-12 classrooms into twenty-first-century classrooms. In addition, recent education reforms call on teachers to use technology tools in meaningful ways that enhance student learning. The *National Science Education Standards* call for teachers to engage students in inquiry and to collect, analyze, and share scientific data (NRC 1996). Meaningful use of technology within inquiry-based instruction has been found to enhance student learning (Hug et al. 2005). For example, technology tools such as laboratory probeware allow for real-time data graphing that provides students with immediate feedback and develops students' data interpretation skills (Friedrichsen et al. 2001). Yet, in this era of financial investment and federal directives, most teachers are still not integrating technology into their classrooms. Successful use of technology is still challenging for most teachers since they experience numerous obstacles. These obstacles can be grouped in two basic categories: first-order barriers and second-order barriers (Brickner 1995). First-order barriers include external factors such as access to technology resources, technical support, and time to plan technology-rich lessons. Second-order barriers, on the other hand, include internal factors such as teachers' beliefs about teaching and technology and their openness to integrate technology.

It is often the case that today's schools are equipped with technology tools, and first-order barriers are considered to be less of a barrier to implementing technology-enhanced instruction. However, second-order barriers are a challenge as technology integration as recommended in the science education literature often requires teachers to restructure their belief systems about teaching and learning. Science teachers' personalities, beliefs about the effectiveness of technology on student learning, and pedagogical and content knowledge of the educational technology tools play critical roles in technology integration (Yerrick and Hoving 1999). For example, in a study of a school laptop initiative, Windshitl and Sahl (2002) found that teachers' beliefs directly mediated their use of laptops in their classrooms. For example, one teacher who viewed the laptop as a presentation tool rather than a learning tool ultimately did not encourage students' individual use of laptops in her classroom. Similarly, many schools have participated in interactive whiteboard initiatives to promote interactive whole-group instruction. However, the whiteboard is easily assimilated into science teachers' existing teaching styles and tends to reinforce teacher-centered presentation (Armstrong et al. 2005). Throughout the science education literature, technology integration initiatives utilizing interactive whiteboards, laptops, computer simulations, probeware, etc., make clear that teachers are the critical agents of change.

Windshitl and Sahl (2002) made particular note that laptops, as opposed to fixed desktops, afford the sharing and comparing of ideas among students. They noted that students would "reconfigure themselves into "learning cells" of two or more individuals. They would bring their laptops together to work jointly on a product or to share digital information resources (p. 201)." David, the second author of this chapter, is an advocate of technology-enhanced classroom practices, and he has extended this form of co-production and sharing of knowledge afforded by laptop computers to leverage the power of Web 2.0 technologies as a shared knowledge-building tool.

Social Issues

In addition to incorporating technology to enhance students' science learning, twenty-first-century skills, and personal development as citizens, socio-scientific issues (SSI) (Zeidler et al. 2005) should be incorporated in science programs. SSI are "usually controversial in nature but have the added element of requiring a degree of moral reasoning or the evaluation of ethical concerns in the process of arriving at decisions regarding possible resolution of those issues" (Zeidler and Nichols 2009, p. 49). Classroom discourses around SSI fosters students' argumentation, reasoning, and decision-making skills since students are required to use evidence-based reasoning. As emphasized earlier, these skills are critical for students to acquire in the twenty-first century. Thus, incorporating SSI in contemporary science classrooms is essential.

A Twenty-First-Century Classroom

When you walk into David's 9th grade biology classroom in a high-poverty, urban school with predominantly minority student populations, you will see students working in groups to complete a task, much like in any other science classroom where students solve tasks in groups. However, upon closer inspection you will see

Fig. 16.1 Student volunteer helping update table technology

the 3.5 ft square tables, at which they sit, are quite unusual. Students are looking through tempered glass tabletops at flat-panel computer displays, two computers per four-person table (see Figs. 16.1 and 16.2). This provides not only the traditional, clutter-free workspace on which to place microscopes, posters, soil samples, or plants, but it also provides a world of networked possibilities. Using recycled computer hardware (though new displays) and open source software and efficient network-booting design provided by Ubuntu, a popular version of Linux, David has created an affordable albeit unusual setup.

Knowledge Building

In spite of the growing emphasis within society and the workplace on teaming, collaboration, and participatory learning, schools still adhere to a model of learning which emphasizes individualized acquisition of knowledge (Lemke 2010). The development of both hardware and software as well as the explosion of computer interconnectivity has presented us with the capability of transforming a classroom from a collection of individuals working to learn science to a community of novice

Fig. 16.2 With the support of Web 2.0 capabilities and 3-D models, English Language Learners are able to explore the structure and function of DNA

scientists striving to create science knowledge in the public realm. David's classroom is designed around the theoretical perspective of knowledge building (Scardamalia and Bereiter 2003).

The knowledge creation metaphor subsumes both the participation and acquisition metaphors of learning, sidestepping the battlegrounds between the situated cognition and constructivist camps. Knowledge creation conceptualizes a community of practitioners (Brown et al. 1989) working together to create "knowledge objects." Although these knowledge objects are abstractions (e.g., ideas, questions, concepts), they have many of the properties of physical objects in that they can be constructed, worked upon, and improved. Knowledge creation is situated within the context of post-positivist epistemologies.

Knowledge building is a particular implementation of the knowledge creation paradigm, especially applicable to understanding the work of communities of scientists (Paavola et al. 2004). It is often described as a process of progressive problem solving and advancement beyond one's present limits of competence. Scardamalia and Bereiter (2006) propose six principles of knowledge building: community knowledge advancement, idea improvement, knowledge *of* in contrast to knowledge *about*, discourse rather than argumentation, use of authoritative information, and emergent understanding.

The principle of the community knowledge advancement theme supports the claim that creative knowledge work, which enhances the knowledge of the community rather than just an individual, should take place in classrooms. However, most current educational practices emphasize individual learning rather than advancing the knowledge of the classroom community. The second principle of knowledge building—idea improvement—suggests knowledge advancement is not simply progress toward existing truths; rather it is the improvement of ideas. Students are not expected to "prove" something accepted by authorities, but instead to use these authoritative knowledge sources to improve the knowledge of their community. The third principle builds on the argument that knowledge building is not about the development of factual knowledge (knowledge about) as is traditional focus of classroom instruction and assessment. Knowledge building is the process of developing conceptual understanding of scientific concepts and issues. Another critical principle of the knowledge-building approach is that it favors classroom discourse rather than argumentation. The goal of the knowledge discourse is idea improvement, whereas argumentation places emphasis on "evidence and persuasion" (Scardamalia and Bereiter 2006, p. 102). Furthermore, knowledge building encourages students to become skeptical about the authoritative information which is the fifth principle. Rather than simply accepting information from the Internet or books, students are encouraged to judge the quality of the information.

In his book, Education and Mind in the Knowledge Age, Bereiter makes a distinction between learning and knowledge building (Bereiter 2002):

> [In knowledge building] learning does occur but it is not the main focus of these domains of activity. The primary goal of members of an innovative expert community is not merely to learn something but to solve problems, originate new thoughts and advance communal knowledge.

In other words, people in this community develop, create, understand, and criticize various conceptual artifacts; they don't just (individually) learn something. Advances in technology provide a critical affordance in structuring a classroom for these kinds of knowledge-building interactions. Instant and seamless access to computers, as in David's room, multiplies the potential.

Technology and Knowledge Building

Technology is an invaluable tool for teachers to form knowledge-building communities in the classroom. Knowledge building in a classroom has an interesting relationship with computer technology: without particular computer applications, knowledge building is unlikely on a long-term basis (Scardamalia and Bereiter 2006). Two well-known web-based knowledge-building solutions for classrooms include the proprietary Knowledge Forum and the open source Future Learning Environment (currently version 4 FLE4). David used FLE3 for three years and is now in his second year of using FLE4. Versions of FLE up through version 3 contain a suite of tools for communities of students to collectively and effectively build knowledge. FLE4 is no longer a suite of tools; the developers extracted the critical and most unique component of the software and transferred it to the most popular Internet blogging software, "WordPress." In doing so, they are bringing the potential of this discourse software "to the masses." Both versions of Future Learning Environment were designed and built by a group of education researchers at the Media Lab, University of Art and Design in Helsinki, Finland (for more information, http://en.wikipedia.org/wiki/Fle3).

FLE4 is used by David and other science teachers to develop communities of novice scientists in their classrooms. Through using FLE4, classes strive to answer core scientific questions by searching for and collecting information, developing working theories, and constantly improving these working theories, all toward the goal of answering the big questions developed by the teacher and their community. A critical aspect of FLE4 and knowledge building is *classroom discourse*. The knowledge-building discussions provide meaningful context for student inquiries and also effective strategies for teachers to assess student learning.

FLE4 in Action: Initiating Knowledge Building

The topic of Evolution is an example of a recent unit implemented in David's 9th grade biology classes. Students had recently finished a unit on Mendelian genetics, as well as an introduction to molecular genetics, so they were primed for this challenging topic. Following a pre-assessment of students' current understandings of evolution, David immediately began to intellectually engage his students in the concepts and contexts underpinning this theory. Students examined a newspaper article about new research on the original domestication of dogs, an online reading of the history of corn, and an online simulation of breeding ("biomorphs"). This activity provided a fun and interactive context in which the teacher could assess students understanding of breeding (artificial selection) while teaching important concepts.

The next stage of the evolution unit involved setting up the knowledge-building discourse. Using the online PBS video, "What Darwin Never Knew," David encouraged students to generate questions that were of interest to them as they watched the video. Each class generated between 40 and 80 questions which they organized into five to seven thematic groups. To set up a class knowledge-building discourse, David selected a single student's question from each group and designated it as that group's "big question," representing all questions in that group. These final big questions become the centers of inquiry and knowledge building for each class.

FLE4: Scaffolding Students' Responses

FLE4 looks deceptively simple, starting out as a very short blog post. For example, in Fig. 16.3, the title of the post shows one of the big questions from one class, while the text under the "big question" lists the other student questions within this thematic grouping.

Q3–Mandi, Maritza, Olga: How do scientists know that all [4-limbed land] animals came from an ancient fish?

Posted on April 26, 2011 by dgroos

Desiree — what water animal did we come from?
Martha O — is it a theory that we turned from animals to humans?
Nelly — how do some species form a whole different species?
Keenan — can animals not just evolve features but also habits?
Kaltun, Doneza, Ashley — how does evolution work?
Mandi, Elizabeth — how long does it take for evolution to occur?
Keenan — how did we evolve and from what?
Ladan — if we did come from evolution why don't we look more like other animals besides "monkeys"?

Fig. 16.3 Initiating knowledge building—introducing a "Big Question"

The stage is now set for students to enter into the discussion. During the first online participation, students declare their initial positions by posting comments to the big questions. While threaded commenting systems are common fare on the Internet, FLE4 introduces a clever twist and thereby "scaffolds" a classroom of novice scientists to engage in knowledge building at a level beyond what they could do without it. FLE4 accomplishes this by requiring students to select the intent of their post before creating it. Students must choose between five predefined kinds of posts or "knowledge types." These knowledge types correspond to five different kinds of contributions that expert scientists make as they engage in knowledge building: Problem-Question, My Explanation, Scientific Explanations, Observations of the Process, and Putting it all Together.

For the initial knowledge-building session, David instructs students to use either the "My Explanation" or the "Problem-Question" knowledge types. Figure 16.4 shows another big question (from a 9th grade biology class), while Fig. 16.5 shows two student posts that followed. On the computer screen, My Explanations are a dusty green and Problem-Question posts are yellow, further scaffolding student communications.

The initial dialog, as illustrated in Fig. 16.5, is critical in setting the stage for more advanced learning and the development of scientific explanations. This first step allows students to put forward their ideas, opinions, and explanations; in effect it initiates a personal relationship (in the public realm) between the big question and the student and between the students themselves. These first interactions on FLE4 allow David to view the range of understandings and beliefs on the topic. It also allows him to develop activities for the class that are responsive to student ideas.

The following screen shot is from further down the same thread and shows that Eddy also challenges those who espouse a scientific position (Fig. 16.6).

The teacher's role in facilitating this discussion is complex, just as is teaching in general. The knowledge-building discussion provides a meaningful context for including readings, inquiry activities, direct instruction, simulations, concept mapping, and other instructional activities. While planning is very important in a

Fig. 16.4 Another big question created by the 9th grade class

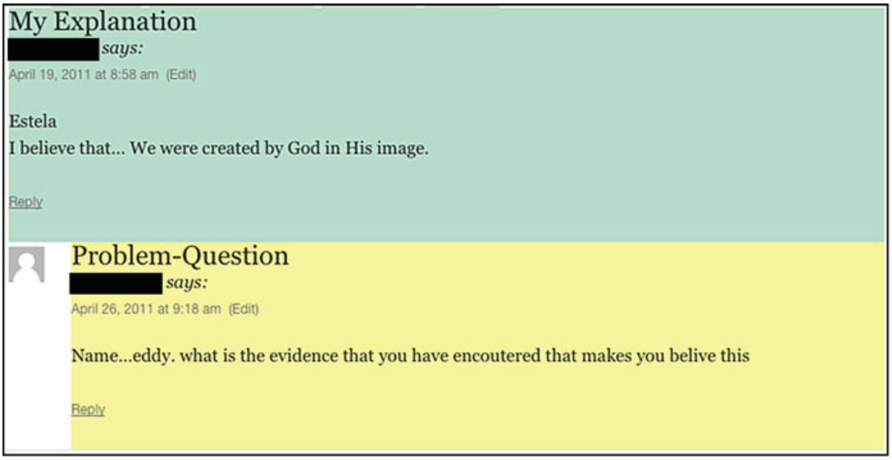


Fig. 16.5 Initiating a knowledge-building discussion

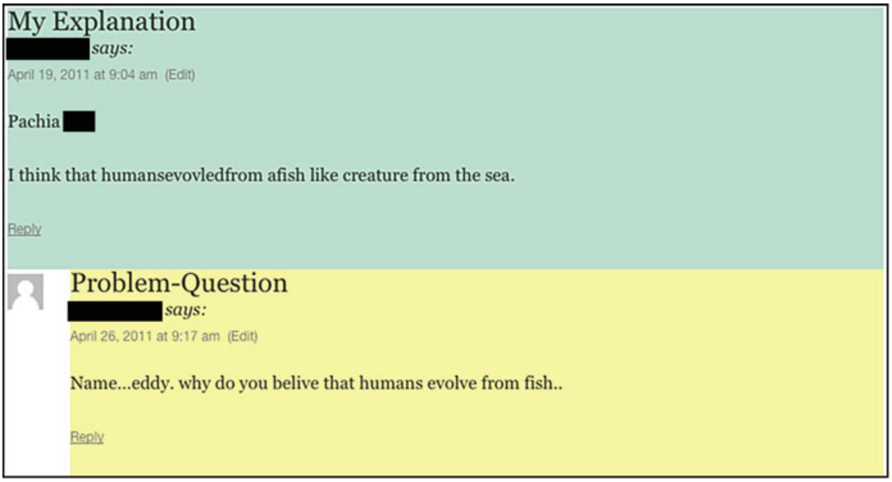


Fig. 16.6 Continuation of a knowledge-building thread

knowledge-building classroom, spontaneity which builds on current student discourse increases student buy-in and motivation in the process. For example, in seeing many students demanding of evidence, David was able to refer to those posts when introducing fossil evidence of evolution.

Advantages of FLE4

A traditional class discussion could of course also help students to build knowledge and is still an important instructional strategy. However, the FLE4 knowledge-building tool provides important benefits. Embedding images and hyperlinks to informative web pages and simulations into the forum allows for many ways and levels of participation, in other words, "differentiation." Also, in general, a more profound depth of thinking occurs when students write as opposed to simply talk. Perhaps most importantly, written discussions provide the community of novice scientists with a searchable archive of student contributions, serving many possible purposes.

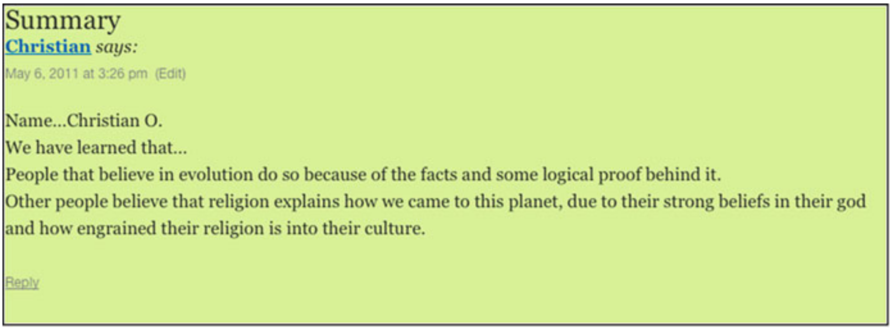
Students are accustomed to constant interaction with peer "friends," multitasking. Upon entering a science classroom, even in collaborative discussions, there still is a preponderance of one person talking and everyone else listening. And it is well known that the teacher occupies the lion's share of discussion space. By providing students with access to a scaffolded discussion tool in the classroom, all students can constantly engage in an active capacity in the community. This active engagement is ideal for ELL students. Students are able to read and reread comments from peers as well as science resource materials, as much as necessary to understand the information. Additionally, they have full opportunity to produce language (in writing), giving them opportunity to edit and reedit their communications. FLE4 provides ELL student the opportunity to practice more difficult and educationally significant academic language.

In a classroom where dialog is only oral, comments come and go and complex, extended conversations are rare. Some conversations require time and mature not over minutes but days. These extended conversations are difficult to maintain in an exclusively oral discussion environment. For example, the Summary post shown in Fig. 16.7 sums up 12 previous posts made over a 10-day time period. The responding Problem-Question post shown in Fig. 16.8 was made just four min after the Summary post and eloquently initiates a deeper round of inquiry.

Assessing Student Learning

Assessing discourses allows teachers to evaluate students' critical thinking skills and abilities in ways that cannot be assessed through standard summative assessments. As noted earlier, student discourse is an essential component of knowledge building and non-coincidentally a central goal for proponents of twenty-first-century skills.

Before examining FLE4 as an assessment tool, it is important to indicate inappropriate assessment approaches. While it would be easy to measure student

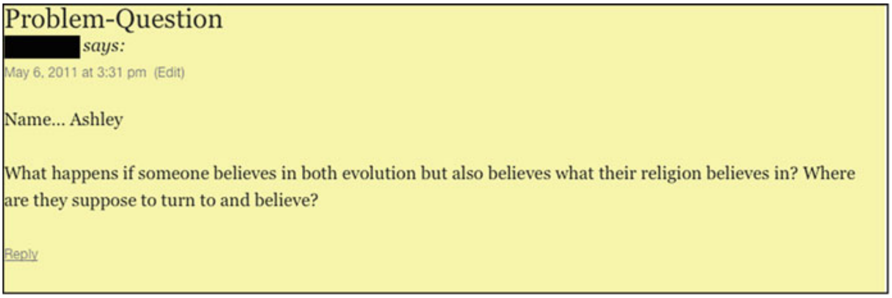


Summary
Christian *says:*
May 6, 2011 at 3:26 pm (Edit)

Name...Christian O.
We have learned that...
People that believe in evolution do so because of the facts and some logical proof behind it.
Other people believe that religion explains how we came to this planet, due to their strong beliefs in their god and how engrained their religion is into their culture.

Reply

Fig. 16.7 A Summary post summarizing the sources of student beliefs about evolution



Problem-Question
[redacted] *says:*
May 6, 2011 at 3:31 pm (Edit)

Name... Ashley

What happens if someone believes in both evolution but also believes what their religion believes in? Where are they suppose to turn to and believe?

Reply

Fig. 16.8 A Problem-Question post launches an ever-deepening inquiry

participation by number of posts as is often done in some systems, this is discouraged. Ostensibly this measures productivity and participation; however, as experienced teachers know, "good students" learn to play the system and would out of habit focus on their post-count at the expense of quality and significance or authenticity of the posts. Similarly, one should be cautious of assessing the correctness of usages of science concepts in a post. While the scientific accuracy of a post can and should inform a teacher's practice, what counts in knowledge building is how someone's idea, whether correct or not, initiates or advances a scientifically significant dialog. Sometimes errors, or in this case scientifically incorrect posts, initiate more meaningful and significant knowledge-improvement dialogs. By placing a premium on correct use of concepts in a dialog, students' sincere participation would not be recognized and instead be discouraged through this process.

Uses of FLE4 in Assessment

FLE4 plays an important role in David's assessment system. The unit of assessment is both the individual and the community as a whole. When assessing the whole community, David analyzes the relationship between individuals and the class, aiming at better understanding of the hard-to-measure synergy a teacher aims for in his/her communities. For individual assessment, David focuses on what American Association for the Advancement of Science (AAAS) refers to as “habits of mind” including Values and Attitudes, Communication Skills, and Critical-Response Skills (AAAS 2009).

To better understand how FLE4 richly informs a teacher of students’ development of Critical-Response skills, we examine student dialog in light of the specific learning goals from AAAS (2009). For example, students should ask and respond to the question “How do you know…” as shown by Eddy in Figs. 16.5 and 16.6. Students are expected to be able to “Buttress their statements with facts found in books, articles, and databases, and identify the sources used and expect others to do the same” and “Seek reasons for believing something rather than just claiming “Everybody knows that…” or “I just know” and discount such claims when made by others.” Eddy’s posts in Figs. 16.5 and 16.6 are pushing for students to provide evidence and rationale for their statements in this early stage of the knowledge-building process.

As the discussion proceeded and students attempted to provide scientific explanations for their positions, it became clear that they were confused and were arguing over whether scientists said we had come from fish or from monkeys. Students also struggled to explain how new species were generated. For example, in Fig. 16.9, a student is responding to the big question “How did the animals in the Galapagos become different from the animals in the other parts of the world?” with a scientific explanation that reveals an alternative conception.

FLE4 thus provides a powerful formative assessment tool that allowed David to see that his students were unable to meet his learning goals related to critical-response skills and evolution content. David was able to provide a just-in-time lesson to assist students with their questions. The second and third posts in Fig. 16.9 follow David’s mini-lesson. The third post shows improved understanding as it integrates the information that the Galapagos Islands is not just one island but a collection of 13 islands with different characteristics. This knowledge artifact is an important resource and a source of pride for the community. There is something special in that it was created by a student in the class, not a video, teacher, or book. As others recognize the significance of her contribution, her status in the knowledge-building environment will rise. We note that all three of these posts failed to include a reference to their sources; this illustrates the students’ lack of sophistication with this knowledge type.

FLE4 provides students with an opportunity to engage in sincere dialogs, as initiated in Fig. 16.6 where Pachia states her belief that we came from a fish-like creature but at that time is unable to provide evidence. In the continuation of this thread (Fig. 16.10), Pachia responds and Valeria echoes her sentiment expressing doubt in the authority of scientists. However, eight minutes later, Valeria qualifies her statement with the acknowledgement that they do know about adaptation changing over time in a population because *they* did an activity with “sporks and spoons.” Comments like this provide teachers with knowledge about students’ beliefs on the nature of knowledge, as well as the effectiveness of their instructional sequences. Finally, we note here that students are still learning how to use the knowledge types

Scientific Explanation

[redacted] says:

May 6, 2011 at 9:08 am (Edit)

Estela,
Because of the geographical isolation animals mix with other species and create a new one.

Reply

Scientific Explanation

[redacted] says:

May 6, 2011 at 9:13 am (Edit)

Name...Pachia [redacted]
The animals from the Galapagos differ from other animals in the world because their habitat or environmant was on an island which allows them to only have limited resources, preys, predators, and plants. They differ because of Geographic Isolation, different environments change species and make them become more adapted to the habitat they currently live on.

Reply

Scientific Explanation

[redacted] says:

May 6, 2011 at 9:23 am (Edit)

Name...Pachia
In addition there are multiple islands which also allows only limited resources, preys, predators, and plants. Each of these islands are very different even though they are in the same region.

Reply

Fig. 16.9 Scientific knowledge type used in dialog

and that Valeria's final post is an "Observation of Process" not a "Scientific Explanation," although it is interesting following the progression of this thread that students assign themselves the voice of a scientist in selecting this knowledge type.

Final Remarks on FLE4

Online discussions are known to be an effective tool for students to develop and experiment with their classroom identity or persona. This experimentation is especially active toward the start of the school year and generally includes instances of bullying and limit testing. These aspects of a discussion are an important indicator of the health of a classroom and an opportunity to improve it. These challenges are publically made and must be addressed. Since only the teacher can delete a comment in the FLE4 discussion, students in David's class who make antisocial comments quickly learn that this kind of interaction can't be hidden and won't be tolerated.

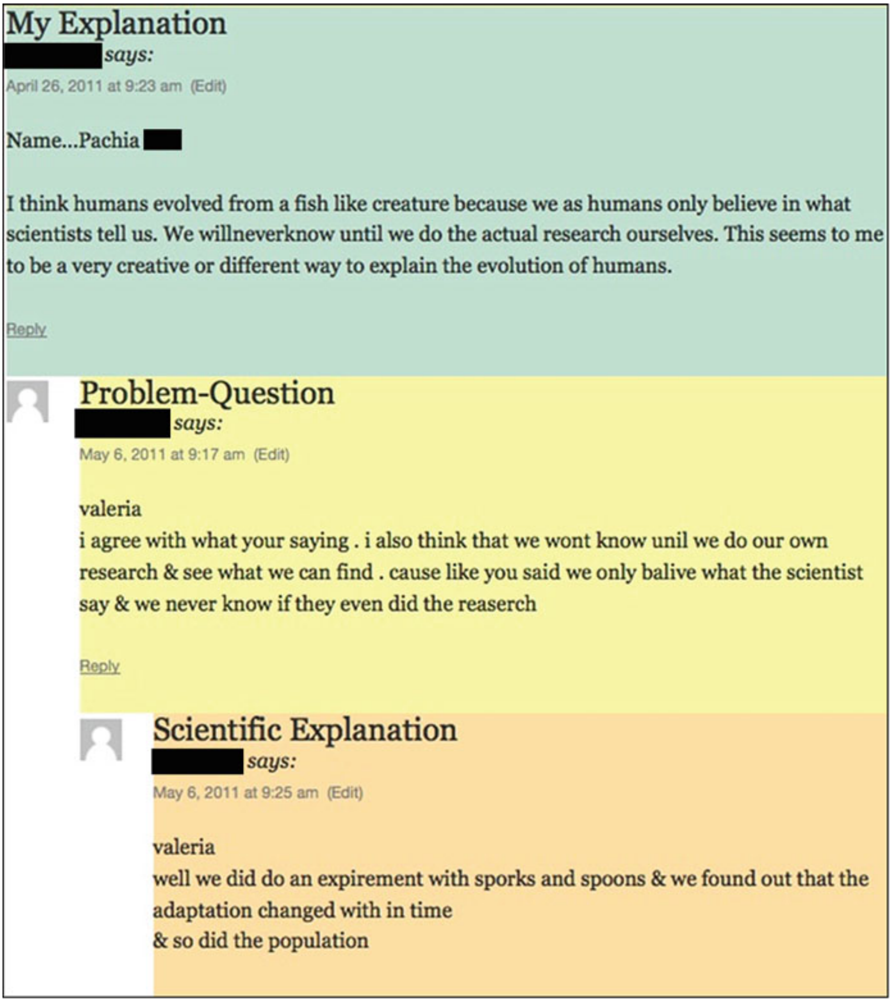


Fig. 16.10 Continuation of thread shown in Fig. 16.6. Though error in knowledge type, Valeria shows learning

Although David sets limits through FLE4, he constantly uses it to highlight pro-social comments, encouraging the growth of a positive classroom environment.

In many ways nonetheless, this experimentation with identities continues throughout the year. For example, it is interesting to watch students “try on” a “scientist’s voice” using the specific vocabulary and formal sentence structure of science, something many students might never be bold enough to do if the only classroom medium for discussion were oral. Also, these students might never have been willing to try this foreign voice, this voice of a scientist, if their familiar voice had not been fully accepted in the community of scientists. FLE4 provides a medium though which this voice can be heard and developed.

Conclusion

In the twenty-first century, we have witnessed the rapid development of educational technology tools and reform efforts to transform classrooms to technology-enhanced learning environments. What have we learned from the educational reforms on technology integration? Successful technology integration is not a quick and easy process. While there are some "exemplary teachers," such as David, who can use technology effectively, it is well known that "individual teachers cannot bring about a sustainable school-wide change… and individual schools cannot bring about system-wide change" (Law et al. 2008, p. 25). Change cannot occur without holistic, systematic reform. A systematic reform deals with various issues at different levels (e.g., school level and national level) and involves a range of problems simultaneously. When systematic reform concerns the use of technology, it is critical to consider conditions at the teacher level (such as knowledge, confidence, and level of access), school level (such as technology infrastructure), state level (such as funding), and national level (such as policy makers).

In most current reforms, technology is presented as a simple solution to improve education. "Technology is not a panacea for educational reform, but it can be a significant catalyst for change" (Sandholtz et al. 1997, p. 186). Technology is a powerful tool to support student-centered educational approaches that are responsive to calls, such as twenty-first-century learning, to develop critical thinking. Particularly, as applied in David's classroom, technology has great potential to apply knowledge-building pedagogy which "involves students not only developing knowledge-building competencies, but also coming to see themselves and their work as part of the civilization-wide effort to advance knowledge frontiers" (Scardamalia and Bereiter 2006, pp. 97–98).

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Chapter 17
GameWerks Camp: Using Gaming to Foster Learning by Design

Lucas John Jensen, Gregory M. Francom, Deborah J. Tippins, and Michael Orey

GameWerks is a video game camp for middle and high school children that are interested in learning more about video game design. Though it is a video game camp, it must be noted that campers do more than just sit around and play video games all day. Admittedly, the camp includes frequent video game breaks, but GameWerks is more than that. It is a project-based experience with the ultimate goal being a "game pitch." GameWerks participants design a game from the ground up and pitch it to a panel of video game industry experts. Each game proposal has, at its core, an educational content domain, usually in the sciences. The most highly ranked proposals are those that integrate content knowledge into the narrative of the game. Here, we discuss the rationale for developing the video game camp and explain how it works. We will also discuss some of the research on the relationship between video games and science education and provide several examples of the participants' game designs.

GameWerks was conceived in 2009 as a joint effort between the Learning, Design, and Technology program; the Continuing Education department of the University of Georgia; and the MoWerks e-learning company. GameWerks uses

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computer and video game design activities to motivate children to learn twenty-first-century skills. From our perspective, educational success does not mean filling students' heads with isolated bits of information that can be measured on standardized tests. These facts are irrelevant if not seen as part of some larger context. In contrast to the economic metaphors that drive many educational reforms, GameWerks camp redefines traditional notions of twenty-first-century skills by providing a space for middle-school learners to uncover new talents, ask unique questions, see connections between concepts, and reinterpret their own lives. Camp participants learn to solve problems, work in groups, design software, and understand a plethora of ethical and social issues associated with game development. Perhaps the most powerful aspect of the GameWerks video game camp model is its ability to harness youth passion for video games and provide young people a relevant context for understanding concepts across different educational fields. The participants develop analytical skills by looking critically at games through the lens of a game designer. Participants learn to identify components of game design, development, and production. The campers learn to take responsibility for their own learning and to take criticism as well. Finally—and rather hopefully—they discover that games can be used to teach and learn about social issues, tackling "serious" subjects with as much aplomb as they can surviving the zombie apocalypse. GameWerks camp participants discover ways to create and use media to inform and instruct people about problems and potential solutions in entertaining ways. In this way, they become responsible media designers and developers, rather than passive media consumers. They are empowered to share information, brainstorm, and ask questions of other students and educators.

Why Video Games?

Despite their relative lack of media coverage in relation to media such as movies, television, and music, video games are mainstream entertainment—and big business, to boot! No longer the sole province of sugar-addled adolescents or basement-dwelling loners with Cheeto™-stained fingers (although such stereotypes exist for a reason!), the video game industry now appeals to a broad range of people. In 2010, the US video game industry generated $10.5 billion (B) in revenue (The Entertainment Software Association 2010). The video game industry added $4.9 B to the GDP in 2009 and grew at a rate of 16.7 % from 2005 to 2008, a period in which the US economy only grew 2.8 % as a whole (Siwek 2010).

More importantly, it is clear that video games play an increasing role in the lives of our children (Gee 2003). A recent report found that in 2009, children ages 8–18 played video games an average of 1 hour and 13 minutes per day, up nearly 24 min from 5 years ago (Rideout et al. 2010). Video games have motivational and cognitive benefits for players. Research indicates that play itself is important to a child's development (Rieber 1996). Research on the benefits of gaming in educational settings in terms of leaning outcomes is mixed (Schrader et al. 2010). However, the act of designing a game can be a powerful educational exercise (Kafai 1994).

Edutainment Versus Serious Games

For years, games with educational content have been packaged as so-called edutainment. Most of the games designed to focus on education have obvious educational-sounding names, such as Genomics Design Lab, Math Blasters, and Gizmos and Gadgets, and feature educational content shoehorned into existing game paradigms. Math Blaster, for example, is a shooting game wherein the player shoots numbered targets with the appropriate answer to a simple math problem. It has more to do with drill and rote practice than with deep engagement with mathematical content—but the Blaster series has endured for two decades and remains popular with schools and parents (Rice 2007). Presently, it is fair to say that “edutainment”—save for the occasional Carmen Sandiego game or permutation of the Oregon Trail—has been a failure from a critical and educational standpoint in part because the educational content has been superimposed to the detriment of narrative and an immersive experience (Zyda 2005). Edutainment games typically present instructional content in either an obvious manner or in a format too subordinate to the game design (Zyda 2005).

The term “serious games” has garnered increasing cache in the past decade. “Serious games” address complex issues and systems and look beyond the “skill and drill” edutainment formula while retaining their narrative and entertainment appeal (Zyda 2005). Serious games have the potential to be used to educate about public policy or environmental issues (Annetta 2008).

GameWerks seeks to break from the edutainment of the past and inspire camper participants—today’s gameplayers and (hopefully!) game designers of the future—to focus their gaming interests in a “serious” direction. During the GameWerks camp, we encourage nascent game designers to choose complex topics and constructs as foundations and ask them to weave their game narratives around these, rather than pursue a facile, additive approach. Furthermore, we believe that these Generation R game designers can create games featuring social responsibility, environmental activism, and serious concerns. We expect campers to come away with the notion that video games can address more than just fighting ninjas. We hope that these nascent Generation R game designers come away with the sense that gaming can address complex issues and ill-structured real-world problems and still be fun. We also hope that as they learn aspects of game design, they are able to more critically examine the content, characters, structure, and message of the games that they play.

The Objectives of GameWerks

We live in a media-propelled landscape where youth are confronted daily with a world of computers and video games amidst this world; the GameWerks experience has four main goals:

1. Reimagining and building twenty-first-century learning skills
2. Situating learning in an authentic context of the game industry
3. Constructing domain knowledge
4. Having fun!

One goal of GameWerks is to help the camp participants grow in the domain of the so-called twenty-first-century learning skills and, if needed, to navigate a media-rich landscape. The Partnership for 21st Century Skills defines four "C's" as being essential to a twenty-first-century education: creativity, critical thinking, communication, and collaboration (The Partnership for 21st Century Skills 2009). GameWerks aims to provide camp participants with all four of these skills through teamwork and game design experience activities. The GameWerks model takes a holistic, project-based approach: camp participants must work toward their "pitch" as teams while managing their time and organizing their groups (Han and Bhattacharya 2001). Along the way, they gain experience in public speaking, writing, research, reading, listening, and game design. The camp participants work together on diverse teams and organize and initiate their projects largely on their own, though each team has an appointed camp counselor, called a "team leader." These "team leaders" act more as facilitators than teachers, encouraging the campers and keeping them organized, but staying out of the way of the group's creative flow. Each group is involved in project management, with guidance from its team leader. GameWerks camp participants are expected to be flexible, adaptive, motivated, and self-directed. Crucial to this process is effective information literacy, which is particularly valuable in this age of information glut. The camp participants must do research for the content area of their games and obtain that information from reliable sources.

GameWerks Participants

In 2009 and 2010, 37 GameWerks participants ranged in age from 11 to 18 years. Most of participants were male (only one female attended GameWerks each year). Grade levels for participants ranged from 6th grade to 12th grade. Twenty campers participated in 2009, and 17 campers participated in 2010. In 2009, about 75 % of the participants considered themselves white; the remainder were Hispanic, African-American, Asian, or Italian. In 2010, 63 % of participants self-identified as white; the remaining 37 % self-reported as African-American. Though no data were collected on the economic backgrounds of the camp participants, five scholarships were awarded each year, based on socioeconomic need.

The GameWerks Experience

GameWerks camp participants are recruited via the university's Continuing Education department. So far, recruiting enough participants to fill the one-week camp has been easy. Due to logistical constraints, the number of camp participants has been held to 17–20. Upon arriving on the first day, the campers are given an orientation so that they know what to expect from the camp. They are told that they are going to design games and meet industry experts and that they are also going to have to work and dream together and accept constructive criticism.

During this initial meeting, we reveal the nature of the project they will create: a video game "pitch" to a panel of industry experts. This pitch is explained as a 10-min presentation during which the team will try to convince the panel and audience on the idea for their game. The campers need to discuss every aspect of their proposed game: game design, gameplay, target demographic, potential development costs, and educational content. Each pitch is accompanied by a five-page "high-level concept" document generated by the team that provides detail about the gameplay and the game's concept art.

Immediately after revealing this, we drop another bombshell on the campers: the games must have educational content. Surprisingly, no one has ever bolted for the door, but there have been groans and murmurs. The first rule of GameWerks camp is "have fun," and we remind the campers that their game design must be fun, first and foremost—not a slave to its instructional content. They usually remain skeptical, but the counselors have been surprised by how easily they accept this aspect of the project.

Shortly thereafter, camp participants are divided into teams. They choose silly team names such as "Exploding Pirates," "Space Gas," and "M&M Ninjas." For the next several hours, the teams brainstorm game ideas and choose a content area for their games' educational content. We found that using themes seems to help youth begin to brainstorm. During the 2009 camp, the campers were instructed to choose a Southeastern social or environmental problem. In 2010, their content areas were aligned with a Disney/SIGGRAPH learning contest (see www.learningchallenge2010.com). The eight domains of this contest included broad topics, such as the Solar System, the rock cycle, ecosystems, and coordinate geometry. Even so, giving the teams freedom to choose what they do with their game is motivational and helps mitigate some of the "educational game" ambush effect.

Each day of the GameWerks camp follows a similar pattern. The campers are given an orientation at the beginning of the day to let them know how the day will proceed and what they should aim to accomplish by the end of the day. On the first two days of camp, teams develop their concepts, stories, gameplay ideas, and concept art designs. The next two days are spent refining gameplay and game design and on generating the items necessary for the "pitch." Throughout the day, there are lectures and discussions by guest speakers to break up the group work. At the end of the day, each team shares their ideas with the team leader/counselors. To borrow a phrase from the campers, these mini-pitch sessions are often quite "brutal" in their opinion. But the authentic criticism helps the campers get used to the criticism that they will eventually receive on the final pitch and helps them tighten and improve their projects through formative evaluation. The team members must learn to answer questions like "so what?", "why is this fun?", and "how can someone learn from this?" In this way, campers begin to have a voice in their own assessment through the opportunity to show what they can do.

During the camp, several periods are devoted to recess and hour-long video game sessions dubbed "research" by the GameWerks staff—campers enjoy telling their parents that they are conducting "research." While this time could be construed as playtime, the sessions allow the campers to go through a debriefing wherein they gather in a focus group to discuss different aspects of the game that they observed.

One day, they might discuss the graphics of the games they played; the next, they might focus on the game's gameplay. This research time encourages the campers to think analytically and critically about video games.

On the final day, the campers gather in an auditorium for their final pitches to a panel of industry experts. Over the past two years, the panel has included game producers, artists, engineers, and designers, as well as people aligned with educational research. Each team prepares a 10-min presentation and a "high-level concept" document that goes into more detail. The idea is to make the experience commensurate with an actual industry pitch meeting. The campers must include such information as concept art, sample music, storyboards, gameplay dynamics, story, target demographics, and budgets. Basically, they are making a case for the need to make the game of their dreams. Because of this, they come armed with justifications for all their decisions, and the industry panelists are instructed to "pull no punches." The critiques are often harsh, and it is not uncommon to hear gasps of dismay from anxious and concerned parents in the audience. So far, all teams have acquitted themselves well, since they have prepared for the process for the entire week. Some of the participants even engage in heated debates with the panelists while defending their design decisions.

This part of the process is essential because it models an authentic experience and gives the campers consequences for their choices. They know that if they are lazy or do not do good research, they will get called on it. Further, the ability to accept criticism without knee-jerk defensiveness is an important value to instill in adolescents. Certainly, their parents and guardians are surprised (and pleased) at their ability to stand before a room of peers, adults, and industry representatives and articulately and passionately explain their ideas in convincing ways. This is a common parental refrain: "I wish that he/she was like this at home!"

Game Design Examples

To understand what the campers accomplish during GameWerks camp in a qualitative fashion, we share three exemplars of game design. The campers had latitude as to which content area their games would cover. Although the campers were asked to design educational (serious) games, the expected resistance to this concept was surprisingly low.

Also worth noting is the fact that the games described here are the ones that most fully integrated educational content into the design and addressed relevant social issues with the most rigor. While some groups added educational content into their game design ideas, the examples we present here highlight efforts of teams that built their games from the ground up using their chosen content area. Each of these three projects was well received by the panel of industry experts during the groups' final presentations. A key factor for their relative success, as noted by the judges, was the fact that the academic side of the game was better integrated into the overall experience. Games that used an "additive approach" to the serious content were met with a negative response from the industry panelists, who noted that the games felt "school-y" or "too educational" and that the educational content was "too obvious" or "tacked on."

Over the course of the two GameWerks camps, all teams but one selected science-related concepts and topics as the basis for their games' foundational content. Team members were free to choose from other content areas, such as mathematics, music, and social studies, but only one group chose to do so. Even in that instance, the game was tangentially related to science content, as it concerned mass hysteria following a global pandemic. The researchers did not ask why campers chose the content areas they did, but we plan to do so in the future.

Herbicide

The *Herbicide* team decided to tackle one of the Southeastern United States' most pernicious "enemies": kudzu. Originally planted in 1876 to combat erosion, this Asian invasive—known to some "as the vine that ate the South"—is one of the most common sights in the rural Southeast, fairly covering most open, undeveloped land with its green leaves in the summer (Emery 2007). It recedes to an impenetrable, dry, tangled mass of vines in the winter and is resistant to a number of herbicides, making it extremely difficult to eradicate.

The team behind *Herbicide* decided that this plant would be the perfect villain for the game's hero, Jacob Arrowroot, a humble Floridian farmer separated from his family by this creeping green menace. The game is set in the near future, as a frustrated US government decides to irradiate kudzu just as the plant has reached the Great Lakes. But the plan goes awry, causing the kudzu to grow sentient and turn into giant roving kudzu monsters, which attack people with vines and man-eating flowers. Over the course of *Herbicide*, Jacob attempts to reunite with his family using only his survival instincts, garden tools, flamethrowers, and a tractor outfitted with chain saws.

The plot is a *little* far flung, but this team, made up of 11 and 12-year-olds, threw themselves into the research, immersing themselves in kudzu facts. Every ten minutes, one of the team members would rattle off another kudzu tidbit: "Did you know that kudzu could be used as a biofuel?" "Did you know that kudzu can have a root ball that weighs 20 pounds and is the size of a volleyball?" "Did you know that kudzu grows at a rate of a foot a day?" The Internet research the team members did was impressive, and this made even more so by the fact that they used reputable sources such as the *New York Times* and *Discovery News*, where they came upon a biofuel story (Marshall 2008).

The campers pitched this action-adventure game as a cross between two notable action titles: *Shadow of the Colossus* and *Gears of War*. One of the most creative presentations at GameWerks 2009, they storyboarded an action sequence, created box art, and even had music to go along with it. The industry panelists were effusive in their praise for the pitch and the seamless integration of the instructional content into the whole. The only problem encountered was from a Northern panelist who had never heard of or seen kudzu in the wild and thus had no frame of reference as to its ecosystem-devouring capabilities.

Perhaps even more impressive was the team's project management acumen. With little guidance from their team leader, they identified roles on the first day: an artist, a composer, a researcher, a writer, and a team leader. The team met every benchmark set forth by the camp and spent the last two days of the camp refining their concept and presentation rather than scrambling to pull it all together.

The real success of this pitch was that it existed as more than an assemblage of kudzu facts. The game concept had a strong narrative, and the campers created a descriptive, intriguing universe. Further, the *Herbicide* crew gained an awareness of problems with invasive species and how they can disrupt local ecosystems, as well as some of the resources that plants—in this case, kudzu—can provide. Jacob Arrowroot used kudzu for biofuel to power his tractor and to make healing salves to heal his wounds. He also ate the kudzu that he killed. Finally, the methods for controlling kudzu in the game were similar to authentic methods of kudzu control, minus the hulking, murderous humanoid plants, of course.

Fire Ant War

Another GameWerks team decided to tackle the problem of invasive species—in this case, insects—in its Real-Time Strategy game, *Fire Ant War*. Real-Time Strategy (RTS) games are typically war games wherein the user plays a master strategist or godlike character who controls his/her minions and units in real time from a top-down view. RTS's have a heavy emphasis on resource allocation, and combat tactics such as flanking and surprise attacks are played out in real time. Boiled down to its essence, every RTS is a permutation of this theme: "Harvest, build, destroy" (Geryk 2001). Economies of scale are a huge theme in an RTS, as is unit balancing: more powerful units usually cost more than small units, and they are often slower than their weaker, fleeter, cheaper counterparts. RTS players must balance their armies and make tough choices: assemble a slow, lumbering army of juggernauts or rely on weak, fast units in hordes? All the while, the player is harvesting resources to pay for these units and trying to keep his/her home base from being destroyed. Units are upgraded and buildings are constructed. Needless to say, there is a *lot* going on, and the player must constantly multitask resource management and tactics to be successful. More associated with PC gaming than console gaming, popular titles in this genre include the *Command & Conquer* series, *StarCraft*, and *Baldur's Gate* (Geryk 2001).

In the proposed *Fire Ant War*, the user controls a colony of Southern black ants, fighting off a menacing horde of invasive fire ant species—and that is pretty much it for the narrative. The gamers flirted with giving the ants anthropomorphic features, such as names, but decided against it. One team member remarked, "We'd rather keep it closer to real life." And indeed they did, minus some gameplay contrivances here and there. The team did voluminous research on ant species and insect behavior and wove their accumulated knowledge into the fabric of the game.

In a typical level, the black ants must repel an approaching fire ant horde using their own armies of black ants. It seems simple at first, but the game design is actually quite complex. Different resources are scattered across each level: food, pollen, and mud, all of them waiting to be gathered by the gatherer ants. There are soldier ants for fighting, working ants for gathering and building, and a queen for birthing new units, which are carried around via egg-carrying units. The player controls not only the top-down view of the black ants' tactics and resource gathering but oversees the construction and operation of the colony, as well. Additions to the colony bring benefits: for example, bigger chambers can hold more eggs and resources. Such additions come at the cost of food, and the player must explore further into dangerous territory to keep his/her colony fed and happy. How does the player control the ants? By drawing pheromone trails for other ants to follow…in single-file lines, of course. If something breaks the pheromone trail, the ants scatter, lost and helpless. It is a wonderful detail that demonstrates how much the group cared about making the game characters congruent to real life.

Now, as anyone who has ever been stung by a fire ant can attest, they are much more painful than an average black ant. The participants knew this too and worked this aspect into the game. The black ants can defeat the fire ants only with the help of other species. The black ants must bribe other insects to help them in their quest to repel the fire ants. Wasps can be induced to serve as attack units; they must be bribed to do so with mud. Bees are kamikaze units that die after stinging once, but they can attack in great swarms. They are bribed with pollen. Spiders can be brought in to ensnare the fire ants, but the player then must sacrifice a few of his/her own ants in the process. The game also features millipedes as shields, centipedes as tanks, and pill bugs as boulders that can be pushed at the fire ant hordes. Cockroaches act as sabotage units, destroying the other team's food supplies. Perhaps the most creative aspect was the deployment of phorid flies, assassin units that would lay an egg in inside the fire ant's head; the resulting larva destroyed the ant from the inside, resulting in momentary control of the enemy ant.

Each "helper" unit has strengths and weakness and a cost for their participation in the struggle. The other bugs don't like these invaders any more than the black ants, but these alliances are tenuous. If deployed too close to your own colony, they will attack you instead of the fire ants. Also, these bugs don't like each other very much, so the player must be very careful in invoking them. Bees and wasps on the same team, for example, would be a bad idea.

This team was rightly praised by the industry panel for their creativity. In fact, one of the industry panelists, a game producer in Austin, Texas, remarked that he would fund this project if he had the money. Most of them agreed that this was the game that seemed the most like an actual game, and it speaks well to the diligence the group devoted to the well-researched details as well as the gameplay. They had a strong collaborative dynamic throughout the camp, more democratic than the *Herbicide* team but just as effective. Every member of this team functioned as an equal partner in research, ideas, and presentation.

Operation: Petra

Operation: Petra was developed by a 2010 GameWerks team that chose to use the rock cycle as its foundational educational content. Of the three examples presented here, this project most integrated learning content into the game design. The team took the rock cycle and developed their game on top of it.

Much like *Herbicide* and most other GameWerks games, the plot is not a model of verisimilitude, though it does have origins in scientific fact. Still, *Operation: Petra* gains points for creativity. The gist of it is this: under Yellowstone National Park is a super volcano. The volcano is on the brink of eruption after a series of seismic disturbances and threatens to destroy all life on earth in a firestorm of lava and ash. An intrepid team of government scientists descends beneath the earth's crust to investigate the situation. They find an army of sentient subterranean rock monsters bent on wreaking havoc on this supervolcano. Armed with various rock-busting robots, the government initiates *Operation: Petra* to take on these hard-headed opponents.

Operation: Petra is a Real-Time Strategy game, much like *Fire Ant War*. The scientists must build bases and gather resources to build robots. The player strategically uses these robots to attack the hordes of rock monsters. There are three basic types of rock monster: sedimentary, igneous, and metamorphic. Within each group are various enemy unit types—sand, diamond, obsidian, pumice, and diamond beasts. These evil rock creatures have anthropomorphic characteristics, like the Basaltalisk, who resembles the mythical Basilisk lizard. The team got carried away with units and created dozens of them, each with slightly different weaknesses and strengths. Enemy strength is determined partially by its placement on the hardness scale. A diamond creature would be much stronger than a limestone creature, for example.

Each robot type has strengths and weaknesses against each stage of the rock cycle. Robots that shoot water are good against sedimentary rock monsters because they erode them. Water robots also are good at cooling down lava/magma monsters, so that they might be defeated. There is a time machine robot that speeds up time to erode sedimentary rock monsters. An ice robot breaks apart brittle, cooled igneous rocks from the inside through their expanding ice. A laser robot is the only thing that can destroy diamonds and carborundum. Of course, there are drill and jackhammer robots that pummel the rocks, as well. As with the enemies, the group devised many different robots to destroy the rock monsters.

As the scientists descend through the earth's crust, they find that the monsters get tougher and tougher. This is because the heat and pressure have increased, resulting in harder rocks. The *Operation: Petra* team used this clever and scientifically astute idea to explain increased difficulty as the game goes on. At first, the robots fight primarily weaker sedimentary units, but as heat and pressure increase, so does the robustness of the enemies. Shale becomes slate, coal becomes diamonds, and so on.

This team did much research on minerals, rocks, the rock cycle, the hardness scale, and plate tectonics. If there was an Achilles heel for this team, it was its overabundance of ideas. Right up until the very end, they were creating new robots and rock monsters—but it is difficult to fault enthusiasm! The group's interpersonal dynamics were sloppier than the others, but their ideas won out over looser project management. This game design was the most enthusiastically received of the 2010 camp. Almost all panel members remarked at how seamlessly the educational component was integrated into the game, and all agreed that the game seemed like it would be fun to play.

Some Observations, Challenges, and Implications for Policy and Reform

Participants come to GameWerks camp with differing skills and abilities. Media literacy is a key area of needed improvement, according to the team leaders' observations. Media literacy encompasses skills related to analyzing media for messages, addressing the needs of the intended audience, understanding the legal and ethical issues surrounding access and use of media, and creating media products. According to team leaders' observations, the correct use of intellectual property was a key issue within media literacy. Few of the campers came to GameWerks with any understanding of the importance of using original work and giving credit to authors. Additionally, issues with regard to media audience played a part in the campers' lack of media literacy. One team leader reported that team members took awhile to view video games from other people's points of view in addition to their own. Another team leader indicated that their team members struggled to understand the concept of making a video game for an intended audience. However, the lack of skills related to these aspects of media literacy was balanced with higher activity in the area of media creation. Team leaders felt that media was of a very high quality overall.

The two main areas in which camp participants excelled were ICT literacy and cross-cultural skills. ICT literacy encompasses skills related to the effective application of technology for researching, organizing, evaluating, and communicating information. Social and cross-cultural skills include interacting effectively with others who are different and working effectively in the social aspects of teamwork.

Team leaders commented that groups seemed to be efficient with the use of ICT technology in finding and creating media for their video game designs. Findings from an evaluation survey indicated that all campers have access to video game and other technologies and they all spent a lot of time with these technologies. This may have had an impact on participants' effective use of ICT. Campers even reported going so far as to mod or hack video games using tools provided with the game. Social and cross-cultural skills played an important role at GameWerks camp, because participants were required to negotiate differing opinions as they created and updated video game designs. Many aspects of GameWerks camp requires campers to rethink and improve upon their designs, and social and cross-cultural skills were used to make these changes within a team setting. Team leader observations indicated that campers learned when it was appropriate to speak and when it was more appropriate to listen. Participants also seemed to conduct themselves in a professional manner, and the structured time and activities at GameWerks facilitated this conduct. Most teams had members from different cultures, and team leader observations indicated that despite differences in opinions, backgrounds, and so forth, the groups seemed to work well toward a common goal. This observation supports previous research that indicates that student engagement is influenced by learning task structures providing cooperative learning and teamwork (Ames 1992).

Camp participants also learned how to deal with constructive criticism over the course of the week through the “pitch” meetings. A number of parents remarked that they could not believe that their children stood up there in the presentation and took tough criticism without getting emotional or defensive.

Results from a GameWerks survey indicate that, unsurprisingly, participants at GameWerks expressed overwhelming interest in learning more about video game design and development. Preference for learning more common skills associated with video game design (art/animation and game design) was expressed over other skills that may seem peripheral to core game development activities (such as testing, managing, and level design). However, these expressed interests might stem simply from participants’ lack of knowledge about game design activities/teams and the realities of the game development process. Additionally, camp participants indicated a preference to learn programming and actual game development at GameWerks. Because game design and development activities are characterized as being time-intensive and costly, developing a finished game during a short period of time (such as a week or two) is not possible.

The gender disparity among camp participants has been disappointing. According to the Entertainment Software Association, 40 % of gamers are women, and yet each GameWerks camp contained only one female participant (The Entertainment Software Association 2010). African-American participation increased dramatically in 2010, and campers from a more diverse socioeconomic status background attended in 2010, perhaps because of the increased amount of scholarships. However, recruiting women to the camp has been a struggle, and the boys often display stereotyped notions of gender (e.g., aggression and competition) in their discussions of games.

In terms of policy and reform, much research in education fails to take into account the ways that media technologies, including video games, affect our students. One of the biggest challenges is that research can be difficult to conduct in the camp because much of the available time is spent facilitating the campers’ activities. Team leaders and counselors are participant researchers, and the first order of business is to provide for a smooth camp experience. Frankly, it is sometimes difficult not to get swept up in the excitement of the process. Nevertheless, we believe it is imperative for educational researchers to uncover the hidden effects of the technologies of the contemporary era.

Finally, it is clear that GameWerks capitalizes on student interest to provide a highly motivating experience for participants. Observations indicate that campers are highly motivated to work on game designs and learn about the academic subjects that are required to be a part of their games. Since there is no formal instruction on these topics at GameWerks, participants use self-directed (shared) learning methods to understand and integrate these topics into games. In this sense, our experience with GameWerks camp leads us to suggest the importance of reexamining what constitutes traditional ways of knowing. The final GameWerks projects reveal a complex knowledge of such diverse subjects as ant colonies, plant growth rates, and rock cycles. This knowledge reflects participants' ability and willingness to self-direct learning in order to create a useful video game design. In fact, the exemplary projects noted above integrated their educational content area more than the other groups. One student indicated his level of motivation to *do* video game design activities, decreased his desire to *play* video games, even commenting, "[we spent] too much time actually playing video games…I would have liked to spend more time working on my own ideas with my group." How many parents and teachers can say that they motivated their participants enough to get them to *stop* playing video games?

Looking Ahead

Regardless, GameWerks youth program succeeds at its core mission: being fun. Counselors, team leaders, experts, and campers alike all leave the camp energized at the possibilities of game design as transformative, fun, and—gasp!—educational. One cannot read the examples above and not feel the buzz. Even though school systems often lack access to game industry experts, the GameWerks model is easily adapted to multiple learning environments: after school programs, weekend workshops, and classroom lessons. After all, what gamer doesn't want to create his or her own dream game? At GameWerks 2010, a counselor overheard one camper saying to another, "I wish school was like this." If we stretch our perceptions of what schooling can be, then these ideas might take hold in schooling situations. Obviously children (of all ages) are increasingly drawn to gaming. Why not harness the motivational power discussed here by having them design their own games? Maybe one day that camper will get his wish, and school really will be "like this." Even more so, why not expand the notion of what games can be as well? GameWerks proves that campers are amenable to the ideas and concept of socially conscious and "serious" games. We propose that for Generation R, games can be used to tackle any number of educational and social issues. A generation raised on "serious games" will think of games as something more than pirate battles and zombie slayings (not that there's anything wrong with that!).

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Chapter 18
The Power of the Globe and Geospatial Technologies to Empower Teachers and Students in the Digital Age

Rita A. Hagevik

Geospatial Technologies in Education

Geospatial technologies for exploring and analyzing the world are no longer restricted to a few skilled scientists and professionals. Instead, they are readily available to be widely used by teachers and students. Geospatial technologies include the computer hardware and software used to collect, import, manipulate, store, analyze, and display geospatial data. Examples of these technologies are Global Positioning Systems (GPS), geographic information systems (GIS), remote sensing tools, and other visualization systems. These technologies have become available to nearly everyone through various mobile devices. Over the past decade, consumer demand has skyrocketed for these devices as a way to manipulate and display geospatial information (cf. Folger 2008). For example, the integration of GPS data with digital maps has led to handheld and dashboard navigation devices that are used daily by millions of people worldwide. The release of Google Earth in 2005 made it possible for people from all walks of life to manipulate digital maps and geospatial data (Folger 2008). The ability to swiftly and dynamically represent the Earth's geographic, scientific, social, political, economic, as well as a variety of other types of data visually and from different perspectives, at moderately fine-grained resolution, creates a powerful learning opportunity for teachers and students. Geospatial tools expand the scope of topics that students can explore, promotes interdisciplinary learning, and changes the way that students learn to reason about and interpret data (Audet and Abegg 1996).

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Research on the use of geospatial technologies in schools has shown that teachers and students are able to engage in data visualization and analysis, spatial interpretation, and real-world problem-solving (Alibrandi 1998; Alibrandi et al. 2000; Hart 1979). A recent report by the National Research Council, *Learning to Think Spatially* (2006), states that geospatial technologies have the ability to meet four educational goals: (a) support the inquiry process; (b) be useful in solving problems in a wide range of real-world contexts; (c) facilitate learning across a range of school subjects; and (d) provide a rich, generative, inviting, and challenging problem-solving environment. Additional research has shown other important benefits for students, including increased motivation (McWillimas and Rooney 1997), improved self-efficacy and attitudes toward technology (Baker 2002), better acquisition of spatial analysis skills (Audet and Abegg 1996), increased mathematics ability (Coulter and Polman 2004), and an increase in geographic and scientific content knowledge (Kerski 2003).

A report by the Geographic Data in Education (GEODE) Initiative at Northwestern University (Edelson and Moeller 2004) identified the significant challenges facing teachers and students in their use of geospatial technologies in the school computing environment. These include access to appropriate hardware and software, technical and administrative support, and integration of geospatial technologies into the curriculum. Despite these challenges, teachers convinced schools, for example, in Los Angeles, Chicago, and the Appalachia region of Maryland, West Virginia, and Pennsylvania, to install software on school computers or servers and requested time to (1) find ready-to-use data for their projects, (2) identify and possibly modify existing curricular materials, and (3) find and learn how to use the many types of geospatial technology tools available. The Northwestern University report reinforces the point that it is important for teachers to prepare effectively for teaching with geospatial technologies, and that continued support is very important if the tremendous potential of geospatial technologies is to be realized in schools.

This chapter provides an example of how a group of teachers with their students in a middle school embarked on a geospatial project: it shows how the teachers and students were able to overcome similar challenges while addressing some relevant issues in their community.

The Genesis of the Middle School's Project

Ligon Middle School is located in the traditionally African American quarter in the capital city of Raleigh, North Carolina. While it is now a middle school, the school was formerly a "separate but equal" high school as recently as 1953. The school was a beacon of pride in the African American community. In the 1970s, the school was desegregated and converted into a magnet middle school for the arts and the academically gifted. Many former students of the school continued to live around the school. This middle school enjoys a good reputation among the city's many other middle school choices. Like many other middle schools in the United States, Ligon

Middle School experienced growth, with new wings and expansions completed about every five years. Early one school year, at the turn of a new century (1999–2000) more space was needed for the booming student population, so two large trees were felled to allow for building expansion and renovations. Two teachers rushed out and asked the destruction crew to save some slabs of the trees for posterity. The teachers began to wonder, “If these old trees could talk, what story would they tell?”

Telling the School’s Story

The two teachers that initially saved the slabs of the trees were a science teacher and an instructional technology teacher. These two teachers recruited the assistance of a language arts teacher and a social studies teacher to help guide the project of telling the school’s story from the perspective of the trees, using “tree cookies,” or cross sections of the trunks of the trees. As the project proceeded, the teachers soon realized that the school’s history was relatively obscured from them and its current middle school students. Most of the students had been born well after the 1970s. The first step was to connect with those who had lived the story in the tree rings—the school alumni. The alumni had remained active in annual events such as class reunions, trips and cruises. Among the alumni were individuals serving in leadership roles in the community such as a sheriff, several legislators, and PhDs who taught in the area’s colleges and universities. The alumni were very willing to assist with the project and tell the school’s story.

Using Geospatial Technologies

The instructional technology teacher and the science teacher had been collaborating on how to use geospatial technologies in the middle school classroom. They immediately realized that they could represent what the trees might have witnessed by using a map to represent the African American experience. The first step was using a map of the city with street-level information with data layered behind it. The teachers went about finding this layered data with their students in several ways. The social studies teacher and her students researched the state archives to determine what the city looked like in the past, and where the African American students shopped (retail stores and food markets), recreated (parks and movie theaters), and worshiped (churches). They found old photographs and locations of where these places were located. The language arts teachers and her students collected data by interviewing alumni. They discovered where alumni lived how they got to and from school. The science teacher and her students worked with a scientist from the local university to date the tree ring, and to identify which dates in time would be best to focus on. The instructional technology teacher contacted the city GIS office to secure data regarding the city boundaries and city growth over time. The teachers and their students used geospatial technologies to write their own book and to tell their own story. In the process, the students and the adults learned about their history, geography, culture, and politics, even as they acquired skills in research, reading, writing, communication, science, and the use of technology.

In Their Own Words

Teacher Perspectives

The teachers were surprised to discover how much the city had grown through annexation over time. Further, Sanborn Insurances maps for 1923–1949 from the state archives revealed the extent of racial segregation that existed, with areas labeled as colored and white. This condition was further verified through the alumni stories told to the students, as they interviewed alumni, recorded and wrote their oral histories. The digital maps had to be adjusted to show the locations and names of streets, landmarks, schools, hospitals, and parks over time. They had to correct the data tables and conduct "ground truthing" activities to insure accuracy. This required field checking and cross-referencing the actual (ground) and virtual (digital map) features. The corrected data were shared with the public and with the city GIS office. The results of the project had a powerful effect in the community. For example, the governor of the state heard about the project and attended the culminating event at the end of the school year. The alumni were thankful to the students for telling their stories. The Raleigh GIS office used the students' work in their own projects. The following school year, the drama teacher initiated an artist-in-residence program and the students wrote and performed a play for the community about the school's history.

The teachers learned vis-à-vis the students, and the project helped the students and the teachers develop a stronger sense of place. It unearthed half-buried African American local history, shedding light on who they were and had become, and why their school was special. Before the project, the teachers really did not know much about their local history. The instructional technology teacher said about the project, "Documenting the history of a school is an excellent collaborative project that allows educators and students to do significant research, experience history through the eyes of those who lived it, and express their creativity in communicating the information to others." The language arts teacher said, "Racial segregation is a topic students had read about but never experienced firsthand. The face-to-face time spent with the alumni left a lasting impression on all of us. Collaborating with the Ligon alumni was eye opening for me because I grew up in the same county and because of segregation had limited contact with the African American community." The social studies teacher remarked, "This was really an intergenerational learning experience for the students who had the rare opportunity to consult with those who had lived history. Students saw themselves as 'keepers of the history'. The alumni knew that their little-known stories gleaned from diaries, speeches, and original source documents would be told with compassion." The science teacher was surprised to discover how tree cores could be used as another method of dating. She said, "It was fun to see the students engaged in activities designed to explore this field. Various community partners helped us explore dendrochronology. It has now overflowed to a Ligon History box. What impressed me in the collaboration was the variety of ways in which history could be conveyed through books, GIS maps, human interactions, computers, and natural history's own tree rings." Who could have imagined what these trees had witnessed over time?

Student Perspectives

The students shared the project with the community in a culminating event one spring afternoon after working on the project for a year. In total, 125 students and 100 adults attended the event. It was obvious, as the students shared their work, that they understood that they could make a difference and that others valued what they were doing. The students felt empowered by their accomplishments: they had participated in collaborative problem-solving, decision-making, interviewing, authentic research, and cooperated with each other and with adults in the community to accomplish the project. Their newly developed leadership skills were evident at the event. The students exhibited a new sense of personal competence and self-esteem through the telling of a story, which up until that point, was largely undocumented. The products they had created included digital layered maps; 14 oral histories; a museum-quality labeled tree ring illustrating the school's important historical dates and events (this was put on permanent display in the media center); a database of the school's alumni, by graduating class; and a website that organized and explained the project (see http://ced.ncsu.edu/ligon/about/history/intro.htm for more information). Through this project, the students were able to see a glimpse of the history of their school. They had a chance to relive the community anew, and the products they created continue will to be used during lessons for future generations of students at the school.

Understanding Science from a Human Perspective

The concept of multiple perspectives and change over time is relatively complicated, but some of these complexities can be explored effectively using geospatial technologies. In the case study summarized above, as students learned how to date the tree ring, they also decided which times in the past to include, to research, and document. They included Civil Rights-era data in their own mental maps of a changing city: they were able to tell a story using the processes of science. This project afforded teachers and students alike the opportunity to understand science from a more human perspective. The students collected their own data and created their own geodatabases, which they verified for accuracy through multiple techniques, such as "ground truthing." But they also conducted historical research in the city's archives, visited historical buildings, used current parcel and street-level data, and constructed interview data collected from alumni of the school. On several occasions, data were found to be inaccurate. In such cases, the students learned that they had to dig deeper; and they discovered that sometimes a logical and documented choice was necessary. The images created by the layered map information revealed patterns that were analyzed and discussed in the classroom. The layers of information and data took on more detailed scale as students discovered how their city grew over time. The students discovered how different a story can be, based on the sociocultural construction/mediation of scientific information. They discovered a largely untold story, revealed by the data! Because of a few curious teachers and their students, when these trees fell at their school, somebody heard the story and, with geospatial technologies, revealed it.

The Promise of Geospatial Technologies in Schools

Geospatial technologies are used in many jobs around the world. The use of geospatial technologies in schools permits an interdisciplinary approach to teaching science that combines science as a way of knowing with the direct impact of active learning and being of service within the local community (Berkowitz et al. 2003). This is a powerful constellation of advantages (see Finley, Johnson, and Kamesch, this volume, Chap. 11), as seen in the Ligon Middle School example, in which teachers from different subject areas collaborated, examining a specific place or location from a range of perspectives using geospatial technology tools that enabled students to ask and answer many questions regarding their community. In the past, a significant amount of time was required for students to explore and answer such questions. With today's technologies, however, questions of this type can be explored rapidly, allowing students to investigate deeper and more challenging questions, such as those regarding the historical, economic, social, and scientific underpinnings of the nature and structure of the communities in which they live (see Smith, Neale, Ziegler, and Jackson, this volume, Chap. 15).

Coupling geospatial technologies with a study of the humanities, science, and the environment can open a school to a tremendous range of opportunities to explore local- and regional-scale environments, as illustrated here. Engaging in such studies can improve students' performance (Lieberman and Hoody 1998) and help them connect new concepts to prior knowledge (Carlson 2007). Classroom use of geospatial technologies facilitates the use of local layered data, which helps students to link up with other sites, such as other schools or geospatial technology users in local government and business sectors.

The world is complex and changing rapidly. The power of geospatial technologies are in their ability to allow visualization of multiple types of layered data for analysis, problem-solving, and decision-making in science. Generation R students will benefit from practicing problem definition, data gathering and organization, content integration, collaboration, and creative exploration, for a range of topics, scales, and settings. Such skills will help prepare them to be citizens who are able to make important, informed decisions, and allow them opportunity to share some of the responsibility for preserving and conserving the historical integrity of a community.

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Part IV
Developing Lifelong Relationships and Responsibility

Chapter 19
The Importance of Cultural Studies for Education: For Teachers and Policymakers in America

Barbara J. Thayer-Bacon

I grew up as a "military brat," with a father who had a career in the United States Air Force. I went to school with other children whose parents were from all over the United States (US) and US territories, and my father was stationed at six different bases while I was growing up (not counting the times he was in schools or at temporary duty assignments). Since my high school years were during the Vietnam War and my mother believing in going with my father wherever he was stationed, I attended five high schools in four years. I graduated from high school at Ramey Air Force Base in Puerto Rico, only to have the base closed and my father transferred to Kadena Air Force Base in Okinawa, Japan while I was in college in the States. I have come to realize that growing up around diverse cultures in different parts of the country, and even out of country, taught me to notice my own cultural roots early on. I learned that I was situated within a particular culture (my parents are from Pennsylvania with Scotts, Irish, and British roots); I have a Pennsylvania accent from my parents, even though I never lived in Pennsylvania as a child. I learned my parents' style of relating and communicating, as children do, and was able to compare their style to others from an early age, because my friends came from homes that were different from my own. I learned to love traveling and to view moving as an exciting new adventure. I learned how to make friends quickly and how to maintain friendships over great distances, for most of my friends were in the same situation as me, having to move frequently. It is not surprising that I grew up to be a cultural studies scholar, if *cultural studies* means to compare various cultures, at an international level. That is what I first thought cultural studies referred to—and that cultural studies of education just meant comparing various educational systems and schools at an international level. However, there is more to cultural studies than comparisons.

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My diverse "military brat" friends and I have much in common not only due to our parents' common jobs, but also due to our shared history. We grew up with the Civil Rights Movement and the Feminist Movement going on, as well as with our parents on alert during the Cold War and away for six months or a year at a time while they served in the Vietnam War. We grew up with social justice issues very much in the news, with the assassinations of John and Robert Kennedy, and Martin Luther King Jr., and pictures of race riots and student protests, as well as body counts, on the evening news. Maybe because my father's life was on the line, I learned to pay attention to the news and seek more information elsewhere, to gain different perspectives on current world events. My high school teachers in California modeled this attentiveness for me, especially my Spanish and math teachers. They offered us the chance to ask questions and discuss the current social and political issues, and when they realized we were not well informed, they organized information days at our high school where they invited various guest speakers to present differing views on the topic for the day. Civil rights and Vietnam are the two topics I remember. These information days opened my eyes to the possibility that the news is presented as neutral, when, in fact, it represents a particular point of view, and that a Black perspective of the Civil Rights Movement might be different from a White perspective, just as a Vietnamese perspective (North or South) might be different from an American military perspective. If *cultural studies* is about the study of power issues and the expressed concern for social justice, as it is, then it is not hard to understand how I might be drawn to cultural studies scholarship given the times in which I came of age.

Cultural studies is not just a study of culture in terms of *high culture*, as when we say that someone is *cultured* and we mean the kind of culture associated with wealth and a higher level of education, such as the enjoyment of Shakespearian plays and classical music. Cultural studies makes the argument that it is important to pay attention to everyday *low culture*, or what we might also label as *popular culture*, such as the rhythm and lyrics of the rock 'n roll music my friends and I listened to on the radio, while television shows exposed us to family models such as "Leave it to Beaver," and "Father Knows Best." Those shows served as lessons on race, class, gender, and sexual norms, for example. My friends and I were exposed to the same popular culture, watched the same television channels and listened to the same radio stations; we did not have the diversity of choices students have today. Cultural studies of education does not mean just a focus on schooling, formal education, for education takes place in many settings, including our homes, churches, and communities, all examples of informal education, as well as the forms of milieu education that take place through acculturation, such as the television, film, and the radio, and now through our computers. What could be more fascinating or important than studying the impact of media and popular culture on our values and views about life? These daily exposures impact our decisions about what *cultural wealth* we should pass on to our children, and what should be censored and left out. Cultural studies of education include this kind of focus too.

Another characteristic about me that drew me in particular to *cultural studies*, is my background in philosophy, in particular pragmatism. Pragmatism is an American philosophical approach that emphasizes the importance of using philosophy to solve real problems people have. For pragmatists the measure of one's ideas is judged by the consequences of those ideas. What impact and effect do the ideas have? "Pragmatism … takes the continuity of experience as revealed through the outcome of directed action as the starting point for reflection" (Seigfried 1996, p. 6). Pragmatists seek to heal either/or splits that have developed in philosophy over time, between ideas and experiences, thinking and doing, the mind and body, belief and action, thought and purpose, and self and others, for example. It heals these splits with both/and logical approach. When I applied to the University of Tennessee for a job as a philosopher of education in the Cultural Studies of Education program I did not know how much my pragmatist perspective had in common with cultural studies. I associated cultural studies more with Karl Marx (1961), the Frankfurt School, and the critical theorists who developed further Marx's ideas in terms of schooling and education, such as Myles Horton (1990) and Paulo Freire (1990). However, Horton was just as much influenced by John Dewey as he was by Karl Marx, and John Dewey is one of the founding contributors to American pragmatism. Pragmatists connect theory to action, the same thing that cultural studies scholars seek to do, using the idea of *praxis*. Praxis is a term associated with Paulo Freire's (1970) work in the world of education, but can just as easily be associated with John Dewey's (1990) work in the Chicago Lab School that he started in 1896. *Praxis* literally means theory + practice, and Dewey sought to show how philosophy connected to the daily practice of education; in fact, he defined philosophy *as* education. For cultural studies scholars, just like pragmatists, it is not enough to develop theories to help us better understand cultural issues; it is important to connect such theories to the daily practice of our lives. Compared to pragmatists, cultural studies scholars focus their theories more sharply on power issues, but pragmatism's emphasis of philosophy's tendency to divorce itself from context draws our attention right back to the kinds of social justice issues upon which cultural studies scholars want to focus. We are simpatico, thus making my fit within the Cultural Studies of Education program at the University of Tennessee an easy one.

My overall task in this essay is to make the case for the value of a cultural studies approach to educational studies for teacher education programs that prepare future teachers and support the continued learning of teachers working in U.S. schools. I make the case for my colleagues in higher education and teachers in the schools, as well as the intended audience of legislators and policymakers, to help them understand the importance of cultural studies programs as they seek ways to improve schools. In the section "Educational foundations", I describe some historical context to educational foundations as a field of study within teacher education programs; in the section "Cultural studies of education", I describe cultural studies as a multidisciplinary approach to educational foundations. In the section "Policy studies and educational studies", I consider what cultural studies has to offer for educators in the future and explore ways that cultural studies contributes to the understanding of educational issues for those who make education policy.

Educational Foundations

As a philosopher, what drew me into the field of education are my own children. I purposely avoided education courses as an undergraduate student because every woman I knew who had a career was either a teacher or a nurse, and I did not want to be a "traditional woman," doing pink-collar work. Instead, I followed my heart deeper into the world of philosophy. Clearly, I was influenced by the Feminist Movement, however now I am much more aware of the importance of honoring the work women have historically done as educators in the home as well as in schools, instead of devaluing their work and taking it for granted. I would not be here today if not for the teachers I had as a child growing up. Even though I had no desire to be a teacher as a young adult, I was actively teaching my children at home. I began to read about child development theories and educational possibilities when my children were very young, comparing various ways of educating children that were being developed in Europe—to what we were doing in the US. I learned about A.S. Neill's (1960) *Summerhill* (Neill was Scottish), Steiner-Waldorf (2004) schools (Rudolf Steiner was Austrian), and Montessori (Montessori 1909/1912) schools (Maria Montessori was Italian). My own daughter's enthusiasm about her Montessori preschool drew me to work at her school and eventually I became certified as an elementary Montessori teacher. Once I walked into the classroom, I have never walked out. I cannot think of a more challenging and rewarding job! Thus began a career in education that has spanned more than two decades so far. When I discovered the field of philosophy of education, and the possibility of earning a PhD that brought together my love of philosophy with my love of education, I felt like I had come full circle around, and now the circle was complete. Little did I know, I would spend my career defending my existence.

As far back as our written records go, philosophers have been worrying about the education of our young, and how to raise future leaders for a country/state. In ancient Greece, Plato wrote about this in his *Republic*, and his ideas deeply influenced the British philosopher John Locke's *Some Thoughts Concerning Education*, and the French philosopher Jean Jacque Rousseau's *Emile*, both of whom helped to inspire the American Revolution (Cahn 1970, 2009). Thomas Jefferson based his plan for a national education system in America on Plato's plan, an educational system that would teach our children the skills they needed to be democratic citizens and would help us find and develop our future leaders for our country. John Dewey (1916/1996) was also influenced by Plato's plan, as well as Rousseau's, and wrote about the importance of education for democracy in his classic *Democracy and Education*. Dewey's student, colleague, and successor, William Kilpatrick, and their colleagues at Teachers College (such as George Counts and Harold Rugg), developed in the 1930s the model of educational foundations I inherited in the 1990s. In 1929, as the country headed into the Great Depression, Kilpatrick convened an interdisciplinary study group of foundations scholars from the fields of History of Education, Philosophy of Education, Educational Sociology, Educational Psychology, Comparative Education, and Educational Economics to build on Dewey's ideas (Butts 1993; Tozer 1993). Kilpatrick's Study Group "was particularly interested in those ideas which acknowledged the social and political contexts of public schooling and their influences on student learning and achievement" (Davis 2008, p. 32). The faculty members participated in cooperative curriculum design and team-taught two 4-h courses that were required as part of the teacher education program at Teachers College. The courses offered an inclusive and integrated orientation to education that examined education as a cultural process grounded in social institutions; they offered future teachers a way to consider their past and think about their aims for the future.

In America, new teachers used to apprentice with more seasoned teachers and learn their craft on the job, similar to other apprentice-type jobs. Lawyers and doctors learned in a similar fashion, studying what could be learned through books while working for someone more senior and experienced, as a clerk or intern. As public schools developed in the US, more teachers were needed and formal teacher education programs developed, typically in the form of Normal Schools. The first state-funded school specifically for teachers opened in Lexington, Massachusetts in 1839. The early Normal Schools were two-year programs similar to what we think of today as associate degree programs. Nursing was a two-year program as well. Both programs, teaching and nursing, have expanded to become four-year college degree programs. In fact, many teacher education programs are now designed so that students earn a bachelor's degree in a subject area, such as history or mathematics, and then earn a teaching credential as a 5th-year student in a graduate program. Many states now require practicing teachers to earn their master's degree. We have today more highly educated teachers working in K-12 schools than we have ever had in the history of education in the US. Yet, teachers are taking fewer courses related to educational foundations than they did in the 1930s.

Since the 1980s and the publishing of studies such as *A Nation At Risk* (April 1983), states have put more pressure on teacher education programs to teach teachers formal assessment procedures; they also increasingly insist that future teachers learn x, y, and z, even as teacher education programs have become increasingly squeezed, by their states and their specific universities and colleges, to not require more credits to their teacher education programs or make it more difficult to obtain teaching licenses. Therefore, programs have looked for courses they could cut, to make room for the new requirements. Educational foundation courses that introduce teachers-to-be to the history of education in the US as well as to the development of philosophical thought and its influences on education used to be a standard part of all teacher education programs, along with courses in educational psychology on child development and theories of human learning. When I started teaching in higher education in 1991 and was working at a large, teacher education college that used to be a normal college (Bowling Green State University, in NW Ohio), I was in a department with 19 others, eight of us who taught the same educational foundations courses from our various discipline-base perspectives (history, philosophy, educational psychology, and comparative education), as well as research and counseling faculty. By the time I went up for tenure, there were 11 faculties in my department, including my research colleagues, as my senior colleagues retired and were not replaced. We had five foundational courses in our department that all students in teacher education took, two of which I taught ("Introduction to Education" and

"Teachers, Schools, and Society"). Today these educational foundations courses are being cut and courses in educational psychology on child development and theories of human learning are finding assessment curriculum added to their courses, while methods courses are picking up topics such as multicultural education as part of their curriculum. Our future teachers in America are, on average, learning much less about the history of current school practices and systems. Yet, an understanding of what happened in our past that put us where we are today, is urgently needed if we are to make effective changes in our educational system now. Nor do our teachers have much of an opportunity to think deeply about what they think the aims of education should be, and what methodology and curriculum, as well as roles for teachers and students, will support those aims. Educational foundations courses have been easy targets because they do not teach students what they need to know for tomorrow, to pass the National Teacher Exam or to be able to walk into the classroom and actually begin to teach. However, without foundational, theoretical courses that encourage students to think of teaching as a profession as defined by Harry Broudy (1956), supported by extensive research and theory to support its daily practice, teachers will have much difficulty critiquing what is and imagining what should be instead. Teachers will not be professionals who rely on educational research to inform their daily practice and supporting their practice with sound reasons based on that research; instead, they will remain craftspeople who apprentice to more experienced teachers and rely on teacher-proof curriculum.

At Bowling Green State University, an annual survey was conducted of students when they graduated with their teaching credentials, and again five years later, to determine what they thought were the most important courses they took at graduation, and which of their courses ended up being the most important to them as they looked back, five years later. At graduation, their educational foundations courses were not at the top of their list; instead it was their nuts-and-bolts methods courses. But five years out, the educational foundations courses had risen to the top of the list. By then, the teachers had learned that day-to-day situations and people change, making their methods courses limited and/or outdated. They also had learned that they have little control over much of what goes on, on a day-to-day basis. Yet, if they have a deeper understanding about schools as institutions, and have a longer perspective on the past as well as the future, teachers can more easily adapt to day-to-day changes, and keep their sights on their larger, long-term goals—why they got into teaching to begin with, and what they hoped to accomplish. These long-term goals are what help to keep alive their desire to teach. They realized that in the long run, their educational foundations courses helped them to stay in teaching and become good teachers.

Cultural Studies of Education

It has been two years since the last of the educational foundations courses I used to teach have been cut from the University of Tennessee's (UT)—teacher education licensure program. Students can still take a history, philosophy, or sociology of education course, or a multicultural education or social justice course (all of these courses are offered in the Cultural Studies of Education program), but only as electives, counting as credits toward a master's degree in education, beyond their teacher licensure requirements. Only those students who are already drawn to educational theory sign up, those who are concerned about *issues of social difference and diversity*, are worried about *issues of power and social justice*, and want to try to *understand the larger social context* in which schools as institutions are embedded. These are the defining characteristics of cultural studies as I described them in my introduction. Loss of these history, philosophy, and sociology of education courses for UT's teacher licensure program is beginning to show up empirically in the lowering of test scores on the teachers' licensing examinations. While the teaching licensing exams do not ask many questions that can be directly linked to educational foundations courses, those courses offered future teachers a place to develop important critical/constructive thinking skills (Thayer-Bacon 2000).

In the educational foundations courses I used to teach, students from all our various teaching licensure programs within the college of education were represented. While methods courses focus on early childhood, elementary, middle, or high school education (broken up by age ranges), social foundations courses include all of the age ranges. This means students from different teaching licensure programs had the opportunity to hear and read about social issues across the spectrum of ages, giving them a more *holistic* perspective on educational issues. Also, while students who plan to teach math or science, for example, take multiple courses in their subject-specific areas to establish depth of content knowledge, they rarely have the opportunity to interact with future teachers who will be teaching art, music, or physical education, for example. Once again, the social foundations courses gave them a way to look up, across the curriculum, and see the curriculum in a more *interdisciplinary* way. While courses such as educational psychology and particular methods courses may try to draw teachers' attentions to the diversity of students they may work with, in terms of various unique, individual styles of learning, social foundations courses reminded teachers that their students are members of many social institutions, including their families, communities, churches, and geographic regions, and they bring with them into their classes all of that social, cultural, economic, and political context. Thus, the social foundations courses provided opportunities for students to *enlarge their thinking*, and consider the history of educational discrimination against Native American children, for example, who were taken from their families forcefully and sent to boarding schools where they were not allowed to speak their language, wear their traditional clothing, or practice their community's rituals, or African American children, who were denied an education in the South before the Civil War, placed in segregated schools in Jim Crow South, and then bused to White schools when their Black schools were shut down, and their teachers lost their jobs after *Brown I and II* and the *Civil Rights Act*. Knowing the educational history of minority groups, who have been discriminated against in the United States, helps teachers understand why some parents distrust schools, due to their own bad experiences, and why parents may struggle to attend after-school events or student conferences, due to job conflicts, other family obligations, language barriers, and lack of transportation to the school their child attends, for example (Spring 1994/2010).

In sum, educational foundations courses offered students in teacher education programs across the country ways to enlarge their thinking; the courses let the teachers-to-be become more aware of their own cultural practices and how these connect to schooling, as well as assumptions they make about education. When one approaches educational foundations from a cultural studies perspective other important dimensions are added, too; cultural studies insists that we look at schooling through a political lens, and that we make sure educational foundations courses are tied directly to the daily practice of education, in the home, in our community centers, and in our churches, for example. It is not enough for would-be teachers to study history and/or philosophy of education; it is important to help teachers understand the impact of these experiences and ideas on our actions today, as praxis. It is important for teachers to be able to find the theories they learn applicable to daily life, and to understand that they have consequences. The theories are what give meaning to experiences, thus giving us the tools we need to be able to critique what is and find ways to improve upon our current conditions, by helping us imagine what could be otherwise.

Cultural studies examine closely the criteria we use to determine what cultural wealth we will pass on to our children, and what we choose to leave behind. Cultural studies remind us that educational choices in schools concerning curriculum and methodology are not objective and neutral; instead, these choices come from particular, situated perspectives that represent certain values, not necessarily general, universal values shared by all. Cultural studies underscores the politics of education, that there are power issues involved in who gets to describe the country's historical events. The naming is done by the winners of wars; they get to describe themselves as "freedom fighters" and "patriots" instead of as "savages," "traitors," or "terrorists." The voices that are empowered and allowed to speak and be heard, those with the right language and cultural as well as material wealth, these are the voices that have the opportunity to name students' behavior as "normal" or "deviant" (as teachers and counselors); they decide who will be hired as teachers and what curriculum will be taught (as superintendents and school boards), whether Native American teachers who are bi-lingual and bi-cultural will be allowed to teach in Reservation schools if they do not have the right (read "legitimate") credentials (as state and national policymakers), and if Mexican American children where English is their second language will have to take the same test as native English speakers, to determine what track they will be placed in for courses in middle school or high school (this decision is made at all levels, from the specific school teacher all the way up to state and national policymakers).

Would-be teachers who are able to take educational foundations courses taught from a cultural studies perspective will have more of a chance to graduate from colleges of education with the tools they need to adapt and adjust to the changing world in which we live. They should know how to be inclusive of students from diverse cultural backgrounds, and to be able to offer strong critiques of policies and procedures that are discriminatory and harmful to their diverse student population.

They should graduate with the tools they need to continually inquire and grow as well as help their students do the same. They should be better able to work collaboratively with each other as well as their students' families, and their larger communities, to address their students' needs and help to make changes that improve social and material conditions. The teachers should be empowered to offer solutions to the many problems we face in our educational systems from a more humble position, with the deeper understanding they will hopefully reach through their enlarged perspectives. They should be better able to serve as change-agents and they should be better able to help empower their students (and their families by extension) to become active, participating democratic citizens able to share responsibilities as they act to help improve conditions in our world as well (Thayer-Bacon 2008).

Policy Studies and Educational Studies

Maybe policymakers in the United States do not want teachers and the students they teach to be able to serve as social change agents who are able to critique current policy and offer suggestions for improvement? If so, Thomas Jefferson and John Dewey would be among the first to warn us that a democracy depends on educated, socially active, responsible, engaged, and participating citizens in order for it to thrive and grow. I know for myself, I would never have become a teacher in k-12 schools, given the conditions in which public school teachers must work today. Our current conditions give teachers the message that we do not trust them with the task of passing on our cultural wealth to the next generation. I became an elementary teacher due to the academic freedom I experienced, which allowed me the opportunity to experience what it felt like to be treated as a professional who was client-service oriented, respected, and given autonomy to design my curriculum and follow a methodology with which I was comfortable and yet able to take risks. The academic freedom I experienced, and with it the responsibility entrusted to me, is what helped me reach my aims of education. It was a love of learning, a desire to inquire, research, and seek to understand, that drew me in to education and keeps me here, the opportunity to critique what is and imagine what should be, ideally.

I started this essay by positioning myself as a child who grew up exposed to many cultures due to my father's career in the military. That upbringing made me stand out as "worldly" in comparison to my friends who grew up in one place and knew their neighborhood and community in a deeply rooted way that I never had the chance to experience. While I thoroughly enjoyed the adventure and growth my wandering life offered, I was jealous of my non-military brat friends who had deep connections to a hometown that they may leave and branch out from, but always know they can come back home to as well. All the military bases I grew up on have since been closed. We do not live in a world anymore where our children are isolated and not exposed to others who are different from them. America has become increasingly diverse overly the years, so that the multicultural experiences I had as a military brat are now easily available to most children. Our children do not have to travel to meet people from all over the world; the world comes to them, through the immigrants to the US, the visitors, and temporary transfer students, as well as through the internet. We live in a diverse, cosmopolitan world where we all experience the impact of globalization, economically as well as through our shared cultural experiences, such as the news, music, movies, fashion, and sports, for example. We are learning how ecologically connected we all are too, for we share the same ecological environment. Climate changes are not just happening in one's own country, they are happening all over the Earth.

Nationwide, social foundations and cultural studies faculty continue to find other ways to work with would-be-teachers and future scholars. We are developing new courses for undergraduate students interested in international education, to help them make comparisons among diverse schooling practices and national policies, and in education and service learning, to help them become engaged scholars, community organizers, and social activists at local levels, for example. Our focus remains on social justice as it relates to education and our hope is that these kinds of courses will help attract would-be teachers to come join us in our undergraduate and graduate programs and learn the skills they will need to help prepare, motivate, and inspire our next generation of students for responsible social action. Maybe some of these graduate students will go on to doctoral programs such as the one in which I currently work (Learning Environments and Educational Studies), and become the next generation of policymakers, more aware of the dangers and pitfalls of legislation, as well as the hopes for improvement.

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Chapter 20
Culture, Environment, and Education in the Anthropocene

David A. Greenwood

Are Cultural Studies Sufficient?

In the era of climate change, economic unrest, deepening inequalities and insecurities, peak oil, perpetual war and mass extinctions, educational leaders and policymakers have to begin asking each other: are schools relevant to the complex realities of a changing planet? Or, do they mainly serve an outdated vision of an industrial society that is turning rapidly into a complex mix of decline and transformation? Educational inquiry grounded in cultural studies needs to take such a question seriously.

What "cultural studies" means in education is contested, but the work associated with the cultural studies label generally shares a concern with social justice, democracy, the politics of diversity, and attention to popular culture. Cultural studies scholars recognize culture as a kind of vast school in flux where identities, values, behaviors, and the culture itself are constantly being shaped. They are especially concerned with the nature of power and its effects: the production of privilege and oppression, and the possibilities for resistance and change. In addition, scholars who are drawn to a cultural studies approach to education often embrace interdisciplinarity in their thought and methods, and frequently take an activist stance toward their work (Carlson and Dimitriadis 2003; Hytten 2011).

Contemporary educational discourse contains many references to culture, cultural groups, cultural understanding and cultural knowledge. It has become a commonplace notion in education that school curriculum and pedagogy ought to be "culturally responsive." To be responsive to culture in education today generally means that one understands how the power dynamics of difference in race, class, gender, sexual orientation, ability, and other forms of "otherness" play out in schools and classrooms, and that one has the skills or the "cultural competence" to educate

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for equity, social justice, and democracy. These are important ethical goals that exist in education because people from minoritized groups have taken political action to influence the policies and discourses of schooling. A key reason for attempting to train teachers for cultural competence in the United States is that while the teaching force remains overwhelmingly white, students are increasingly diverse in terms of race, culture, ethnicity, nationality, and language.[1] Without teachers who are sensitive to and knowledgeable about differences among individuals and groups, "other people's children" can be marginalized, neglected, undervalued, poorly served, and even greatly damaged by their experience of school.[2]

Cultural competence and culturally-responsive teaching are important goals in the project of schooling. However, such rhetoric can easily be absorbed by a school culture that functions more as a mechanism of cultural reproduction than as a means for cultural study and democratic transformation. The No Child Left Behind Act (NCLB) of 2001, for example, was promoted in part as educational policy aimed at "closing the achievement gap" for historically underperforming learners that had been left behind. However, in practice, the gaps remain, the fundamental inequality of school culture is unchanged, and the primary outcome of NCLB has been a tightening stranglehold of neoliberal accountability discourse on educational policy and school culture (Hursh 2007). One phrase—No Child Left Behind—has thus absorbed the cultural politics of social justice, democracy, and reinforced the mind-numbing culture of standardization that now dominates American schooling. Such standardization in turn narrows the curriculum to what can be most easily measured, while reducing the capacity for creative work on the part of administrators, teachers, and students. Ironically, as the future of people, place, and planet becomes more uncertain, our educationally leaders and policymakers appear more and more certain about the logic of educational standardization.

What gets lost in the ensuing debates over scarce educational resources is the ability to step back and assess the role of education in the larger culture. How, for example, do we assess our cultural investment in education when teachers and schools are routinely scapegoated for a host of social problems and when education budgets are routinely cut in the name of fiscal responsibility, even as trillions of taxpayer dollars flow toward corporate bailouts, subsidies and tax breaks, and toward unpopular wars that are devastating foreign lands as the unnamed death toll rises? How do we understand, educationally, the erosion of the social contract, the threats to social security and health care, and the everyday political assaults on the social safety nets for people in poverty? Further, as it becomes increasingly clear that the very biosphere is threatened by the global spread of western industrialized culture, how do we step back and consider the role of education on a fast-changing planet that is very different from the one that even our recent ancestors inhabited? What, in such contexts, is the role of education in helping to shape experience and culture, and to respond to an uncertain future, locally, regionally, and everywhere on earth?

While I generally support educational proposals and practices grounded in a vision for social justice, equality, and democracy, in this chapter, I claim that *all cultural studies "in" and "of" education that do not engage with larger socio-ecological* *trends are outmoded*. This rather sweeping claim is not meant to discredit scholars, policymakers, practitioners, and activists who are committed to the important cultural work of acting for social justice and equity within the project of schooling. The point, rather, is this: in an era of perpetual war, mass extinction, unprecedented inequality, food, water, and energy insecurity, a warming planet, all manner of environmental degradation, and the social stress associated with global development and sustained population increase, cultural study can no longer be divorced from the larger *socioecological contexts* in which culture now unfolds (Kahn 2010; McKenzie and Greenwood 2009).

The Anthropocene: The Socio-ecological Context of Education

That we are a culture, species, nation, and planet in the midst of converging socio-ecological crises is not an overstatement. Anyone who reads the newspapers even occasionally will see that war, social inequity and violence, environmental degradation, food, energy, and water insecurity, threats to cultural and biological diversity, and climate change are converging to create very new and uncertain ecological and cultural contexts for living and learning on Earth. Uncertainty on multiple fronts is the new normal, and it marks a new context for cultural and educational thought and action. In the year 2000, the Nobel Prize-winning atmospheric chemist Paul Crutzen (Crutzen and Stoermer 2000) coined a new geological term for the current human epoch: the Anthropocene. Crutzen and other scientists recently described the Anthropocene as "a new phase in the history of both humankind and of the Earth, when natural forces and human forces became intertwined, so that the fate of one determines the fate of the other. Geologically, this is a remarkable episode in the history of this planet" (Zalasiewicz et al. 2010).[3] Awareness of this entwining of human and natural forces has been part of the collective consciousness of western thought for several decades and has been a major theme of the environmental movement since the 1960s. Such awareness is also central to Indigenous epistemology, or other cultural ways of knowing that have not turned nature into an object for dispassionate use and scientific investigation (the role of Indigenous thought in socio-ecological cultural study will be explored below). That human beings live in and have literally formed through their technologies a *new geological epoch* now needs to be taken seriously by a much broader public, and we need to develop the language capable of accurately describing it (McKibben, 2010).

Educators worldwide need to understand this: since the post WWII acceleration and globalization of the industrial economy, and the rapid growth in human population (expected to reach 9 billion by mid-century), we now live on a bio-physically different planet than the one in which modern civilization developed and in which our common assumptions about education were formed. At the time of this writing, a very conservative group of geologists—the Stratigraphy Commission of the Geological Society of London—is considering formalizing the new epoch. That is, the Anthropocene may soon join the Cambrian, the Jurassic, the Pleistocene and other such units *on the Geological Time Scale* (Zalasiewicz et al. 2010).[4] Are educators taking sufficient notice of the times we are living in?

Anthropogenic climate change, habitat fragmentation, species extinction, ocean acidity, water and food insecurity, and toxins are all increasing and establish a new planetary background for humans and cultural conflict. Educators need to develop ways of acknowledging and responding to this new reality, and we need multiple ways of communicating it. Another iconic expression of the relationship between human culture and ecological context can be found in Barry Commoner, Paul Ehrlich, and John Holdren's IPAT equation from the 1970s. Briefly, these scientists devised an equation ($I = P \times A \times T$) where ecological impact (I) is expressed as the product of population (P), affluence (A), and technology (T). While improved technology can function as a mediating factor, the basic equation shows that environmental impact multiplies as the world gets more crowded and as more people become more affluent consumers (Chertow 2000; York et al. 2003). IPAT is a simple mathematical reminder that human population growth and economic development must eventually face the reality of ecological limits. Invoking a new term for a new epoch—the Anthropocene—and a simple iconic expression—IPAT—is an effort to signal that we live in an age of massive and escalating anthropogenic ecological impacts, and that culture and the proper role of education are best understood from a larger ecological perspective.[5]

On Earth over the last few decades, the glaciers are melting faster than education is changing: education now fails to meet, or even acknowledge, our changing socio-ecological contexts and related crises. Cultural and educational inquiries are stuck in a "pre-ecological" worldview where environmental contexts at local and planetary levels are ignored, neglected, and/or denied (Bowers 1997). With few exceptions, the project of schooling in America remains nonresponsive to a wide array of globalized sustainability problems impacting local environments everywhere. This is so in part because schools are less a product of careful educational, cultural, and ecological thought, and more a network of bureaucracies that operates under an outdated and largely unexamined cultural logic (a leftover from a past geological epoch). Epitomized by the No Child Left Behind Act, schooling bureaucracies explicitly and implicitly reflect political and economic ideals that are fundamentally at odds with a vision for social and ecological sustainability at local, regional and global spatial scales. Especially since the *A Nation at Risk* report, the political rationale for the huge sums of money committed to schooling has been to outcompete our economic rivals. As global oil supplies tighten and demand accelerates, this competition continues to be framed as a race to increase GDP (gross domestic product), an economic indicator that conceals problematic socio-ecological trends such as the consolidation of wealth, income inequality, massive ecological costs, and colossal debt. New rhetoric about education for "the knowledge economy" (as if such an economy existed apart from the energy-intensive industrial economy) further conceals the reality of a culture dependent for its affluence on global industrial extraction, production, consumption, and waste.[6]

The underlying meritocratic, capitalistic, nationalistic, and militaristic rationale of schooling means that the fundamental of purpose of education in the USA and elsewhere is not to educate young people to better understand themselves and their relations to others with whom they share the planet, human and other-than-human, but to prepare them for the economic marketplace, an enterprise that has always been grounded in questionable intentions and has always produced questionable results for people and places worldwide. Furthermore, the common practices of teacher education and schooling reproduce and reinforce educational structures, curricula, and pedagogical practices that do more to contribute to the problems of unsustainability than they do to acknowledge and respond to these problems (Gruenewald [Greenwood] 2004; Gruenewald [Greenwood] and Manteaw 2007; Kahn 2010; Stevenson 1987).

"Development" in the Anthropocene

The dilemmas noted above stem from cultural myths, assumptions and patterns that pre-date the Anthropocene, and that pre-date widespread cultural concern about ecological impacts of human activities on place and planet. Chet Bowers (1997) refers to these pre-ecological assumptions as guiding "root metaphors" of modernism from which spring our cultural and educational practices. According to Bowers, three root metaphors that are expressed in education include hyper-individualism, unbounded faith in progress (especially science and its technologies), and extreme anthropocentrism, or the idea that human interests are all that really matter. From a wider cultural studies perspective, other guiding metaphors that find expression in education include patriarchy, Whiteness, mechanism, colonization, and other terms describing patterns of domination and control that privilege some social groups at the expense of others and that privilege humans at the expense of habitat. All of these metaphors converge and find expression in the universal call for "economic development." Economic growth and development is the guiding myth or assumption of the modern age, and it has become the *raison d'être* of public school and university education (Hursh 2007). The political assumption is that economic growth is both necessary and good to national, regional, and personal wellbeing. Therefore, schools and universities should function to support and promote economic growth.[7] This tautology is so strong that few educators (even those ostensibly committed to social justice), and even fewer policymakers, question an educational system premised on fostering economic growth.

Defining our current epoch as the Anthropocene, however, calls into question the relationship between human cultural institutions and the larger socio-ecological contexts in which education takes place. Acknowledging that we live in a new geological age defined by human impacts on the earth's natural processes, if taken seriously, could be a cultural and educational game-changer. Acknowledging that we live in the Anthropocene means that the ecological impacts of economic growth and development need to be taken into account ($I = P \times A \times T$). It means that we need to recognize that our economic and educational institutions operate within a larger socio-ecological context. If we acknowledge that we live an age where the socio-ecological impacts of development have become problematic and sometimes catastrophic, we can no longer continue promoting education as an obedient servant of economic growth and development. We have to begin to *qualify* our cultural and economic goals with socio-ecological thinking: *what kind of growth and development* will serve diverse people, places, species and cultures, now and in the long-run?

Currently, while the USA and other nations are hooked on growth mythology, this question is not being seriously considered in mainstream educational and economic policy. The idea of "the long-run," or long-term thinking itself, is alien to a political system that functions on short-term economic projections and election cycles. Instead, the idea of ecological impact is mostly ignored by market fundamentalists, or effectively wished away by technocratic utopians. Market fundamentalists maintain that economic growth and development do not need to be qualified or regulated with attention to socio-ecological impacts. According to this brand of fundamentalism, the market is the ultimate arbiter of good: it is self-correcting and will respond appropriately to consumer demands. Techno-utopians similarly resist significant government regulation of growth (such as a carbon tax), and presume that new technologies will rescue humanity from damaging cultural and ecological practices. In practice, these two kinds of responses differ only slightly. The climate change debate provides a useful example. Market fundamentalists argue that regulating greenhouse gasses would damage the growth economy; therefore, greenhouse gasses should not be regulated. This appears to have been the policy of former President George W. Bush and the policy of the Canadian government under Prime Minister Steven Harper that in 2010 scrapped proposed climate change legislation that included only very modest carbon reductions. Techno-utopians argue that while modest regulations are an appropriate response to an obvious problem, big regulatory changes are too risky for a recovering economy (or for re-election), and that new, greener technologies will ultimately allow us to maintain economic growth and development. This appears to be the stance of the Obama administration, which has supported moderate, yet failed to enact meaningful, climate change legislation. In practice, the same logic of growth and development governs the actions of the techno-utopians and market fundamentalists, and governs also the logic of our educational institutions. While Obama's rhetoric may be greener than Bush or Harper's, his and others' vision of a techno-utopia fail to seriously question the myth of unlimited and unqualified economic growth and development and to acknowledge its mounting social and ecological costs.

It would be a mistake, however, to simply blame elected political figureheads and other policymakers. Our predicament in the Anthropocene stems from old assumptions about progress and economic opportunity more or less shared throughout western industrialized culture. Even critics of this culture, such as myself, are wrapped up (through complicit patterns of consumption) in networks of complicity. Our political challenge is that more and more billions of people on a planet increasingly ravaged by the industrial machine continue to demonstrate a massive collective failure to acknowledge the problem of unsustainability and to collectively change course. Education for the Anthropocene must be rooted in the fact that economic growth and development while the source of undeniable comfort, convenience, and overall wellbeing for some of earth's humans, also trails behind a long legacy of social and ecological costs. Acknowledging these costs and confronting the myths that creates them must be part of an education rooted in cultural study.

From Global Colonization to the Reinhabitation of Place and Planet

As iconic expressions of science, the Anthropocene and IPAT suggest that is it vital today to take a global perspective toward the impact of culture on the environment. This does not mean that a global perspective is more important that local perspectives, but that the scale of anthropogenic impact transcends and connects local, regional, and continental boundaries. Everywhere on earth, however, human beings live in, experience, and impact local places. How are we to understand the political ramifications of our cultural rootedness in place so that we are prepared to meet the local and global challenges of the Anthropocene?

If the root metaphors of modernism— individualism, anthropocentrism, faith in progress—help us understand the ideological origins of pre-ecological thinking, the cultural construct of "colonization" can help us to understand how those assumptions have been expressed in geopolitical practices that impact people and places everywhere. If cultural studies in education are to be rooted in the historical and geographical reality, they need somehow to confront the fact that underneath the story of progress and economic development (which undergirds the story of schooling) is the story of colonization. By colonization I refer to: (a) the historical practice from the colonial era through the present of dominating other people's homelands and territory, and other people's bodies and minds, for the production of privilege maintained by military, political, and economic power, and; (b) other assimilative cultural patterns (e.g., schooling or consumerism) that over-determine or restrict possibilities for people and the places where they live. There are abundant examples of cultural critique in the education literature that focus on the exploitation and marginalization of people. As I've suggested, however, cultural thinking in the Anthropocene needs to focus not only on people and their cultural stories, but on people in their larger socio-ecological contexts. Cultural studies, in other words, needs to be responsive to cultural relationships to place and planet. What is needed is not merely more critique of how power circulates among different groups in culture, but a vision of how people can live more sustainably in relation to one another and the total environment on which everyone—human and more-than-human—depends. The concept of *reinhabitation* of place and planet is an attempt to articulate a vision to counterbalance the historical legacy of centuries of colonization. Reinhabitation of place is thus a rejection of colonizing cultural patterns—an effort to *decolonize* unsustainable relationships with self, other, place, and planet.[8]

Colonization is a vital cultural construct to uncover and explore because of its historical legacy, its current expression in neoliberal globalization, and because of the way it operates as an unconscious assumption in an education culture devoted to economic development. From the perspective of the human evolutionary past, colonization can describe the population explosion of the human species and its near total domination of terrestrial habitat. Biologically, humans have been the ultimate colonizers, effectively outcompeting, displacing, and eradicating earth's other species and modifying (sometimes destroying) ecosystems to suit the social practices associated with human economic development. Politically, the European nation state enshrined the colonial mindset during the age of exploration when the premises of "divine right" and "first discovery" justified the exploitation, modification, and destruction of land and people in "the New World" in the name of God and the crown. This colonial mindset continues to dominate global economics as corporations and their supportive governments map the globe for cheap human and natural resources and for expanding the market base of consumers. Since the colonial era, the role of education has been to normalize the politics of colonization (i.e., the production of privilege and wealth as well as the myth of limitless growth) through a hidden curriculum that ignores and minimizes its social and ecological costs (Spring 1998).

Understanding modern education as a continuation of the politics of colonization is difficult for many Euro-Americans, whose epistemology and cultural practices are products of colonial thinking. From a geopolitical perspective, this is why Indigenous thought is vital to a cultural studies approach to education that is ecologically and historically grounded. Attention to Indigenous inhabitation and the impact of settler society is fundamental to understanding socio-ecological relationships in North America, or any place on earth impacted by the long history of Indigenous-settler relationships. In an article that examined educational controversies surrounding the 1999 Makah whale hunt around Neah Bay at the northwest tip of the Olympic Peninsula (Washington State), Michael Marker (2006) commented on the dissonant nature of epistemic encounters between settler societies and the Indigenous other:

> There is a deep insecurity within the consciousness and conscience of settler societies that, when confronted by the indigenous Other, is awakened to challenges about authenticity in relation to land and identity. There is embedded in this encounter with indigenous knowledge a challenge about both epistemic and moral authority with regard to indigenous relationships to land and the spirit of the land. Whereas other minoritized groups demand revisionist histories and increased access to power within educational institutions, indigenous people present a more direct challenge to the core assumptions about life's goals and purposes. (pp. 485–486)

Among cultural studies scholars, invoking Indigenous perspectives around the relationship between people, place, and education is sometimes critiqued as "romanticizing" or as "misappropriation"; such critiques can offer valuable cautions (Nespor 2008). However, critiquing efforts to invite a more central role for Indigenous thought and experience in education as mere romanticizing is historically and politically problematic when it becomes another excuse for forgetting the past and misunderstanding present and future geopolitical relationships. Contrary to the critique that to invoke Indigenous thinking is to romanticize, any honest look at Indigenous experience, or at the majority of the world's population, is to reveal the extreme romanticization and denial behind "settler" notions of "progress," which are fundamental to the project of schooling, and synonymous with the ongoing project of colonization under global capitalism. An ecologically rooted cultural inquiry calls progress and development into question, and invites the perspective of first inhabitants. It also calls into question life's goals and purposes, and all of the assumptions of settler society on which contemporary ideas about education, economics, and culture are based.[9]

Within Indigenous cultures and epistemologies, thinking about people, place, and land, as well as the lives of other species, has not been submerged in the global myth of unlimited economic development. Education informed by Indigenous thought has the potential to help heal the nature-culture, self-other dualisms endemic to industrialized society; it has the potential to help qualify and rethink the idea of development and progress from the perspective of people, place, and the other-than-human world. Such a rethinking amounts to reinhabiting and restorying our place in the cosmos, and our place on the earth, as part of a larger web of sacred life. Yet, the chief lesson of Indigenous experience is not only that Indigenous people maintain an epistemology that can contribute to more sustainable relationships between people and the places they inhabit. Just as significant is that to acknowledge the enduring presence of Indigenous people and their struggles to exist is to confront the root story of modern colonization—which all of us carry in our body/minds—and to acknowledge the possibility for other ways of being (Cajete 1994; Grande 2004; Smith 1999). A cultural-studies approach to education that does not embrace Indigenous experience would by virtue of this oversight be reinforcing historical patterns of continued colonization and denial. These patterns persist in global economic relationships between corporations, governments, and educational institutions that function to serve the development paradigm without acknowledging and assessing its costs to people, place, and planet.

The Limits of Environmentalism

Indigenous peoples, of course, are not the only cultural groups with histories and ways of knowing that are worth remembering and recovering in order to reinhabit a colonizing culture and landscape. American social, environmental, and even educational histories include many voices and movements for resistance and change. The environmental movement, for example, has been somewhat successful in helping to change particular behaviors and attitudes of some individuals, groups, and corporations, and in establishing the political momentum to promote more ecological consciousness. However, even this powerful worldwide movement has not significantly slowed the treadmill of production and related ecological impact (IPAT), which is the modern industrial economy in its continual state of global expansion.

It has been 40 years since the 1972 publication of the *Limits of Growth*, the pioneering study into limits of industrial activity on a finite planet (Meadows et al. 1972). Still, nearly all policymakers speak today as if growth-oriented development is an uncontested good. “Appropriate” is a rarely mentioned qualifier. This does not mean, however, that policymakers and their constituencies are unaware of the basic idea of the ecological impact of modern industrial economies. Rachel Carson’s *Silent Spring* (1962), the 1973 OPEC oil embargo and resulting “energy crisis,” the toxic disaster at Love Canal discovered in the mid-1970s, the 1986 nuclear catastrophe at Chernobyl, and a steadily growing and environmentally-aware counterculture—all of this and more contributed to catalyzing a politicized and diverse environmental movement in the late twentieth century. Public awareness of the negative effects of pollution and toxins, and of the benefits of energy conservation, is generally high. This can, in part, be attributed to the rise of issue-oriented environmental groups, and to the field of environmental education, which have both since the 1970s infused environmental themes and issues into the political debate and into the school and university curriculum. In the 1990s, the discourse of environmental education was influenced by the new language of sustainability and sustainable development. The introduction of the concept of sustainability into environmentally oriented thinking has broadened the landscape of inquiry to include the “three-legged stool” of sustainability: the environment, the economy, and society. Education for sustainable development (ESD) currently has many proponents worldwide, and the United Nations declared the years 2005–2014 as the Decade of Education for Sustainable Development. While ESD and the Decade have gained some political traction around the world, it is hardly mentioned in USA educational discourse (Gruenewald [Greenwood] and Manteaw 2007). Indeed, the economic collapse of 2008 helped to reinforce the economic and educational goal of *unqualified* economic development, with no reference to the ideas of limits, costs, or sustainability. Whenever the rhetoric of “economic growth” is touted without qualification—as it often is—it has the potential to mean development that is based on the old colonial economic paradigm.

It has become clear, then, that four decades of increasing environmental awareness among the general public, and four decades of environmental consciousness-raising, has done little to change the foundational cultural myths or assumptions about progress, growth, and development, or to challenge the strong link between the constant call for more unqualified- economic-development-without-limit and the increasingly instrumental valuation of school and university “training.” Yet, to a certain extent, the lack of ecological consciousness found in policy surrounding school and university curricula is the result of a poorly coordinated environmental movement, and an enduring disconnect between those who identify as ecological educators and those educators focused on cultural issues of social justice, diversity, anti-racism, and democracy. Many educators working for aspects of social justice simply do not connect social justice ideas about equality and access to ecological issues. The same is true of environmental educators: many do not connect their work to issues of cultural conflict. Even among those educators who have worked to bridge cultural and ecological perspectives, turf conflicts over ideology and language continue to create disabling division rather than enabling alliance (Greenwood 2008). Thus, there are many names for an ecologically conscious education, including environmental education, ecological education, outdoor education, ecojustice, ecopedagogy, sustainability education, education for sustainability, education for sustainable development, place-based education, experiential education, holistic education, humane education, and so forth. Renaming our current epoch, the Anthropocene, is a rhetorical and political challenge to all educators working the terrain of environment and culture. The point is that if educators are going to be responsive to the impacts of the human species on social and ecological systems, and the impact of these systems on our own consciousness, we need to look beyond the educational adjectives of specialized interest groups and work more deliberately together toward changing the cultural practices of educational institutions.

Conclusion: Welcome to the Anthropocene

Education is an expression of culture. A cultural studies approach to education is one that tries to make sense of the cultural contexts in which education occurs. But culture itself is a contested term, and because cultures are made up of people and institutions with diverse and sometimes competing interests, a cultural studies approach to education is complex. It can often be difficult to see whose interests are being served by a particular vision of education or by a particular cultural critique of educational institutions. Whose vision of culture, after all, should shape the work of education?

This is a difficult question inviting various responses in politics and in educational theory, policy, and practice. However, if we are to take seriously the fact that people live on a planet and that all cultures depend on maintaining a relationship between people and environment, then our education should reflect this reality. Unfortunately, current educational policy generally neglects ecological consciousness, and actively and uncritically promotes unqualified economic development. Thus, it appears generally oblivious to the idea of ecological limits of any kind. On Earth, cultural studies in education should incorporate an ecological perspective as a core principle. This does not mean merely making room for environmental education in the curriculum or sending kids to nature school once a year in grade five. Such ecofriendly actions can remind us of our connection to a larger lifeworld, but they do little to alter the fundamental assumption of our political economy—growth without limit—and its fundamental outcome—increasing social inequality and increasing ecological destruction. Therefore, all of us who are concerned with the ecological state of the world need to promote ecological consciousness as a part of every cultural studies approach to education. This is not a stretch or an abandonment of social justice perspectives, as every cultural group depends on relatively stable ecological systems and on a stable biosphere *from which, without exception, arise every cultural and identity formation.*

In conclusion, I have suggested some iconic language, concepts that may help to bridge cultural and ecological approaches to education in our times and that may generate some needed reflection among all educators. First, human beings live in and have created through their ecological impact a new geological epoch: the *Anthropocene*. The changes that the human species are bringing to our earth are dramatic and profound from many scientific perspectives. Never before have humans so altered planetary and ecological systems. Naming the new epoch we have created may help us wake up to the facts of dramatic change, and might spur us to consider: what kind of education is appropriate in the Anthropocene? Second, for many decades, scientists have understood that our ecological impacts are a function of a growth-without-limits paradigm, and that impact is the product of increasing population and increasing levels of affluence. If unqualified economic growth is problematic, the iconic expression *IPAT* should remind us that our economic paradigm comes with consequences. We need to attend both to these consequences and to the thinking that produces them. Third, in dealing with the global narrative of unlimited growth, students of culture need to uncover how this story is rooted in a longer history of *colonization*. When connecting economic development to the exploitation of land and people, *Indigenous experience* should be acknowledged for at least two reasons: to honor other ways of knowing with respect to the relation between land and people, and to better understand the living legacy of colonization from the perspective of First Inhabitants. Finally, a cultural studies approach to education that is responsive to the Anthropocene, that recovers a sense of the relationship between economics and ecological impact, and that interrupts the colonial mindset, is an approach that will seek to *decolonize* and *reinhabit* self, relationship, place, and planet.

The Anthropocene, IPAT, colonization, decolonization, and reinhabitation offer cultural studies of education some concepts with which we must come to terms. Whatever language we use to describe the cultural contexts of education, we need to change our thinking to reflect that culture and environment are not separate realms. Cultural analyses of education that do not actively embrace ecological consciousness will continue to reinforce the problematic fiction that cultures somehow exist free of ecological context, free of the land base on which all people depend—and which is increasingly threatened by pre-ecological thinking.

Welcome to the Anthropocene.

Notes

1. Similar trends are evident in Canada, where the Indigenous student population is the fastest growing demographic.
2. Classic examples of this approach to culturally-responsive teaching include Delpit (1995), Gay (2000), Ladson-Billings (1995, 2001), and Valenzuala (1999).
3. Similarly, theologian Thomas Berry (1988) named the new era the "ecozoic," which he described optimistically as an era for mutually enhancing earth-human relationships. Older terms that signal how humans are changing the planet include Anthropozoic, Psychozoic, and the Noosphere, or, the phase of earth history being transformed by human cognition.
4. This does not mean that such issues trump issues of social justice, but that all social justice issues exist within, and are often interwoven with, ecological issues.

5. Many cultural critics argue that a culture of militarism and perpetual war and the superpower status of the USA maintain this mode of production and its associated affluent lifestyles.
6. At my own university, the Vice President of Research office was in 2010 renamed as the Vice President of Research, Economic Development and Innovation—a stark example of how the development paradigm now dominates the idea of research and knowledge production in higher education.
7. The concepts of decolonization and reinhabitation are the twin aims of a critical pedagogy of place developed by Gruenewald [Greenwood] (2003).
8. For some, this emphasis on Indigenous place will still seem overdone. However, from a historical perspective, settler society in the place where I live is only 150 years old, while Indigenous presence goes back thousands of years. The point of re-membering Indigenous history and presence is not to idealize culture, but to look honestly at settler society's impact on people and places.
9. Ironically, when Indigenous rights are advocated in education the argument is often limited to better access to an educational system, which takes for granted the development—i.e., the colonial—paradigm.

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Chapter 21
Science Education in and for Turbulent Times

Kenneth Tobin

We live in turbulent times, and are inextricably linked to technology and science. Seemingly continuous TV news bulletins announce that the United States (US) has initiated its third war, news correspondents report live from Libya, other parts of the Middle East, and Japan where the country is dealing with a triple catastrophe. Scenes of devastation caused by a cruise missile are followed by scenes of devastation caused by a tsunami that struck Japan and produced associated problems in a number of nuclear reactors. Even with the customary delays due to the television signal having to travel long distances there is effective communication between the US and all three international sites. Viewers accept the news as a part of social life. Cruise missiles are depicted as precision tools and nuclear power facilities as dangerous and old technologies not built to withstand huge earthquakes, devastating tsunami, and associated deprivation of resources needed to maintain safe operation. The wellbeing of citizens is at stake because of events like these occurring globally, almost every day. Science affords us hearing about and learning from such events, and inevitably knowledge of science and technology are needed to understand what is happening and for others to solve the problems. Further, difficult decisions have to be made, and citizens in a democracy ought to be able to sort through difficult problems using intellectual processes that include identifying problems and solving them.

Consistent with a view of science as enacted culture, I adopt Bakhtin's genre of the novel (i.e., a genre-in-the-making) to represent science as dialogic, full of tensions and contradictions, and part of daily life (Bakhtin 1981). As individuals go about their lives they learn from each of their experiences. I work from the epistemological stance that science knowledge is cultural enactment (Tobin 2010) and I value highly what people do in society as well as what they say and write about science. From a sociocultural perspective, there are many more ways of representing scientific knowledge than being aware of and recalling science facts on demand.

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Scientific Literacy

Concerns about scientific literacy are not recent. Hurd (1998) noted that: "The cultural roots of scientific literacy go back in history to the introduction of modern science into Western civilization in the 1500s" (p. 407). Elsewhere, Hurd (1990, p. 133) connected advocacy for scientific literacy in the US to Benjamin Franklin's efforts in 1747 to "improve the scientific experience … to the benefit of mankind in general." He noted that (p. 134): "For 200 years it has been the scientists who have opposed, blocked, and thwarted science teaching that did not serve the ends of their own narrow field of research." This bold statement immediately draws attention to a potential division between the goals of science education for (a) producing scientists and thereby advancing science, and (b) educating the citizenry to enact science to live responsible and productive lives. The gist of Hurd's argument seems to be that the goals of science education serve the disciplines of science to a disproportionate extent when compared to their connections with everyday citizens and the situations they encounter in their lifeworlds. In regard to K-12 curricula standards, Hurd argued for the need to include goals pertaining to sustainability, health, resources, and recreation. In comparison to approaches that emphasize canonical science, Hurd regarded curricula that focus on scientific literacy as more useful, more relevant, and more attainable in the sense that they are embodied in "science for all" citizens. Hurd's perspectives raise questions about what is of value in science education and how best to think about seemingly conflicting alternatives. Arguably science education would be considerably different if there was an emphasis on the enactment of science in social life so as to sustain the planet and thereby enhance the quality of life for all citizens. However, it does not follow that assigning high-value to goals associated with sustainability and environmentally responsible lifestyles, for example, diminishes the importance of knowing about and being able to do canonical science.

In other parts of the world, the goals of science for citizenship have been embraced without interfering with the pipeline that produces scientists. For example, in Western Australia changes to the science curriculum were considered in the 1940s, to focus on producing a science-literate citizenry (White 1998). The impetus for such a change involved "a vigorous debate raging in the UK and North America between adherents of general science curriculum and those promoting separate discipline curricula" (p. 93). It took about 20 years for the changes to be enacted—in the early 1960s regulations were instituted to require all students in Western Australia to study the same foundation of science for citizenship as part of a compulsory core curriculum. Provision also was made for elective in-depth studies that focused on preparing youth for college level studies of science. This initiative signaled an end to the previously established policy of studying science disciplines on an elective basis as separate courses, such as physics, chemistry, etc. According to Jenkins, the move from teaching separate elective disciplinary based science courses (physics, chemistry) to a unitary science course for all students was consistent with the rationale provided by Thomas Huxley in England almost a hundred years earlier (Jenkins 2007).

In the 1960s through the 1980s, numerous Australian science educators received their graduate education in the US. Many were involved in research and curriculum design and development that emphasized applications of science in society. When these scholars returned to senior science education positions in Australia, changes were enacted because of the political context and relatively small size of the population, and because concerns for the environment had greater traction in Australia compared to the US at the time. Accordingly, science curricula in Australia changed to emphasize applications and connections with social life—especially for students up to Grade 10. Of course, the situation in Australia and other Western countries has continued to be dynamic, and trends within the US have mediated curriculum development in these countries. As the US moved toward *world-class standards,* for example, other countries have followed their lead with comparable standards even though the US continues to flounder in tests of international comparison (i.e., the US ranks lower than countries that follow their lead).

The US is large compared to Australia (the Australian population is equivalent to about two large US states). Historically, economic competitiveness has been a high priority in the US and diverse points of view are supported by structures such as the Constitution, which affords free speech and the university tenure system. Accordingly, even though there were robust arguments for change in the approach to science education in the US, the center of mass supported a continuing emphasis on disciplinary science. What seemed like a contradiction, that Australian educators got the idea to emphasize science for all citizens from debates in the US (even though the US continued to emphasize disciplinary focused science education) can be understood within a context of mainstream ideology in the US comprising schemas such as those associated with capitalism (Harvey 2006), scientism (Kincheloe and Tobin 2009), and meritocracy (Tannock 2008).

Science can be described as a power discourse (Delpit 1995), a subject in which all are expected to succeed so that the doors to the middle class are opened, irrespective of structures such as race, gender, and social class. It is possible that scientism serves as an ideology, which regards science as a superior way of thinking that has broad applicability in social life. It may be that business people and the population at large embrace values associated with scientism, capitalism, and meritocracy as foundations for thinking about science education; preferring to emphasize disciplinary science. When stakeholders have to make choices, it is possible for them to express a value for forms of scientific literacy associated with such goals as sustainability and environmental justice while giving higher value to goals associated with disciplinary science, assumed to produce economic advantage. Given that only so much can be included in a school curriculum, something is inevitably left out, because it is judged to be less important. This may explain, in part, the science education policy orienting toward K-12 schooling and emphasizing disciplinary science. In the following section, I analyze personal experience to shed light on these emphases in science education.

Signs of the Work Being Done

A significant problem pertaining to policy formulation in science education is illustrated in an event in which I participated when I came to Florida in 1987. Almost immediately I was appointed to serve on a Statewide Task Force (hereafter Panel) for reforming science and mathematics education, which the Florida Department of Education and the Florida Chamber of Commerce jointly sponsored. Panel representatives consisted of university professors with affiliations in science, mathematics, and science and mathematics education, business leaders from companies that hired scientists and engineers, scientists and mathematicians employed in industry, and K-12 teachers. The Panel held monthly public hearings in which recommendations for reform were considered and debated, and individual citizens and groups made submissions.

Increasingly, I became skeptical about a process in which it seemed that what was said did not make much difference; the importance was that public meetings occurred. Even though heated debates sometimes occurred during Panel meetings, it was difficult to see how the proceedings made any difference to what was written in the recommendations. Conversations and arguments that occurred during Panel meetings were essentially inconsequential. Rich differences of perspective that emerged were not regarded as persuasive when it came to formulating recommendations. The chief concerns of those with most power on the Panel were oriented toward producing a report with recommendations to which all panelists were signatories. Staff from the Department of Education, including two graduate policy interns, had the responsibility to write the report based on the outcomes of Panel meetings.

As the report neared completion, I found myself disagreeing with many of the recommendations. For example, being number one in the world in school science and mathematics was a primary goal of the committee and the major competitor (at that time) was Japan, because of its robust economy and high performance in comparative studies of K-12 science and mathematics achievement. It was not considered a priority to consider goals that were collaborative and global. Instead, competition was deemed the most appropriate way to improve achievement. Also, science education was not considered comprehensively outside of a K-12 framework. The Panel focused on a goal of obtaining a ranking of *best state, best nation* on tests of international comparison, based on an assumption that accomplishing this status would increase economic competitiveness. The rhetorical appeal of striving to become the top-ranked state in the US and the world was politically indicative of valuing science and math education as a condition for economic competitiveness.

Mainly out of frustration, I sought and obtained a meeting with the interns who were writing the report of the Panel's activities and recommendations. The walls of their office were covered with chart paper onto which they had summarized recommendations from key reports in science and mathematics education—state, national, and international—including all significant reports produced in the last five years. The loudest voice in our reform effort, it seemed, would be what similar groups in other places had recommended. I expressed astonishment and frustration to an intern, an education policy student at the university at which I was employed. She smiled and remarked: “it doesn’t matter what is written inside this report. All that matters is that the document exists and can be waved at stakeholders like legislators, as evidence that the committee has done its work.” It struck me like a ton of bricks that the process in which I was involved was predominantly political and possibly had little to do with improving science and mathematics education. Legitimacy was sought by creating recommendations based on previous reports, endorsement by experts appointed to the Panel, and widespread support from school districts, business organizations, and citizens. On this occasion, the process used to arrive at an agreed-to set of recommendations gave priority to synthesizing what had been proposed in earlier reports over what had arisen in the public forums and meetings of the Panel. The goal of the process appeared to be to secure additional state and national funding for science and mathematics education. Now, more than two decades later, the situation with respect to science education in Florida is not discernibly different than it was when the Panel did its work. For example, in 2009, in comparison to 47 states participating in the National Assessment of Educational Progress, Florida ranked 35th in Grade 8 science and 26th in Grade 4 science.

Representation is an issue that arises when panels are formed with the goal of reforming a field such as science education. Should a panel be formulated to produce consensus, or should its goal be to identify and learn from robust differences that exist within a community? My experience is that the membership usually is based on recommendations of a selected chair and a small group of colleagues. Quite often those who are selected represent major stakeholders, such as institutional presidents etc., and people who have a track record of being involved in similar committees. Diversity is valued in terms of ethnicity, gender, and roles within the science, mathematics, engineering, and technology domains; however, my experience is that panels usually are constituted with reaching consensus as a goal. A common problem with this approach is that panels constituted in this way largely represent mainstream ways of thinking and thus tend to reproduce the status quo.

Despite the huge number of reform documents produced in science education in the 50 years I have been associated with it, there is “sameness” when it comes to recommendations. Is sameness due to the dominance of scientists and their valuing of an education system geared toward the production and reproduction of science? Perhaps the widespread acceptance of scientism within the community and its use as a rationale for reforming science education is a strong factor contributing to sameness. For example, the following excerpt from the website for the National Math and Science Initiative (http://www.nationalmathandscience.org/) identifies science and mathematics as *universal languages of the global workplace*. One of the sponsors of the National Math and Science Initiative wrote: “ExxonMobil’s strategic focus in education is on math and science, since they are now—and will increasingly be—the universal languages of the global workplace, and are critical tools for success in today’s high-tech world.” When unexamined assumptions like these are used as rationale for science education, priorities can be distorted in much the way I would argue they have been in the US. There is no denying the centrality of science and technology in everyday life, including the workplace. However, causal connections between science education, the workplace, and economic productivity can provide a rationale for curricula and associated priorities that are ill-founded and in many ways inappropriate. It seems certain that there are myriad visions for science education and satisfactory progress necessitates that we pay attention to differences and reject once and for all the ideas that there is a solitary view of science education that is good for all circumstances.

Science for Literate Citizenry

It strikes me as a contradiction that there is relatively little concern about levels of scientific literacy for those who have passed the age of compulsory schooling. Even though there is widespread acceptance that we live in an era that has been dominated and perhaps defined by science, engineering, and technology, there have been few formal attempts to systematically enhance scientific literacy for this group of Americans. The costs of ignoring scientific literacy for this group might be high in terms of personal and political decisions made by citizens within this demographic. Such costs clearly go beyond economics and extend to include health and welfare, lifestyle choices, employment, recreation, and accessing media and entertainment.

I assume that science is an integral part of everyday life and that people enact science as they live their lives. Since most people do not categorize what they do in disciplinary terms as they are doing it (*that was science*), or after the event (*I just did science*) people are largely unaware of the science-like character of their knowledge. Perhaps science education can provide spaces for people to engage reflexively with their knowledge so that they become aware of what they know that is science-like, and after objectifying what they know, critically review their knowledge with a view to further learning (adapting what they know to afford higher quality life). It is important that science educators expand the goals of science education to include science in everyday life and afford opportunities for continuous science learning, including the years after compulsory schooling.

Jenkins (1999) described citizen science as "a form of science that relates in reflexive ways to the concerns, interests and activities of citizens as they go about their everyday business" (p. 703). Jenkins noted that one of the functions of schooling is to produce and sustain an informed citizenry, science for all being accepted globally. The following excerpt provides important insights into the meanings of citizen science:

> The rhetoric is that citizens need to be "scientifically literate" in order to be able to contribute to decision-making about issues that have a scientific dimension, whether these issues be personal (e.g., relating to medication or diet) or more broadly political (e.g., relating to nuclear power, ozone depletion, or DNA technologies). (Jenkins 1999, p. 703)

The category that Jenkins referred to as political is obviously important for myriad reasons because of the technological/scientific nature of social life.

Understanding political debates often involves knowledge of science and technology, and representatives and candidates frequently hold positions that can be critically reviewed through the lenses of science. Since these resources are so varied, it is impossible to know what is needed to make sense of experience as it unfolds. Perhaps what people need is the capacity to use the Internet and other electronic resources to obtain relevant information and to know enough to build necessary understandings through critical appropriation. Hence, a goal would be for citizens to learn enough to be literate, critical appropriators of science-related knowledge available through electronic media.

Recent tragic events highlight the centrality of science in everyday life. Consider what happened in Japan. First, a devastating earthquake struck off the Northeast coast of Japan, triggering a massive tsunami that took the lives of thousands of people. The tsunami and the earthquake combined to significantly damage nuclear reactors, as well: the cores of several of the reactors overheated, as did spent fuel rods stored nearby. Radioactive contaminants were released to the air and water, threatening the lives of those who sought to control the damage, and compromising the environment for those who had survived but who had been left homeless. Day after day, news media reported on the unfolding events. To understand the magnitude of the problems and costs to the world, many aspects of science became relevant, including what to make of the news. For example, this morning a nuclear physicist was explaining the importance of weather patterns to the possibility of maintaining the remaining nuclear reactors in a safe condition. In order to have people work in the nuclear reactors, they needed to be protected from hazardous levels of radiation; and wind and rain were variables to be considered. Another commentator noted that radioactive contaminants were now entering the jet stream, and that there were measurable increases in background radiation in Tokyo and as far away as the US. On the one hand, it was seen as desirable for the radioactivity to be swept away by the wind, over the sea, and then washed into the sea with the rain. Then, the issue of contamination of the food chain was identified as a problem, especially in seafood. There was much to digest as experts and news anchors covered the events in Japan on a 24×7 basis. When consequences for the US were considered, the focus inevitably turned to safety of the nuclear power stations in the US and charts showing the nearest reactors to our homes were displayed on television and the Internet. How concerned should we be that something similar to what happened in Japan would re-occur in the US? Is it reasonable that citizens of the US would be sufficiently scientifically literate to make sense of the science underlying what is happening in Japan? And how would scientific literacy make a difference to the political decisions being considered in the US?

Given the above scenario, there seems to be a prima facie case for all citizens to have scientific literacy sufficient to comprehend the news of the day. On any given day, the news is saturated with science and those who bring us the news do so with passion and an ideological commitment that can often remain invisible to consumers who accept what they see and hear as truth. Should citizens have the knowledge to identify biases in the media and create alternative scenarios based on their understandings of science? To me, the case seems strong to support a view that all citizens should be able to access media with understanding and know how to search for alternatives they can appropriate to further educate themselves. It is evident from the example concerning the earthquake in Japan that there is too much basic knowledge needed to have more than a surface understanding of the science of earthquakes let alone the science of tsunamis and nuclear energy. However, what does seem reasonable is that individuals would have sufficient knowledge to find out, for example, how the size of a 9.0 earthquake in Japan compares to the 6.3 earthquake in Christchurch and the 7.3 earthquake in Haiti. Similarly, individuals might reasonably expect to be able to search for, analyze, and make sense of relevant resources to provide them with opportunities to understand the science underlying any of the aspects of science that arise in everyday events. In the case of the catastrophes in Japan, individuals would need to access knowledge of earth sciences, physics, and health sciences.

The media are replete with items that address the interface between health and science. Often times these articles relate to research that has recently been undertaken. However, what gets reported in the media involves selection and the biases of reporters and editors. For example, earlier in the week there was an article on the necessity for women to understand the potential harms of third-hand smoke on the unborn child. What level of understanding should citizens have of news such as this, what questions might they ask about them, and where would they look for answers? As soon as I read the article I wondered why only women? It seemed to me that smokers would be the target for such an article and if not smokers then all potential parents. On the other hand, second- and third-hand smoke affect us all. Is it reasonable for all individuals to be able to consume media reports such as this, ask questions, and find answers? I respond affirmatively and ask, what is the role of science education in providing for this level of education within society?

Consider an example of the 67-year-old woman who took out her retirement papers when she reached the age of 66. This retired schoolteacher, with a background in literacy, was highly educated, although her last science course was taken when she attended college, approximately 45 years earlier. Since then, her science education reflected her own efforts to stay literate by accessing media, pamphlets from the doctor's office and other health institutions, and as the Internet became more sophisticated, through the use of browsers and search engines such as Google. In other words, she did not access formal institutions to expand and maintain her scientific literacy, but instead followed her interests as they were shaped by hobbies, political, and personal events/phenomena. For example, when her eye doctor informed her that she had age-related macular degeneration she used Google to identify relevant material and studied the structure of the eye and possible chemical interventions until her understanding was sufficiently sophisticated to interact with her doctor in an informed conversation. This example raises questions about the quality of resources available on the Internet to support science education for senior citizens. At the present there is a dearth of research on levels of scientific literacy in this demographic, which resources adults appropriate to learn what they need to know, and how the quality of these resources might be improved.

Science Education and Well Being

After work comes retirement and old age. What is the role of science education in the years following the completion of work? Are there benefits to be derived from doing science that extend beyond the examples already discussed, which pertain to literate citizenry? Proponents of the scientific method developed an approach to science education in the 1960s that was referred to as the process approach. Science educators, with the assistance of scientists and psychologists, identified the intellectual processes considered to be associated with the scientific method and developed curricula to teach them systematically from prekindergarten through high school. Basic process skills, such as observation and classification, were considered to be prerequisites for integrated process skills such as predicting and hypothesizing. An assumption about the process approach to science education was that basic and integrated process skills were generalizable across time, space, and subject matter. Accordingly, process skills learned in school could be applied in everyday life to solve problems. Also, process skills learned in the context of sinking and floating objects could be used while shopping or while doing chemistry (Tobin and Capie 1982). However, in the past few decades there has been increasing acceptance that generalizable skills such as those represented as basic and integrated process skills probably are more grounded/connected to the fields in which they were learned (Roth 1995).

Recent work suggests there might well be in-the-moment benefits of participating in science. An unpublished study by Liu reported that senior citizens in Taiwan participating in physics delayed the onset of pre-Alzheimer disease symptoms (Liu 2010). A plausible interpretation of this research is that doing physics focused participants' attention, resulting in desirable forms of brain activity and associated physiological processes. Although there is no reason to believe that it was the study of physics per se that produced the desirable outcomes, the study was undertaken in physics, not literature. Accordingly, it is reasonable to conclude that the elderly students benefited in an embodied sense from studies of science. It might be that they would have benefited similarly by participating in any intellectually stimulating activity, but similar research has not yet been done for other areas of study. What is important is that science can be used to benefit senior citizens in a wellness sense. The study aligns with other work undertaken in social neuroscience—addressing mindfulness. Brown et al. (2007, p. 212) defined mindfulness as "a receptive attention to and awareness of present events and experience." They explained that mindful (compared to a conceptual processing) involves a receptive state of mind in which attention is oriented toward registering facts observed, shutting down habitual processing, and making an effort to be present in the moment. In their extensive review, Brown, Ryan, and Creswell highlighted many advantages of mindfulness and pointed toward individuals having: greater control over their thought processes; greater awareness of experience while being immersed in it; and being: more objective, more likely to defer

Table 21.1 Empirical and conceptual structure of mindfulness

Nonreactivity to inner experience (nonattachment)	I perceive my feelings and emotions without having to react to them.
	In difficult situations, I can pause without immediately reacting.
Observing/noticing/attending to sensations/perceptions/thoughts/feelings	I pay attention to sounds, such as clocks ticking, birds chirping, all cars passing.
	When I am walking, I deliberately notice the sensations of my body moving.
Acting with awareness/automatic pilot/concentration/non-distraction	It seems I am "running on automatic" without much awareness of what I'm doing.
	When I do things, my mind wanders off and I'm easily distracted.
Describing/labeling with words	I have trouble thinking of the right words to express how I feel about things.
	I can easily put my beliefs, opinions, and expectations into words.
Non-judging of experience	I think some of my emotions are bad or inappropriate and I should not feel them.
	I tell myself I shouldn't be thinking the way I'm thinking.

judgment, more likely to be ecological stewards, more cooperative in their responses to others, better social skills, and less emotional.

Davidson et al. (2003, p. 564) reported that mindfulness meditation produces demonstrable effects on brain and immune function and, in another study, Davidson and colleagues (2010) used functional magnetic resonance imaging to show that meditation on an external visual point compared with a rest condition was associated with activation in multiple brain regions implicated in monitoring, engaging attention, and attentional orienting. Meditation usually is associated with obtaining control over the body and the mind, often through focusing on some aspects of the body, such as breathing. Also, mindfulness is closely associated with being in the moment and becoming unstuck—that is, becoming less attached to emotions. Accordingly, a high level of emotionality is central to what some have described as mindlessness, a state that is neither conducive to learning and doing science nor to being successful in everyday life through the use of scientific literacy (Roberts 2007).

Baer et al. (2006) identified five underlying structures for mindfulness (Table 21.1): (a) nonreactivity to inner experience; (b) observing/noticing/attending to sensations/perceptions/thoughts/feelings; (c) acting with awareness/automatic pilot/concentration/non-distraction; (d) describing/labeling with words; and (e) non-judging of experience. Similarly, Sahdra et al. (2010) explored nonattachment, an aspect of mindfulness that is similar to nonreactivity to inner experience (i.e., (a) above). Existing scales and items for these constructs might be used heuristically in research on the relationships between science education and mindfulness. I regard such research as a priority for forging new directions in science education.

Citizen Science in the Near Future

It is important that science educators are proactive about expanding the goals of science education to increase the relevance of school science in relation to the preparation of a literate citizenry. Ensuring that goals relating to the production of literate citizenry for all should not preclude those wanting to become scientists from pursuing advanced level, disciplinary oriented, studies of science. The either/or modes of thinking that tend to characterize debates about the goals for science education need to be rethought in these rapidly changing times in which making sense of everyday life necessitates knowledge of science and technology.

It seems indefensible that science educators should continue to focus predominantly on the K-12 education system. I do not argue that it is unimportant; it is a necessary but insufficient goal set unless literacy of all citizens is included. Greater attention needs to be given to scientific literacy of people who are beyond the compulsory years of schooling. This is a priority that should not be left to scientists, education policymakers, and politicians. It is an opportunity for science educators to think carefully about the nature of science education and its purposes for the relatively long span, from about 18 years to death. As Jenkins implied, there are solid reasons for citizen science programs to address political and health related science. In addition, I add the development of mindfulness and well being. I regard it as imperative that continuous science education is available for all Americans and indeed for all citizens of the world. Although the formulation of goals and materials will necessarily be interdisciplinary and collaborative, there is no need for science educators to sit back and wait for others to lead. It is imperative that we use available technology, for example, to further explore relationships between doing science and social neuroscience. Research methods would necessarily employ multiple theoretical frameworks and multiple methods that undertake research, from the neural level through to the global.

There was comfort in the idea that science process skills, or thinking scientifically, might transcend time, place, and subject matter. Accordingly, it is reassuring to consider research on mindfulness and neural processing in relation to science education. Davidson's work on meditation is encouraging. One of my favorite studies involves his research on meditation and neural processing of Buddhist monks who have spent thousands of hours in meditation. There are distinctive differences between the neural processing of the monks' brains, those who have just started to meditate, and those who are not meditating at all. In both of the meditation conditions, the brain shows evidence of focusing attention and maintaining the focus for extended periods. In addition, an outcome appears to be the production of antibodies and a more active immune system. In other words, there is a possibility that meditation and mindfulness practices can improve wellness and problem solving. An issue for science educators to consider is the extent to which science education can promote mindfulness and wellness. In making the suggestion that science education might have a role in the production of mindfulness, I am not adopting scientism (the perspective that science is a superior discourse for today's world), since I am confident that learning other discourses also can produce mindfulness. But, this is not a question for science educators. Given the established links between science education and political and personal health goals, it would be a bonus if goals related to mindfulness could be pursued simultaneously.

Is it possible for communities to provide the resources for their citizens to be continuous learners of science? I read a newspaper article recently about science programs being offered in bars. Obviously, bookshops, bars, coffee shops, and educational institutions, both formal and informal, can encourage the teaching and learning of science. But there may be other sites worth considering as potential learning environments, such as learning spaces for commuters on bus, train, and car. Similarly, resources for learning science might be available in restaurants, public parks, and shopping malls. Other institutions that might support science education include senior citizen villages and extended-care facilities, YMCA and Scout organizations, community oriented schools and libraries, and museums, parks, and zoos.

The media already are resources for science education (e.g., websites for CNN, BBC, National Geographic, and New York Times). Lacking is research on how these resources mediate science education and the extent to which they are appropriated for the purposes of expanding citizen science. Science educators might collaborate with media organizations to enhance the possibilities for improving the quality of the resources for the learning of science.

I close this chapter with a final comment on voice and my history of experiences with the reform of science education. If science educators want to retain the status quo then their roles are clear—do as we have done previously. On the other hand, if we want transformation, the status quo must be breached. Science educators should not wait for scientists to lead the reform effort, and neither should they turn to leaders from the business community and politics. Instead, meaningful transformation of science education can and should be initiated by science educators, in ways that can produce comprehensive scientific literacy through expansive and continuous science education for all (i.e., science education would be multinational, multi-age, and multipurpose).

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Chapter 22
A View Through Another Window: Free-Choice Science Learning and Generation R

Lynn D. Dierking

In the previous chapter, Tobin describes the changing world and astutely points out that the focus of science education globally has been with children and youth in school between about 3 and 18 years of age; much less attention has been given to post-high school adults other than modest efforts to improve undergraduate and postgraduate education. But the vast majority of adults either are not privileged enough or do not choose to further their schooling beyond high school, and increasing numbers of youth, particularly from low-income, disenfranchised groups underrepresented in STEM, do not even graduate from high school (Falk and Dierking 2010). Current approaches to science education reform rarely address these individuals.

Tobin poses a provocative question: is it possible for communities to provide the necessary resources for citizens to be lifelong science learners? Without hesitation I say it is not only possible but rich examples already exist in many communities. For instance, Tobin mentions reading about science programs offered in bars. Science cafes and science pubs, first developed in Europe in the early 1990s, have flourished here in the USA for nearly a decade. They are being replicated now in "less usual" communities: rural areas in Montana and South Dakota in the USA and Cockermouth in the Lake District, UK; on islands, Corfu, Greece, and Orkney, Scotland; within immigrant and gypsy communities in Europe; and even in Palestine. Science programs also take place in parks, shopping malls, scouts, senior communities, YMCA/YWCAs, libraries, museums, zoos, and even cars and restaurants. (CDs featuring current research conducted on site can be borrowed while visiting national parks, and French fry wrappers and recyclable paper cups at the Pacific Northwest fast food chain, Burgerville, feature information about rough-skinned newts and

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sockeye salmon, respectively.) These are but a few examples of a vast and vibrant science education infrastructure which is unseen, undervalued, and underfunded (certainly by public dollars), because the window through which most science educators and policymakers gaze is focused on K-12 (or P-20).

Like Tobin, I am deeply concerned about science understanding among the public and believe it is time to fundamentally change the approach we take as a nation (and world) to reform science education. While access to and opportunities for education in general (and science education in particular) have been increasing, across both setting and life span, the rhetoric, either implicitly or explicitly, continues to focus on the failure of US school-aged children to excel at mathematics and science in international comparisons (TIMSS 2007; PISA 2009). Likewise, solutions center on improving K-12 schooling and teaching (Carnegie Corporation 2009; National Academies of Science 2006).

I believe this is a short-sighted response. The centers of this "quiet revolution" (increasing diverse opportunities in all forms of education) are not the traditional educational establishment of schools and universities. Rather, these centers are a community network of educational entities: libraries, print, and broadcast media; the Internet, personal games, podcasts and social networking media; museums, zoos, aquariums, and science centers (Horrigan 2006; Falk et al. 2007b). The school-first approach also neglects the contributions of the workplace as another venue for science learning. Although a relatively small percentage of the public (3.8 %) are employed in jobs requiring a science or engineering *degree* (National Science Board 2004), the percentage rises dramatically if one considers the number of people who work in science- and engineering-related jobs that require technical training, but not a degree. In addition to the free-choice learning arena, the workplace is a neglected yet important third educational sector in our society (Falk and Dierking 2002).

If as Gen R science educators we want to help envision an effective and comprehensive whole life science education system, we must recognize *and support* the various places and ways in which people of all ages learn and engage in science across their lifetime—in school, certainly, but also at work, in the home, and in everyday life. To do this well, we must understand how to more effectively connect science learning opportunities across settings and the life span. If we understand the connections and interrelationships within this science learning web, we should be able to build a system that better leverages and contributes to lifelong science engagement and learning.

In this chapter, I will focus on what I know best: the critical role free-choice science learning plays in a comprehensive, whole life approach to science education, not as a nicety, or a supplement to science learning engaged in at school, university, and the workplace, but as a different but equally essential component of a *lifelong, whole life* science learning system. This is not a condemnation of school-based learning. The point is merely to emphasize the fundamental role played by nonschool-based learning when taking a comprehensive approach to educational reform. I also discuss the need for an education and research infrastructure to support this educational sector and the educators who work within it.

The Free-Choice Learning Revolution

Much evidence supports the contention that the public learns science in settings and situations outside of school. A 2009 report by the National Research Council, *Learning science in informal environments: Places, people and pursuits* (NRC 2009), describes a range of evidence demonstrating that even everyday experiences such as a walk in the park contribute to people's knowledge and interest in science, technology, engineering, and mathematics (STEM). For example, in any given week, a person might watch a television program on evolution, research a diagnosis of high cholesterol by her physician, and build a model rocket with a child. Each of these is an example of free-choice[1] science learning. Children and adults are spending more of their time learning, not just in classrooms or on the job but through free-choice learning at home, afterwork, and on weekends.

Where do knowledge-thirsty people turn to learn about science and technology when not in school or at work? There are books. Despite the hype about declining literacy, the number of books sold in the USA in 2006 was up from 2005, and with the increasing adoption of e-books (the share of adults in the USA who own an e-book reader doubled from November 2010 to May 2011), the number of books sold is at an all time high; many of these are science and/or technology related (Purcell 2011; US Bureau of the Census 2010). There is television. Not only is television viewing up (US Bureau of the Census 2010) but so, too, are the number and diversity of information-oriented programs, many of them science and/or technology related (Miller et al. 2006). There is the staggering growth of the Internet—and science and technology topics are being communicated there, also; data shows that once people turn to the Internet for science news and information, they learn to rely on it as a source, especially young people (Horrigan 2006). And there are science-related museums and other free-choice science education settings such as zoos, national parks, aquariums, and science-technology centers. Not long ago, most people would rather have been bound and gagged than visit a museum. Museums, particularly science-technology-oriented ones, currently rank as one of the most popular out-of-home leisure experiences in the world; ASTC estimates that there were 89.6 million visits to their member science centers and museums worldwide in 2009, with 62.9 million of those visits made in the USA (Association of Science-Technology Centers 2010).

From the growth of the Internet to the proliferation of educational programming offered by IMAX, educational television, and museums, there are more opportunities for self-directed, free-choice learning than ever before, much of it science and

[1]In 1998 John Falk and I began advocating *free-choice* learning as a preferred term to the more commonly used *informal* learning for two reasons: (1) political, informal connotes less important, perhaps why such learning is often undervalued and under-investigated, and (2) conceptual, we chose to define the learning by its characteristics—nonlinear, personally motivated, and involving considerable choice on the part of the learner rather than by what it is not (formal) or where it occurs (Dierking and Falk 1998).

health related. People engage in such learning every day, tapping into a vast science learning infrastructure available seven days a week, 24×7, across a life span. These opportunities are important, in fact, essential ways that people learn. Even more critical, these modes of learning allow individuals to *contextualize* their science knowledge, interest, and understanding throughout their lifetimes. In doing so, it is hoped that they become science-informed citizens, perhaps even *engaged science participants*.

The Science Education Infrastructure

Well over a decade ago, St. John and Perry (1993) proposed that science educators rethink the entire learning enterprise, suggesting that school and free-choice learning sectors (and the workplace) be considered components of a single, larger educational infrastructure which supports and facilitates learning in a society. In the twenty-first century, society needs a broad-based and richly integrated educational infrastructure capable of supporting millions of unique individuals attempting to meet widely varying learning needs at any point in their lives, any time of day. The educational entities that provide citizens with current and accurate information about health, politics, economics, the arts, or science form the fundamental backbone of a learning society, and as suggested, this basic infrastructure already exists in most communities, and ideally all the entities work together to support and sustain learning across the life span (Dierking and Falk 2009). From this perspective, the educational/learning infrastructure is vital to a nation's economic well-being—but even more importantly, its intellectual and spiritual well-being.

Each educational sector—schooling, workplace, and free-choice learning—contributes to the science learning of the public. However, of the three, the free-choice sector is far and away responsible for providing more people more educational opportunities more of the time than either of the others combined. The free-choice sector also is the most diverse, fastest growing, and arguably the most innovative. The explosion of the Internet and World Wide Web provides significant evidence for the perceived value of having a readily accessible tool that can provide virtually anyone, anywhere, with any information, any time. The Web, though, is just one aspect of an ever expanding and, hopefully, improving network of learning resources available to the general public.

One consequence of taking a broad-based approach to science education is that one begins to notice science teaching and learning in novel places (like cafes and pubs!). Other examples of innovative free-learning include efforts by the Astronomical Society of the Pacific, based in San Francisco, California, who over the last 20 years have explored and experimented with ways to tap into the vast resource of amateur astronomers. With initial funding from the Informal Science Education division of the National Science Foundation (NSF), they have involved amateur astronomers in elementary and middle school teaching in classrooms through *Project ASTRO* (Dierking and Richter 1995) and, through *Family ASTRO*, have provided engaging astronomy experiences for families through a network of museums, science-technology organizations, and community-based organizations such as amateur astronomy clubs. They are now providing more focused astronomy training to free-choice learning educators in small science centers, museums, and planetariums. Although NSF funding ended several years ago, programs remain in many communities around the country supported by existing networks of educational partners.

As noted earlier in the chapter, free-choice learners are not the usual suspects either. They include the post-high school adults that Tobin describes (some of whom did not further their schooling), as well as those who did not graduate from high school at all (Falk and Dierking 2010). As the US population ages, there are significant and increasing numbers of young elders also. All of these adults have the potential to participate in science-related special interest groups and leisure pursuits, watch nature, or science specials on television and/or use the Internet to access science-, environmental-, or health-related information (Azevedo 2004; Falk et al. 2007b). Research shows that many adults also visit settings such as national parks, science centers, and botanical gardens to satisfy their intellectual curiosity and stimulation, as well as to fulfill a need for relaxation, enjoyment, and even spiritual fulfillment (Ballantyne and Packer 2005; Brody et al. 2002; Falk 2006). School-age children also spend a significant amount of time outside of school (current estimates are 80–90 % of waking hours are *outside* of school), and some of this nonschool time is devoted to free-choice science learning, most often with family: they visit parks, zoos, and libraries and participate in various after-school and extracurricular experiences, including scouting and summer camps (e.g., Dierking and Falk 2003; Dierking 2013; Rounds 2004). A small but growing movement of home educators also value science and mathematics learning for their children and engage in it regularly (Bachman 2011).

But it is not only the learners who are different: as societies become increasingly *learning societies*, the traditional boundaries and roles that have distinguished various groups of science educators change also. In the twenty-first century, free-choice learning institutions such as museums, the Internet, and broadcast media are assuming ever more prominent roles in the science education of the public–but the facilitators of free-choice science learning are often not classroom teachers. They include nontraditional teachers and mentors, such as after-school youth leaders, professional and amateur scientists, museum educators, educational Web developers, and even parents. This point is not trivial: to make a comprehensive science education system work, science educators must embrace free-choice science learning institutions and organizations, as well as the educators who work within them, as equal partners.

Unfortunately, the value of these educators is not recognized, nor is there a broad-based realization that they require expertise in teaching science in different ways and configurations than classroom teachers and with learners of all ages. Typical teacher education programs only are effective if the free-choice educator plans to work within schools or at free-choice learning institutions that primarily serve schools. A little-known fact also is that most free-choice science educators work 12 months yet earn less annually than their counterparts in classrooms, receive more modest benefit packages, if at all, and have less job security (Bureau of Labor Statistics 2011a, b, 2012).

Taking such a comprehensive approach to whole life science teaching and learning has implications for funding. Currently at the national, state, and local level, more than 95 % of all public resources for education are spent on schooling. Building a more comprehensive educational system suggests rethinking what constitutes public education. If a comprehensive educational system encompasses all community resources that citizens access for learning across their life span, including those in the workplace and free-choice learning sectors, we should also consider how federal funding for education is allocated. Insufficient data exist to conclude that free-choice science learning experiences contribute more to public understanding of science than do in-school experiences, but data certainly support the claim that free-choice learning is vitally important, in particular for youth and families living in poverty (Bouffard et al. 2006). I argue for increased efforts to measure the cumulative and complementary influences of both in- and out-of-school science learning. Also, given that school-based science education efforts currently receive an order of magnitude more resources than free-choice learning options, even a modest change in this ratio could make a huge difference. The data suggest it would be a wise investment.

An Infrastructure for Free-Choice Science Education Research

In addition to an infrastructure that supports the *facilitation* of free-choice learning, there is a need for a *research* infrastructure, perceptively recognized by Tobin also. There is existing research in this arena (and science education researchers focused on it). But like many free-choice education efforts, much of this research has been unseen, undervalued, and significantly underfunded.

For instance, in the area of media that Tobin points to, a number of investigators in the late 1970s and early 1980s, in particular those studying Children's Television Workshop programs, such as Sesame Street, began a series of investigations into the role of television in children's learning and cognitive development. Although most investigations focused on the impact of television on children's school performance, a few examined broader learning impacts—including general literacy, creativity, and children's self-regulation and self-esteem (see reviews by Fisch 2004; Pecora et al. 2006). Specific science-related studies include Potts and Martinez's (1994) investigation of the relationship between television viewing and children's beliefs about scientists and their activities, King's (2000) historical overview of instructional television as a tool in science education, Dhingra's (2003) investigation of how television viewing shaped student's understanding of the nature of science, and the most comprehensive Korpan et al.'s (1997) research on the nature and scope of children's science-related activities outside of school, including television viewing.

A range of fine-grained investigations have also been conducted, including Hall et al.'s (1990) research on how Square One influenced children's problem-solving and Anderson et al.'s review of research (2000) on Blue's Clues' influence on young children's viewing behavior and skills such as sequencing, patterning, and creative thinking. This research was advanced by the creation of the Center on Media and Child Health at Children's Hospital Boston and Harvard's Medical School and School of Public Health in the late 1990s.

There are also emergent research opportunities. With the spread of the Internet and the growing ubiquity of wireless mobile networks, a new generation of free-choice learners, many young, are growing up in a "wired" world (Brown 2000). Referred to as "millennials" (i.e., graduated high school starting in 2000), these learners are avid consumers of traditional media, electronic games, and Web-based information. They not only use digital tools in their everyday activities for communication, school assignments, way finding, and play but also create and exchange personally meaningful messages, tools, and digital products across social networks and online communities (Marriner 2010). While use of the Internet and online media is more commonly documented and researched during school hours, one expects these media to be used even more outside school given that youth have more free time and opportunities for technology access through libraries, friends, and at home. This is a seriously understudied line of inquiry. In particular, there are few systematic longitudinal studies of youths' experience with digital media from childhood to adulthood that document the cumulative effects of digital media upon learning and development across settings (MacArthur Foundation 2006; Hsi 2007).

These examples in just one free-choice learning domain demonstrate the growing recognition of the importance of such learning and of a small, but growing group of scholars. However, these promising trends are not enough to influence change to the degree that is required. We need to create in some cases, and coalesce in others, an intellectual infrastructure for lifelong science education research, building critical partnerships committed to investigating science learning during all of the times and in all of the places it occurs. Further, even though these ideas are new to some, there is existing work on which to build. The unique nature of the settings, configurations, and spaces also dictates the need for less traditional research approaches.

Over the years, efforts have been devoted to building a free-choice learning research infrastructure. These efforts, though, have been diffuse, uncoordinated, and underfunded and thus, insufficient to transform the field. For example, the Studies in Engineering, Science, and Mathematics Education (SESAME) program at the University of California, Berkeley, produced numerous leaders in the field in the mid-1970s to mid-1980s, but the program was not sustained. Similarly, John Koran, University of Florida, Gainesville, supported science education graduate students in this area for many years. In the mid-1970s, John Falk created a research group at the Smithsonian Institution's Chesapeake Bay Center for Environmental Studies, which was focused on free-choice learning; this group was later transformed into the Smithsonian Office of Educational Research (SOER). Unfortunately, the SOER was disbanded in the mid-1980s and a school-based collaborative effort between the Smithsonian and National Academies of Science established in its place, a missed opportunity for the Smithsonian to be a leader in the arena. Falk then founded a 501(c) 3 not-for-profit research organization, the Institute for Learning Innovation, which has accounted for a significant percentage of research in this area, particularly work focused on learning in and from museums.

Most of these efforts were small, and in the case of the university-based ones, they were viewed as add-ons to existing programs. What was lacking was a critical mass of established programs, each with sufficient resources to attract clusters of faculty and graduate students, each cluster pursuing long-term and sustained research aimed at answering basic and applied questions fundamental to the field. This landscape is now changing as evidenced by a growing research community, neatly revealed by two major meetings and the books that emerged from them.

In 1994, with support from the Informal Science Education division of the NSF, the Institute for Learning Innovation hosted a national conference, *Public Institutions for Personal Learning: Establishing a Long-Term Research Agenda.* The goal of the meeting was to discuss the nature of museum learning and formulate a research agenda resulting in a book: *Public Institutions for Personal Learning: Establishing a Research Agenda* (Falk and Dierking 1995), which served as a catalyst for numerous museum research endeavors and many master's theses and doctoral dissertations. By necessity, this effort drew upon social science research expertise outside the free-choice science education community (Barbara Rogoff, John Ogbu, and Mihalyi Csikszentmihalyi were among the scholars attending). A decade later, another NSF-funded meeting was held, resulting in another book: *In Principle, In Practice: Museums as Learning Institutions* (Falk et al. 2007a) which reflects upon the last decade of research in museums. This time, though, there was an established community of researchers who work *within* the community itself, reflected in peer-reviewed journals, conferences, professional associations, and many NSF funding initiatives.

Two leading science education organizations also have provided leadership, one focused on research and another on practice. A free-choice/informal science learning strand was formed in 1995 by the National Association for Research in Science Teaching (NARST) after years in which research in this area was in an "other" strand. Also in 1999, the NARST Board established an ad hoc committee focused on Informal Science Education with the goal of exploring interest among NARST members for additional leadership in this arena. A major product was a policy statement in the area of out-of-school (free-choice) science education research published in the *Journal for Research in Science Teaching* (Dierking et al. 2003).

In 1998, the National Science Teachers Association (NSTA) published a policy statement on informal (free-choice) learning, and in 2000, NSTA leadership established a board seat representing this community of science educators, allowing them to play a larger role in developing policy. And in 1998, the American Educational Research Association also created a Special Interest Group focused on Learning in Informal Environments, and though more general in focus, this group has provided an outlet for scholarship in science education also.

Significant funding also was given to a few consortia that enabled small research communities to flourish. In 2001, with major funding from the US NSF's Centers for Teaching and Learning effort, the Exploratorium in San Francisco, King's College, London, and the University of California, Santa Cruz, established the Center for Informal Learning and Schools (CILS), which focused on the intersection of informal and formal education institutions and provided graduate education for a handful of free-choice learning researchers. Similarly funded in 2002, the Center for Inquiry in Science Teaching and Learning (CISTL), at Washington University in St. Louis, devoted some of its resources to studying inquiry in informal learning environments. Both of these centers were part of teacher education programs and thus focused primarily on free-choice learning research designed to improve schooling. Neither center was refunded by the NSF, although CILS, through the Exploratorium, has successfully procured funding focused on after-school science. Unfortunately, neither of the academic programs continued; thus, no full-time faculty members remain at the three universities who are solely committed to investigating free-choice learning.

A handful of graduate programs focusing on free-choice learning, in particular programs at the University of Pittsburgh, the University of Washington, and Oregon State University, now exist. The University of Pittsburgh's Center for Learning in Out-of-School Environments (UPCLOSE) founded in 2004 with NSF funding is supporting students through doctoral programs in the Learning Sciences and Policy. The program at the University of Washington is part of the Learning in Formal and Informal Environments (LIFE) Center, one of the first of four Science of Learning Centers funded by the US NSF in 2004. One of the LIFE Center PIs is focused on free-choice learning, and although he also engages in teacher education, the program has been able to support a few graduate students interested in free-choice science learning. In 2004, the Oregon State University (OSU), Corvallis, Oregon, with the leadership of NOAA and Oregon Sea Grant, established a graduate program in the Science and Mathematics Education Department in the College of Science. The program is the first comprehensive, lifelong learning research program in the country focused on the role that lifelong STEM learning plays in supporting sustainable communities. Core courses are taken by all students together (there are K-12, college teaching, and free-choice learning options), building a community of researchers that crosses settings, ages, and backgrounds and fostering cross-disciplinary and cross-institutional learning. Each area of concentration also builds a specific knowledge base and expertise. Clearly, more funding in the future is essential if these three programs and others are to flourish. As envisioned at OSU, the future of education should not merely focus on free-choice science learning but on efforts that embrace the idea of science learning, anywhere, at any time.

Other evidence of a growing research community is the number of meetings focusing on the topic and increasing venues for peer-reviewed publications. Over the last five years, there have been two additional NSF-funded meetings, one national, focused on collaborations between researchers in free-choice learning and the learning sciences, and the other international, focused on a 2020 vision for educational research that crosses settings, ages, and backgrounds. Both meetings had goals of building relationships between researchers in different sectors, many of whom may be unaware of one another, or rarely collaborate.

In terms of publication avenues, there have been special free-choice learning issues in the *Journal of Research in Science Teaching* and *Science Education.* And as the result of a special *Science Education* issue edited by Laura Martin and me (Dierking and Martin 1997), Richard Duschl, *Science Education* editor at the time, John Falk, and I established an ongoing section in 1998; originally called Informal Science, changed to Science Learning in Everyday Life in 2006, Falk and I were its editors through June 2011. The section has matured and is recognized as a valuable resource by the international free-choice science education research and policy community. In addition, a new international journal focused exclusively on free-choice learning was launched in April 2011. Named the *International Journal of Science Education* (B), it focuses on science communication and public engagement (Stocklmayer and Gilbert 2011). These publications provide further evidence of the relevance of this domain of science education and could be resources for the entire science education field.

Future Research Directions

If the goal is to embrace a broader notion of learning, it is critical to identify what, where, and how to look for its existence. I envision two key lines of research. The first is a top-down perspective attending to understanding the structure and functioning of existing and potential interrelationships between actors and agents in the learning landscape. The second is bottom-up, beginning with the learner and attempting to understand the ecologies of learning from their perspective. Both lines of inquiry require teams from multiple disciplines; they will also be more robust if they involve researchers and practitioners and occur across extended time frames.

The learning landscape. Although it is not a large conceptual stretch to envision a complex community infrastructure of learning resources that supports and facilitates the science learning that takes place there, it is quite a stretch to understand how such infrastructure actually functions "on the ground" for learners. We know this science learning infrastructure already exists in virtually every community. We also know that, increasingly, these institutional constituents are being supplanted by noninstitutional, more fluid entities such as hobby groups and social networks both virtual and physical. We know little about how this learning infrastructure functions, or how the various pieces intersect and interact. Gaining better insights into its structure and workings is critical.

Ecologies of learning. Throughout the twentieth century, the focus of science learning was often top-down with an emphasis on instruction and curriculum. The organizing framework was the institution, which provided what was necessary for an informed, science-literate citizenry. However, learning is increasingly bottom-up (i.e., controlled by the individual) and highly focused on meeting personal needs and interests. This shift has huge implications not only for how learning occurs but how research on learning is conducted. In the new world order, the learner's role is quite different. Although the reasons for learning may sometimes still be associated with the pursuit of formal learning objectives or career goals, as research cited above documents, the majority of individual-generated science learning increasingly is aimed at meeting identity-related needs unassociated with degrees and employment—science learning related to hobbies, personal curiosities, or individual needs such as environmental preservation in the neighborhood or responding to health issues. This altered learning landscape makes historical top-down models of science learning research obsolete.

In short, we need a more learner-centered approach that places issues of learner motivation and identity at the center of inquiry. One approach to this perspective has been pioneered by Jan Visser (1999), who argues that learning entities at different levels of organizational complexity—from the individual to the social—behave like Complex Adaptive Systems (CAS). He argues that it is critically important to recognize the ecological wholeness of the learning environment. Future investigations of science learning need to situate the learner at the center, rather than the periphery of the learning process. In order to meaningfully understand what learning is, but even more importantly, why it happens, studies also should frame learning within the larger ecological context of an individual's life and the learning landscape in which they live. The emphasis on free-choice learning, and its connection to other aspects of the learning landscape, hold the promise for more effectively understanding and achieving measurable, long-lasting impacts on the public's science understanding and interest and science learning for personal fulfillment as well as for an informed citizenry.

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Chapter 23
Educating for Science Literacy, Citizenship, and Sustainability: Learning from Native Hawaiian Perspectives

Pauline W.U. Chinn

Introduction

My views as a science educator are shaped by my work in Hawai'i, the world's remotest chain of islands. Prior to Western contact in 1778, cultural survival required constant monitoring, analysis, and responding to changing societal and environmental conditions. Long-term, place-based knowledge was associated with an ethic of care (*mālama*) and responsibility (*kuleana*) that supported resilience and sustainability. But the science I learned at school was shaped by content and instruction oriented to continental students. As a science teacher, I found many Native Hawaiian students in my Plants and Animals of Hawaii classes but few in my college preparatory and advanced placement classes. My research explored why few Native Hawaiians chose programs leading to science majors and careers (Chinn 1999b).

In my own College of Education, enrollment data from fall 2004 to spring 2010 showed Native Hawaiians were 13–19 % of students in all programs compared to 2000 census data of 10 % Native Hawaiians and other Pacific Islanders statewide (US Census Bureau, n.d.). Over the same period, they comprised 2.9–12.5 % of preservice secondary science teachers, a group that never exceeded 4 % of all education students. This data sets the stage for exploring underrepresentation in science of Native Hawaiians, *Kanaka Maoli* (Pukui and Elbert 1986) literacy, sustainability, and citizenship.

Many *Kanaka Maoli* families continue subsistence practices that rely on ecological knowledge that seldom connects to school science. Disconnects between knowledge

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valued at school and home may contribute to *Kanaka Maoli* children scoring 11 % lower in math and 10 % lower in reading than peers on the Hawaii State Assessment examinations (Hawai'i Department of Education 2010). At 28 % of public school students, they are more likely to be taught by Japanese (29 %) or Caucasian (23 %) than *Kanaka Maoli* (9 %) teachers (Hawai'i State Department of Education 2010). Castagno and Brayboy (2008) note, "The most obvious, but also most lacking, knowledge among teachers is an awareness and understanding of Indigenous cultures, histories, and political issues" (p. 972). An example in science education is the recent removal of a culturally grounded Hawai'i State science content standard, "*Mālama I Ka 'Āina*, Sustainability" when recommended by an outside consulting group.

A sense of place story is described here to illuminate the intersection of culture, science, and education. Dr. Isabella Kauakea Aiona Abbott, the first *Kanaka Maoli* woman to earn a Ph.D. in natural science, a world authority on marine algae, and my mentor in culturally responsive science education, said being Hawaiian was first among her identities as scientist, university professor, wife, and mother (Chinn 1999a, b). Several years later when visiting her laboratory shortly before a NOAA research and education cruise to the Northwestern Hawaiian Islands (now a World Heritage site named *Papahānaumokuākea*), I understood what this meant. I saw a small banana plant in a bucket, the symbol of *Kanaloa*, god of the sea. Dr. Abbott said it was appropriate to notify the *akua* (gods) and *aumakua* (ancestral gods) of the arrival of the NOAA vessel. Sabra Kauka, cultural practitioner and science educator, presented the banana plant as an offering to the *akua* and *aumakua* of *Papahānaumokuākea* when they reached the islands.

This chapter will address three questions relevant to science education:

1. What is the deeper meaning of Dr. Abbott's offering of a banana plant?
2. What role may *Kanaka Maoli* cultural practices and values play in science education oriented to sustainability, citizenship, and scientific literacy?
3. What role may place-based teacher education play in science education oriented to sustainability, citizenship, and scientific literacy?

Before addressing these questions, I present an overview of major US educational ideologies, introduce place and culture-based education, and develop the concepts of sense of place, mental models, and cultural landscapes.

Locating Place-Based Education in Western Schooling

Schiro (2008) views US education as guided by four major western ideologies: *scholar academic* focused on acquisition of disciplinary knowledge, s*ocial efficiency* focused on efficient preparation of learners to be productive members of society, *learner centered* focused on experience-based preparation for the future, and *social reconstruction* focused on problem finding and problem-solving. Sternberg's (2003) research suggests educational ideologies have implications for student learning and society. He finds high stakes tests emphasizing content mastery (scholar academic and social efficiency) favor the success of middle-class, mainstream students. He faults test-based accountability measures for producing *pseudo-experts* lacking learning experiences that foster critical thinking and real-world problem-solving skills.

Fairclough (2006) holds that "people need resources to examine their placing… between the global and the local…and need from education a range of resources for living within socially and culturally diverse societies" (p. 151). Gruenewald [Greenwood] (2008) provides a place-based starting point: "What needs to be transformed, conserved, restored, or created in this place…[could] provide a local focus for socioecological inquiry and action that, because of interrelated cultural and ecological systems, is potentially global in reach" (p. 149). Woodhouse and Knapp (2000) note that place-based learning's multidisciplinary emphasis, experiential and service learning, broader focus than preparation for a consumer-oriented society, and understanding of self as part of a social-ecological system provides "knowledge and experiences needed to actively participate in the democratic process" (p. 33).

According to Moll et al. (2001), place-based learning's inclusion of non-formal learning associated with cultural activities and informal learning associated with day-to-day experiences enables learners to connect school learning to community and culture-based "funds of knowledge" (p. 134). An Organization for Economic Co-operation and Development (OECD 2010) policy paper notes that recognizing out-of-school and non-formal knowledge can provide economic, educational, and social benefits by "allowing human capital to be used more productively," "improving equity and…access to…education," "making individuals aware of their capabilities and validating their worth" (p. 1), and encouraging lifelong learning.

Hawaiian Sense of Place: A Cultural Model Oriented to Sustainability

Craik (1943) first proposed the notion of a mental model as a representation of external reality coupling knowledge of past events with scenarios of possible actions, enabling response to potential crises. A person's "sense of place" is a form of mental model connecting personal experiences to constructed and natural settings. Jackson (1984), a geographer, views place as shaping personal identity: "It is place, permanent position in both the social and topographical sense that gives us our identity" (p. 152). According to Nisbett and Norenzayan (2002), "Cultural practices encourage and sustain certain kinds of cognitive processes, which then perpetuate the cultural practices" (p. 3). A sense of place is thus a culturally shaped mental model with implications for identity and ways of thinking about and acting within the world.

Maly (2001) describes a Hawaiian sense of place as "the intimate relationship (developed over generations of experiences) that people of a particular culture feel for the sites, features, phenomena, and natural resources etc., that surround them" (p. 1). Abbott (1992) writes, "Hawaiians did not belong to a village but rather to an *ahupua'a*, a land division extending from the mountain heights to the sea" (p. 11).

People lived sustainably within their *ahupua'a* through a system of *mauka-makai,* upland-coastal exchange. Hawaiian place names (Pukui et al. 1974; Clark 2002) associated with resources and nature gods created storied, historical landscapes in which myth and reality entered "into all the affairs of daily life" (Beckwith 1940/1970, p. 2). Many stories, *mo'olelo*, such as those of the gods of fishing (*Kū'ula*) identify "authentic fishing grounds and stations for fishermen in island waters" (p. 20) and describe fish aggregation and spawning sites.

A traditional *'ōlelo no'eau* (proverb), "*He ali'i ka 'āina he kauwā ke kanaka*; the land is a chief, man is its servant" (No. 531, Pukui 1983) expressed the relationship between humans and the land that sustained life. George Kanahele (1986) pointed out a key difference between *Kanaka Maoli* and western worldviews when he wrote, "If we are to be truly consistent with traditional Hawaiian thought, no one really owned the land in the past…The relationship was the other way around: a person belonged to the land. We are but stewards of the 'āina and kai, trusted to take care of these islands on behalf of the gods, our ancestors, ourselves, and our children" (p. 208).

The definition of nature below from *Webster's II New Riverside University Dictionary* (Riverside Publishing Company 1984) suggests a separation of culture and nature in English usage:

> Nature: n. [ME, essential properties of a thing < Lat *natura* < *nasci*, to be born] 1. The material world and its phenomena. 2. The processes and forces that produce and control all the phenomena of the material world. 3. The world of living things and the outdoors. (p. 786)

There are no Hawaiian words for nature or environment in the sense of a world outdoors or physical universe (Pukui and Elbert 1986). Kanahele's statement, "a person belonged to the land" unites economics and ecology as complementary concepts. These ideological differences between western and *Kanaka Maoli* worldviews are examples of Harding's (2003) observation that "all knowledge systems, including modern sciences contain at least traces of their particular histories and ongoing practices; they are all 'local knowledge systems' in this respect" (p. 58). She concludes that "all four conditions of inquiry processes—location in nature, interests, discourses, and ways of organizing inquiry—are shaped by a culture's (or subculture's) 'location' in social relations" (p. 59).

According to Wylie (2003), our location within a social system "systematically shapes and limits what we know, including tacit, experiential knowledge as well as explicit understanding" (p. 31). In the context of American economic and political influence and expansionism (Office of the Historian http://history.state.gov/milestones/1866-1898/Hawaii), it is not surprising that within 200 years of western contact in 1778, Hawai'i transitioned from a sustainable society to one importing 85 % of its food and 95 % of its energy (Hawai'i Sustainability Task Force 2008).

Kanaka Maoli commented on this transition in more than 100 Hawaiian language newspapers published from 1834 to 1948 (Silva and Badis 2008). "Saving the Fish," a 1923 article in *Ka Nupepa Kuokoa*, illuminates the role of competing cultural models in sustainability practices (Ka Nupepa Kuokoa 1923). The writer deplores the decline of fisheries within his own lifetime. He notes that sustainable fisheries were maintained by a knowledge-based *kapu* system enforced by harsh penalties. Practices that conserved and augmented marine resources included prohibiting fishing during spawning seasons and specific months, restricting locations and fishing rights, restricting certain fish to men or high-ranking individuals, constructing and maintaining fishponds (Titcomb 1952/1972), and discouraging eating of fish roe (Titcomb 1952/1972; Barrows personal communication).

After US annexation in 1898, traditional resource management systems were abolished as commercial fishing and open access became the law of the land. But *Kanaka Maoli* views of sustainability persist as seen in a 1994–2005 Hawaiian science content standard "*Mālama I Ka ʻĀina*, Sustainability"; a new *ʻōlelo noʻeau,* "The ocean is our refrigerator"; biorestoration of Kahoʻolawe Island a former bombing target guided by traditional practices (Gon 2003); and the Hawaiʻi 2050 Sustainability Task Force's (2008) recommendation that citizens "Preserve and perpetuate our *Kanaka Maoli* and island cultural values" (p. 12).

Complex Systems, Tipping Points, and Cultural Orientation to Sustainability

In 1999 the National Research Council (NRC) prioritized research that "integrates global and local perspectives to shape a 'place-based' understanding of the interactions between environment and society" (p. 10). "Coupled human-natural systems" are complex and susceptible to *tipping points*, "The point at which a system undergoes a drastic change from one state to a very different one" (NSF Advisory Committee for Environmental Research and Education 2009, p. 53). But they also have "the capacity to learn from experience…and change in response to overall system level behavior" and "to recover from disruption." The report by the Secretariat of the Convention on Biological Diversity (2010) expressed similar concerns and recommended support for "effective 'bottom-up' initiatives…empowering indigenous peoples and local communities to take responsibility for biodiversity management and decision-making" (p. 9).

Sustainability relied upon long-term, place-based knowledge constantly updated through monitoring, analysis, and action before tipping points were reached. Beckwith (1940/1970) observes that riddling competitions "between masters of learning" across Polynesian cultures were tests of knowledge in which the loser might pay with his life (p. 462). The knowledge required to live sustainably within *ahupuaʻa* spanning Mauna Kea's 13,800-ft summit to the open ocean is outlined in a response to a riddle describing 23 *wao* (zones) on the Island of Hawaiʻi (Maly 2001). Resource managers, *konohiki*, integrated knowledge of human and natural systems across levels of organisms, populations, communities, ecosystems, and biomes. Abbott (1992) emphasizes the role played by the *Makahiki na o Lono*, an annual, island-wide event dedicated to Lono, "god of peace, planting, and fertility" (p. 16) in sustainability. For two months during the rainy season, while the king (*mōʻī*) or queen (*mōʻī wahine*), priests, and retainers visited each *ahupuaʻa*, fishing, farming, and warfare ceased, and local, place-based knowledge was integrated into broader, island-wide understandings.

Indigenous Inquiry and Science Education: Perspectives from Hawai‘i Educators

As a sustainable society, *Kanaka Maoli* culture exhibits hallmarks of adaptive learning that parallel the National Science Education Standard for inquiry, including "the dispositions to use the skills, abilities, and attitudes associated with science" (NRC 1996, p. 105). In what follows, educators in *Kūlia I Ka Nu'u*, a professional development project underwritten by an award from the Native Hawaiian Education Act, provide insights into a *Kanaka Maoli* approach to inquiry and science education spanning formal, non-formal, and informal learning (Chinn et al. 2011).

In early 2010, we began planning for two culturally responsive, inquiry-based teacher education courses with the question, "What is indigenous Hawaiian inquiry and implications, if any, for science teacher education?" Six themes emerged from discussions spanning several months. The first five suggest the importance of preparing science teachers to recognize and connect cultural knowledge, practices, and place to their instruction. The last describes barriers to implementation of place and culture-based inquiry.

1. *Hula, Chants, 'Ōlelo No'eau, and Mo'olelo*
   Hawaiian educators view traditional narratives as sources for indigenous inquiry. Moana Lee, an archeologist-educator, observes that "*Mo'olelo* kept alive through hula are so much a part of indigenous research methods. There's a red flower [no longer seen] in a hula I was learning. What a loss that we still have our language but not the land to tie it to." Huihui Kanahele-Mossman elaborated on the ecological information contained in traditional oral literature:

   > That is the difference between scientists and Hawaiian practitioners—both hear the song, but when we cannot see what is being referred to it hurts us because our chants are also our genealogies. Our sources of research are these living things in our songs and stories, as books, journal articles and research studies are sources of information for western scientists.

2. *Indigenous Identity and Cross Generational Cultural Expectations*
   Napua Barrows' culturally grounded critique of an invasive seaweed removal workshop organized by marine scientists inspired a school and community-based program connecting culture, stewardship, and science instruction:

   > I thought [the native limu] should be restored. [Now] I work with *limu* restoring and replanting, since the area I live on Maui is where my *tutu* is from and I learned the family *mo'olelo*. She took me around, showed me all the lands and gave me the *kuleana* to take care of this. What I take care of at Waihe'e has extended to all of Maui and connected with other islands. It has generated a lot of excitement--we work with the communities, get the kids involved. We were raised with some of it and we're ready to get back. And I can hear my grandmother. That's where the knowledge is waiting there for us if we open that door. Then you have to go with it after that, you just can't drop it.

3. *Place-Based Cultural Practices*

Interaction with and knowledge of place are culturally inseparable from responsibility, *kuleana*, and active care, *mālama*. Sabra Kauka takes teachers and students to Nuʻalolo Kai, a site that "shows the longest continuous sequence of occupation on Kauaʻi" (Abbott 1992, p. 10):

> Nuʻalolo Kai chose us. In 1992 we took back our first re-interment as a result of the Native American Graves Protection and Repatriation Act (NAGPRA). The trail was only a goat trail so the *kūpuna* led us there. We realized that we needed to begin to *mālama* that special ʻ*āina*, we had to clean and clear. Nuʻalolo Kai is still dynamic. We are studying it hoping to once again to live that place and bring others in to live that place.

4. *Indigenous Knowledge, Practices, and Place-Based Teaching*

Michelle Kapana-Baird teaches both satellite navigation (global positioning system) technology as well as non-instrumental methods in her Maunalua Bay biorestoration project.

> Recently our students were in charge of invasive algae cleanup. A member of the community organization asked, "What are your GPS markings?" I said, "I don't have one today." "So how do you know it's accurate?" I knew she wanted to know the markings of my site, what are the points….these things, it's all the science. So I told my student, "Mele, Hawaiians didn't have GPS. This is what Kaʻau told me when we use to sail into Kualoa. You'd find a high land mark and a low land mark." And I know the lady is listening. "What is a good landmark and what makes sense to you?" So I asked her to line it up with the *hālau*, (canoe house) a coconut tree, the Norfolk tree and the mountain. The lady came to me and said, "You triangulated your sights, I know you know what you're doing."

Mahina Hou Ross, a Hawaiian language immersion teacher on Molokaʻi, integrates traditional, place-based practices in his standards-based science lessons.

> Uncle Mac Poepoe of Moʻomomi says, "If you can teach the kids what the *kūpuna* taught us, we have a chance." We have four sites we visit each quarter; the kids actually see the health of the different parts of Molokaʻi. We take students into the water, look at the fish and check what they've been eating. Like *kole* (*Ctenochaetus strigosus*), to get the cycles and seasons for spawning, you've got to cut them open to find out. Then you've got to eat, so we fried them up. And show the learning is standards-based--they see the relevance of the curriculum when they go hunting, fishing, diving.

5. *Place and Culture-Based Professional Development*

Ag-science teacher Matthew Kanemoto describes how place-based professional development connecting formal to non-formal and informal science helps teachers transform their instruction:

> [Teachers] get to see, smell, feel and do. We built a bioremediation system for the agriculture program at Kohala High School and re-established *lo'i* that were over one hundred years old. We visited Konawaena High School where Maverick Kawamoto built a bioremediation system that uses watercress, aquatic plants, *kalo* and mollusks to clean the nitrogen-rich effluent water from their fish tanks and cooked our food in an *imu* (underground oven). Educators take what they have learned and apply it in their own classrooms and communities. Hawaiian placed-based education can open up and unlock the hearts and minds of our local Hawaiian students and bring relevance and meaning to science concepts and curriculum by drawing upon what our kids already know and love…the *'āina* (land) and the *kai* (sea).

6. *Institutional, Cultural, and Societal Barriers*
   Institutional barriers to place-based, indigenous methods of inquiry include schedules that interfere with community-based learning, high stakes tests that discourage time-intensive inquiry projects, and teachers lacking interdisciplinary knowledge and culture-science preparation. Michelle noted that pollution and development of once-loved places and urban, consumer-oriented lifestyles have disrupted continuity of place-based knowledge and practices. Moana recalled comments about science from the Hawaiian community: "About 25 years ago I was at a public meeting. One of the things being rejected by the Hawaiian community was science. Scientists are no good. Science was outright rejected because it had nothing to do with culture."

Discussion

Three questions oriented the writing of this chapter. The first, "What is the deeper meaning of Dr. Abbott's offering of a banana plant?" may now be addressed in light of understandings of culturally shaped mental maps (Nisbett and Norenzayan 2002; Craik 1943) and standpoint theory (Harding 2003; Wylie 2003) that view inquiry, values, and knowledge as being shaped by location and experiences in particular socioecological settings. As a prominent scientist, Dr. Isabella Aiona Abbott's culturally significant offering from a NOAA research vessel signified the intersection of two cultural knowledge systems. The protocol recognized the Northwest Hawaiian Islands as a Hawaiian place and questioned the "assumption that modern Western science alone has the most desirable resources with which to grasp nature's order" (Harding 2003, p. 55).

The second question, "What role may *Kanaka Maoli* cultural practices and values play in science education oriented to sustainability, citizenship, and science literacy?" is answered by the adoption of *Mālama I Ka ʻĀina*, Sustainability, as a state science standard in 1994. It combined science literacy with a sustainability ethic and sought to connect in-school, non-formal, and out-of-school learning. Its recent removal in a standards review by an outside consulting group underscores teachers' comments about the challenges of teaching in schools oriented to mainstream content and instruction. However, many teachers persist, recognizing the importance of instruction grounded in lived experiences, culture, place, and authentic inquiry.

The third question, "What role may place-based teacher education play in science education oriented to sustainability, citizenship, and science literacy?" is answered by science educators who commented above on the importance of professional development that (1) integrates culture and science, (2) provides models of sustainability science programs, (3) develops a sense of place, and (4) supports collaborations that provide opportunities to co-teach, co-learn, and develop new knowledge. Teaching and learning, concepts that differ in power and knowledge in English, are unified in the Hawaiian word *aʻo*, meaning both to teach and to learn (Pukui and Elbert 1986).

Implications for Place-Based Teacher Education and Curriculum Design

Teachers who recognize and can incorporate students' "cultural and cognitive resources with great *potential* (sic) utility for classroom instruction" (Moll et al. 2001, p. 134) do more than engage diverse students in meaningful learning. They provide educational, social, psychological, and future economic benefits to underrepresented and alienated students who otherwise might not persist in school.

In Hawai'i, place and culture-based science teacher education, community values, and actions continue to be guided by *Mālama I Ka 'Āina, Sustainability*. Teachers who connect science learning to real issues in their students' lives and places recognize the need to develop expertise in local resources, issues, and Hawaiian landscapes. They embrace non-formal and in-school learning when they realize it is professionally empowering. They continue to seek knowledge and tools to engage their students in active learning supporting resilience and sustainability in a complex, changing world. These indications of teacher agency are aligned with the OECD 2010) position that

> Non-formal and informal learning – learning that takes place outside formal education institutions – can be a rich source of human capital. Recognition of non-formal and informal learning makes this human capital more visible and more valuable to society at large. (p. 1)

Conclusion

Western scientists and policymakers now recognize the role of indigenous knowledge and practices in resource management and sustainability. The Secretariat of the Convention on Biological Diversity (2010) notes, "The loss of biodiversity is frequently linked to the loss of cultural diversity, and has an especially high negative impact on indigenous communities" (p. 7).

The saying "*'A 'ohe pau ka 'ike i ka hālau ho'okahi,* All knowledge is not taught in the same school" (No. 203, Pukui 1983) says one can learn from many sources.

Community members chose *Mālama I Ka 'Āina*, Sustainability as a Hawai'i State Science Content Standard because it supports problem-solving, systems thinking, and civic engagement oriented to sustainability. It foreshadowed the NRC's call for a "research framework that integrates global and local perspectives to shape a 'place-based' understanding of the interactions between environment and society" (1999, p.10). *Mālama I Ka 'Āina*, Sustainability continues to inform professional development oriented to science literacy, citizenship, and sustainability. K12 teachers who recognize and are able to incorporate resources of culture and place in science instruction are more likely to increase their *Kanaka Maoli* students' engagement and learning in science.

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Chapter 24
From Local Observations to Global Relationships

Xavier Fazio and Douglas D. Karrow

The one thing I've learned is how unhealthy our school field must be….that there's a total lack of anything in our field. When you go beyond our field, we do see things, so it makes me wonder what the kids are playing on out there? So beyond an academic outcome but more of a social conscience one, what do we have our children playing on, and what do we have to do as a school to ensure that there is something healthy out there? (Interview with an elementary teacher, WormWatch monitoring, June 2007)

The above quote illustrates a teacher's concern for her students and the local school environment in which they learn and play. This unexpected concern arising from the experiences of teachers and students while exploring their school environment raises some interesting questions regarding the purpose of schools and the roles of teachers and students within schools: Should schools, as part of larger educational systems, plan educational experiences for students in environments to unveil local ecological concerns? And should these teachers and students address these local ecological concerns? In an attempt to address these questions, in this chapter we attend to the topic of local and global relationships in science education and provide details of our research in Canada, in which we are examining an ecological monitoring partnership among elementary and secondary schools, a faculty of education, and a federal government agency. Specifically, we report how the *Ecological Monitoring*

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and Assessment Network citizen-science program called *NatureWatch* was adapted by schools and explore the successes and challenges of this partnership. We begin by describing how *NatureWatch* was implemented within local elementary and secondary schools. We illustrate the promise of using such school-based ecological programs as contexts for authentic ecological science and community-based monitoring practices. With important implications for school achievement policy in schools, our empirical studies provide perspectives on how to envision outcomes from environmental monitoring practices as key indicators of school achievement in areas such as environmental literacy and science education. We conclude by highlighting the potential of school-based environmental monitoring partnerships in developing global relationships between schools in Canada, United States, and other nations, providing an important global dimension to school achievement. We envision that these experiences will help Gen R youth to be better prepared to engage in social responsibility and activism.

Ecological Monitoring

Brief Overview of Environmental Monitoring Programs

Environmental scientists in universities and government agencies from many jurisdictions in North America are engaged in a variety of environmental and science education programs through citizen-science or school-scientist collaborations (Cornell Lab 2010). Citizen science is a general term that is used to describe the public participating in authentic scientific studies in cooperation with researchers. Some examples of environmental monitoring programs in North America that involve citizen scientists include *Discover Life, Environment for the Americas, Our Shared Forests, and Project FeederWatch*. Generally speaking, these programs are efforts of volunteers (age or experience varies) that gather (i.e., making local observations) and analyze ecological data about their environment, furthering ecological research. The *Ecological Monitoring and Assessment Network* (EMAN) is a partnership between Environment Canada and Nature Canada which coordinates multiple ecological monitoring programs for citizens (Environment Canada 2010). EMAN is made up of organizations and individuals across Canada, all involved in ecological monitoring, and has the objective of better detecting and reporting on ecosystem change. Interested individuals with limited scientific expertise can participate and successfully implement these programs.

The NatureWatch *Program*

NatureWatch is a suite of ecological monitoring and assessment programs which include *FrogWatch, PlantWatch, WormWatch,* and *IceWatch* (Fig. 24.1). Participants follow the program's specific ecological science protocol for collecting particular

Fig. 24.1 *NatureWatch* suite

environmental monitoring data, whether this be identifying frog species by their species-specific call, collecting and identifying earthworms and their abundance, observing ice-on/ice-off dates on bodies of water, or observing the flowering dates of various plants (*NatureWatch* 2010). Collected data sets are recorded and organized by the citizen scientists and then entered onto Environment Canada's EMAN database; the data are interpreted by environmental researchers and used by government policymakers (Karrow and Fazio 2010). Participants receive feedback on their data, which is uploaded onto a centralized database accessible to environmental scientists and the public.

Citizen scientists and their institutional affiliates have demonstrated the potential to contribute to community-based monitoring (CBM), "a process where concerned citizens, government agencies, industry, academia, community groups and local institutions collaborate to monitor, track, and respond to issues of common community concern" (Environment Canada 2003, p. 8). While some currently used protocols have been identified (Schibsted 2007), there are few exemplars of monitoring protocols adopted for use in schools. As professors of science and environmental teacher education, we first learned of *NatureWatch* while attending an environmental education conference some years ago and became curious about why schools were not using the program with students; the prospects for using the program in schools seemed exciting.

NatureWatch *in Schools*

To support environmental education (EE) and science education curriculum goals, in 2006 we coordinated a collaborative research partnership with an elementary school and a government ecological monitoring agency (EMAN). Before this, no

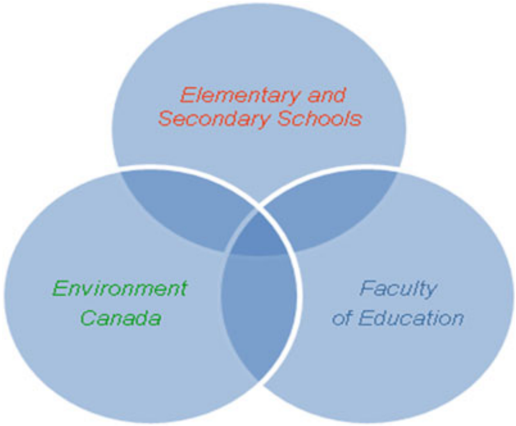

Fig. 24.2 Representation of the collaborative partnership

such research partnership existed, partly because *NatureWatch* had never been implemented within schools, and no research between this form of citizen science and schools had been considered in our region. Our research into school-based ecological monitoring catalyzed our efforts to initiate and secure this research partnership. This partnership was extended to include an additional elementary and secondary school in subsequent years (Fazio and Karrow 2009). Our research focused upon (a) the viability of these programs with elementary and secondary schools and (b) how such programs could educate and nurture environmental literacy of students and teachers.

Figure 24.2, above, represents the collaborative partnership involving schools, a government agency, and a university.

Local Monitoring as Indicators of Soil Health

One of the *NatureWatch* programs, *WormWatch* (2010), addresses soil ecological health by inviting student and teachers (i.e., citizen scientists) to collect data on earthworm species and habitats on school property and natural areas adjacent to the school. In our collaboration, the teachers and students explored their local school environment while learning about the importance of worms and soil ecology as aspects of ecosystem health. Participants were engaged by collecting data on worm species and abundance, along with environmental data such as soil temperature and soil type (Fig. 24.3).

They also learned about scientific inquiry, the importance of using protocols, how to report findings, and processes for providing environmental scientists with environmental data that had the potential to influence government public policy (Environment Canada 2003). Both elementary and secondary schools chose to implement the *WormWatch* protocol within their respective school and community

Fig. 24.3 Students classifying worm species and collecting data in the field

Fig. 24.4 Teachers' *WormWatch* professional development

settings. This particular program was feasible given the constraints of these schools vis-à-vis curriculum standards, time, and available resources. Professional development was provided for the teachers before implementing *WormWatch* by the EMAN coordinator from Environment Canada (Fig. 24.4). The coordinator also provided some resources (e.g., identification cards) and off-site consultation when the program

Fig. 24.5 Elementary school students recording data within the classroom

was implemented. The importance of the program coordinator cannot be overstated. This person is *critical* for sustaining any citizen-science program involving schools and communities: She/he is the gatekeeper to the professional scientific community and the government programs.

WormWatch: Observing a World Below

In this section, we summarize several observations of what *WormWatch* "looks like" when implemented within an elementary school (Karrow and Fazio 2010). Implementation consisted of two kinds of student learning experiences: those that occurred within the classroom, and which were aimed at supporting later field experiences, and those that involved multiple afternoons of field experiences, during which worms were collected and identified (Fig. 24.5).

Within the classrooms, worms became a theme of study for students across the junior grades (grades 4–6). Whenever possible, teachers integrated these monitoring activities into language arts, visual arts, science, and social studies. This emphasis provided students with content knowledge about earthworm anatomy, physiology, and ecology. What we observed were students exposed to a variety of learning experiences, some requiring zoological and ecological knowledge (an academic outcome), and also developing empathic notions such as care for living things (a nonacademic outcome). For example, in a particularly original creative writing activity, students were required to write a letter of sympathy to a "worm family member" whose "worm-child" had been eaten by an American robin, an experience the students had observed on many occasions after a rain on school property. Generally, the junior division students and teachers took great pride in the monitoring experience: The teachers decorated bulletin boards with student work, made presentations to parent advisory councils, publicized activities within the school newsletter, lobbied the school administrator for additional resources, and spent their own money to obtain basic equipment and materials to support field work (e.g., shovels, hula-hoops, and various containers). All of these activities were done to support learning of *WormWatch* and to position students to maximize their field-day activities over a period of a month. These activities developed students' knowledge and skill-set, as would be measurable on a typical achievement test—but also exposed them to experiences that nurtured or stimulated a change in attitudes (e.g., empathy, care, inquisitiveness) with respect to their local environment.

These field experiences occurred at four sites on or near school property. These sites consisted of a soccer pitch (students and teachers called this "the field"), a drainage ditch adjacent to the field, an adjacent deciduous forest area, and a naturalized area (grassy location that was not manicured) in front of the school property. The ecological observations occurred during late May and June. Conditions were less than optimal because of an unusual drought. Each Friday, a teacher and a parent volunteer worked with a group of about 25 students at a specific site. The students were selected for heterogeneous grade groupings—in essence, students from grades 4–6 blended together. During one session, grade 7 students assisted junior students with collecting tasks (e.g., they did the digging for the younger students). The teachers took ownership for one monitoring site, while student groups rotated each week, from one site to the next, collecting, identifying, and recording the abundance and variety of worm species. The final aspect of the project was that the students' data were compiled and entered onto the EMAN website. But ultimately, the data seemed less important than the experiences that we observed at the school as the study unfolded.

Throughout the experience, we observed comprehensive planning and organization by the participating teachers. The teachers demonstrated their own style of working with the *WormWatch* program and the students during these field days. For example, one teacher gathered her students in a circle, devoting 10–15 min at the end of the collecting session for group sharing and discussion. She would ask them to share their results—number and types of worms, soil conditions, and air and ground temperature—in addition to asking them to justify their observations and interpretations. The students identified inconsistencies or discrepancies in their field data. The students appeared engaged, on-task, and enthusiastic about *WormWatch* activities. Indeed, as one of the participating teachers told us when she was interviewed at the end of the monitoring process, students would pester her every week asking: "When are we going out again to *watch worms*?" Who would have believed that observing worms is so much fun!

Important Outcomes

We believe that teachers and students (and even administrators) engaging in school-based ecological monitoring programs can foster academic outcomes and make students more ecologically knowledgeable with respect to their local school environment and community. *WormWatch,* described earlier, is one of many examples of an authentic ecological science program accessible to schools. There is no doubt why so many teachers and school administrators that we've talked to ask why these programs are not more accessible to youth through an environmental curriculum.

Many ecological monitoring programs are part of a regional, national, and international citizen-science monitoring efforts that operate by partnering with professional scientists and environmental agencies. Such programs help identify and monitor ecological changes affecting our environment. Learning more about the distribution of earthworm species, for instance, can be used to help improve soil health by reclaiming damaged natural sites by environmental professionals. From such monitoring experiences, students participate in scientific inquiry, learn ecological concepts, and contribute to the scientific community—all of which are important scientific and academic outcomes for students to pursue in schools. Although these ideas may be important to administrators and legislators, we also want to discuss the *nonacademic outcomes* associated with these programs.

Nonacademic outcomes may best be thought of as significant learning outcomes that are not easily or traditionally measured. Examples include citizenship, health, and ethical character. These types of outcomes are generally accepted by society as implicit aims that schools have some responsibility for implementing and are foundational to a civic democracy (Ladwig 2010). Environmental monitoring and community responsibility are dimensions of any ecological monitoring experience, and each has great potential for encouraging nonacademic outcomes such as environmental attitudes and action competence. While academic outcomes tend to be characterized by knowledge and skill advances and nonacademic outcomes are more attitudinal and action oriented, we do not want to create the impression that they are separate. Any experience has nested within it a potential for various knowledge, skill, attitudinal, and action outcomes: This is the nature of experience itself. A concept that we have found useful for unifying these interconnected outcomes is *environmental literacy*.

Most definitions of environmental literacy include dimensions concerning environmental knowledge, skills, dispositions, and action (e.g., Roth 1992). The knowledge inherent within environmental literacy includes understandings of local and global ecologies within the geographic places and interrelationships of citizens and their practices. Environmental literacy focuses on developing reasonable sustainability principles underlying the community and environment. Examples of environmental skills and attitudes include shared agency, decision-making, and empathy. "Action competence" involves the importance of social action in addressing environmental issues of local concern. We collected some evidence to this effect in our study of the *NatureWatch* program. This program can develop to focus on local environments, address academic *and* nonacademic outcomes, and help cultivate responsible youth who will become decision-makers and advocates for their local community. Yet there are some challenges that must be overcome for this program to be fully recognized in schools in Canada, the United States, and abroad.

> *Addressing academic and non-academic outcomes, helping cultivate responsible youth who will become decision-makers and advocates for their local community*

Challenges Sustaining Environmental Monitoring in Schools

Our research with schools and environmental monitoring (Fazio and Karrow 2009) indicates that the extent to which teachers and students function as citizen scientists and potentially contribute to community-based monitoring (CBM) is premised on (a) the validity of ecological data being collected and (b) the participants' understanding of environmental literacy. These are important concerns for any citizen-science project (Krasny and Bonney 2005). Scientists and educators working together to implement appropriate ecological procedures improve data editing and analysis and provide and receive feedback on their ecological data collection. Such contributions, along with thorough observer education and support, can advance citizen-science programs at every level in schools and universities. In fact, citizen-science data have been used in legal cases and are reported as credible scientific findings in peer-reviewed science journals (Lougheed 2010). This highlights the importance and significance of citizen science for the public good. Imagine its potential in North America!

To reach the full potential of these types of programs, teacher participants will require a deeper understanding of the purpose of community monitoring, along with having the necessary human and material resources required to implement different ecological monitoring protocols. This increased understanding can be accomplished by targeted professional development. With more research focused on elaborating and expanding these initial ideas, additional public commitment is needed to promote a more coherent and comprehensive citizen-science model applicable for schools (Fazio and Karrow 2009). Indeed, for any of these valuable programs to succeed and be sustainable in schools and communities, a more coordinated and comprehensive effort is now needed.

We were astonished when, in 2008, the Canada Federal Environment Ministry announced *significant* reductions to EMAN's operating budget in lieu of pursuing other environmental issues that they considered more politically expedient.

Ironically, some of the data collected for Environment Canada, which is also available for policymakers to use to better evaluate the state of the environment in Canada (such as climate change trends), included *NatureWatch* monitoring data—the very program being eroded because of the withdrawal of government support.

Beyond Traditional Accountability Measures

Environmental Education Policy

Within our jurisdiction in Ontario, a recent policy document was released for K-12 education called *Acting Today, Shaping Tomorrow* (Ministry of Education 2009). Environmental education in Ontario schools is now reinvigorated after a long period of disregard. This new educational policy outlines academic and nonacademic outcomes for students in schools, detailed below:

> These goals [outcomes] are organized around the themes of teaching and learning, student engagement and community connections, and environmental leadership. The first goal promotes learning about environmental issues and solutions. The second engages students to participate actively in practising and promoting environmental stewardship, both in the school and in the community. The third stresses the importance of providing leadership by implementing and promoting responsible environmental practices throughout the education system so that staff, parents, community members, and students become dedicated to living more sustainably. (p. 8)

Clearly, environmental monitoring programs such as *NatureWatch* in schools address these educational outcomes.

Comparable educational guidelines are available in the United States, such as the California Environmental Protection Agency's *Education and the Environment Initiative* (2009). What is unique about the California environmental education program is that it is the result of a multi-agency education and environmental partnership involving, among others, the State Board of Education and the Natural Resources Agency. Although this school policy in environmental education differs from what we have in Ontario, it appears equally effective in terms of promoting the meaningful curricular changes we have found to be successful through our citizen-science research program.

Accountability Measures for Environmental Outcomes

Supporting the coherence of policy goals and environmental education practices in schools using current accountability processes is challenging. For instance, a science education outcome (e.g., understanding carbon cycling) is linear in terms of its inception, implementation, and then its measurement—something that high-stakes testing can assess effectively. But what about significant nonacademic outcomes, such as action competence, environmental ethics, and stewardship? The progression from outcome to measurement for these latter outcomes is not linear; it is more complex. Certainly, high-stakes testing cannot effectively perform this measurement task. So what are schools and districts going to do about this challenge? Fortunately, there are lessons to be learned, in part from other jurisdictions, including recent policy frameworks within our province of Ontario, as well as initiatives in the United States and England. Certainly, many global relationships could be established to engage in meaningful conversations about these topics.

The Ontario policy example described earlier provides a sensible framework that might be suitable as a starting point. Part of this policy is adapted from the *Asia-Pacific Guidelines for the Development of National Environmental for Sustainability Development (ESD) Indicators* (UNESCO 2007), which provides a general rubric for effect indicators, measuring short-, mid-, and long-term results for schools and districts. While not an absolute standard, it's a useful starting point for educational jurisdictions to contemplate and may serve as a framework for developing a more holistic appraisal of nonacademic outcomes.

In England, the Office for Standards in Education (Ofsted) presently uses professional inspectors to not only assess academic outcomes but also to report on student and school characteristics (Rothstein and Jacobsen 2009). For instance, one school outcome assessed by the inspectors, which has relevance to environmental literacy, is the extent to which learners make a positive contribution to the community.

In Ontario, and using a similar assessment approach, is a now well-established program called *EcoSchools*. This program uses an extensive portfolio and external review process to certify environmental initiatives in elementary and secondary schools (Ontario EcoSchools 2010). Versions of this sort of school-based program can be found in jurisdictions in the United States (Eco-Schools USA 2010) and the United Kingdom (Eco-Schools UK 2010). As described earlier, school-based environmental monitoring activities clearly remind us about the importance of both academic *and* nonacademic outcomes, which are significant for youth achieving environmental literacy. But in an era of accountability, if nonacademic outcomes are not attended to, how will they be championed by administrators, teachers, and citizens in the community?

The National Assessment of Educational Progress (NAEP) in the United States, which currently assesses and compares students in academic subjects (math, science, language), had a broader accountability mandate when it was first designed over 40 years ago (Rothstein and Jacobsen 2009). Early activities of the NAEP administered survey questions and used trained observers to assess social responsibility skills and behaviors such as teamwork and cooperation, civil liberty, and citizenship in students. Clearly, the knowledge and capability to assess nonacademic outcomes exists in our educational systems which can complement traditional accountability measures. So, what is stopping us from expanding on our past endeavors?

Local Monitoring and Global Partnerships

Local Ecological Literacy

In our research, we have observed how teachers and students working with professional facilitators and scientists over a period of time and engaging in local monitoring activities can develop various scientific competencies such as observing, classifying, and analyzing ecological data. The students become more literate, conversational, and articulate about ecology, and they became more literate about their local environment. Moreover, they were engaged in activities that encouraged them to think more deeply about their community. Using the environment as a context for learning is not novel but seems to have been pushed to the back burner over the past decade, having not been financially supported. *NatureWatch* is an example of a student-friendly program that has powerful learning opportunities for all stakeholders of schools and requires minimal expense. In addition, we envision the ecological data produced from environmental monitoring as a credible indicator of school achievement that can be readily assessed. These datasets would increasingly expand the notions of achievement and other indicators of school health used by school officials and researchers.

Using environmental monitoring programs as a holistic indicator of school achievement goes beyond academic high-stakes testing and seems appropriate and necessary for assessing the achievement of Gen R youth. Schools exist in relation to their local community; they are necessarily interrelated. What one does in schools is impossible to separate from what happens in the environment. Articulated almost 100 years ago, John Dewey's words continue to remind us:

> To learn from experience is to make a backward and forward connection between what we do to things and what we enjoy or suffer from things in consequence. Under such conditions, doing becomes a trying; an experiment with the world to find out what it is like; the undergoing becomes instruction--discovery of the connection of things. (Dewey 1916, p. 140)

Further, we can learn from Dewey's notion of "doing, discovery and connection" in linking beyond the immediacy of the school and in relation to other nations' schools. Many school-based international monitoring programs might now be used as indicators of environmental and school health, extending beyond local school observations, with views towards global educational communities. This perspective supports the idea that the responsibility of schools is to think globally and act locally and to think locally and act globally. All such efforts are interrelated and collectively support an ethic of environmental responsibility.

Global Environmental Literacy

In terms of global relationships, citizen science and other forms of environmental monitoring partnerships may help expand global connections between schools in Canada and the United States, as well as in other nations. For example, the

Global Learning and Observations to Benefit the Environment (GLOBE 2010) is a long-term, school-based science and environmental program. Many science educators are already using GLOBE in their classes. GLOBE's aims are to support students, teachers, and scientists collaborating on inquiry-based investigations regarding their local environment and global Earth systems. Another international example, which focuses on biodiversity collaboration, is the *Environment for the Americas* (EFTA 2010) program. This nonprofit organization provides information, resources, and networking opportunities about birds and bird conservation, from Canada to South America.

> "The major problems in the world are the result of the difference between how nature works and the way people think."
>
> Gregory Bateson 1904-1980

While schools are not the only users of these programs, we can imagine how schools can become better positioned to contribute more fully to these collaborative initiatives by providing national and international ecological data for policymakers in response to migrating bird diversity, animal populations, and earth systems data. Such data might include habitat size, seasonal phenology, and water quality but also could include many other types of layered information. Increasingly, ecological data are critical in responding to global climate change initiatives, because of changes now occurring in multiple ecosystems that are ecologically connected over thousands of miles.

NatureWatch provides opportunities for everyday citizens (students and teachers) to engage collectively with communities and scientists to monitor simple ecological indicators such as plant phenology, worm abundance, and frog and pollinator diversity, to help assess the fitness of environments. Collecting and reporting such data will provide policymakers with evidence needed to make more informed decisions on environmental policy. We suggest these things could also be used for school policy. Redirecting budgets away from such important programs is nonsensical. Without such programs, not only will the public have little historical evidence to support environmental policy, but it will also impact what outcomes are deemed important for influencing Gen R youth and their relationship with local and global environments.

As an environmental monitoring program, *NatureWatch* is one of many models that focus on local environments which can help responsible youth become decision-makers and advocates and better appreciate the relationships between where they live and what changes are happening in the world around them. As the teacher in the quote at the beginning of this chapter expressed, "….what do we have our children playing on and what we have to do as a school to ensure that there is something healthy out there" should pause our thinking: It should challenge our accepted wisdom about what outcomes are important for schools. In short, we advocate rethinking outcomes and finding synchrony between academic rigor and environmentally responsible achievement in schools. Funding ecological monitoring programs that focus on school-based programming will invigorate long-term environmental collaborations and create conditions for developing knowledge, skills, *and* attitudes that Gen R youth will require for their future.

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Chapter 25
Our Shared Forests: Ecuador and the Southeastern United States' Migratory-Bird Partnership

Anne M. Shenk

How do you organize schools and develop programs that empower US students with the values, knowledge, and skills to understand issues such as pollinator decline and global warming, be wise consumers of a myriad of products that potentially deplete earth's resources, communicate with Indian customers, or work alongside a Mexican coworker? What is needed to adequately prepare Generation R to become tomorrow's leaders in an increasingly global playing field where the only constant is change?

I have grappled with these issues since my early years as an educator when I taught high school biology and middle school science in the Fiji Islands as a Peace Corps volunteer. Culture shock assaulted, soothed, and nurtured me during my two-year tenure in that tropical country. My students walked to school barefooted and hurried out of the classroom to experience the thrill of an airplane as it flew overhead. Having grown up in the northeastern United States, my standards for food, housing, and religion were vastly different than what I encountered in the Fiji Islands. In Fiji, poverty was widespread and "westernization" was marching into the local towns. Having spent my previous three years teaching at a residential environmental education center, I blended my classroom science lessons with frequent outdoor learning experiences on the school site, including adjacent sugarcane fields and nearby coral reefs.

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These early experiences rooted my approach to teaching and instilled a yearning for investigating global education. Later as an educator, I used international meals and festivals as methods for exploring global issues and promoting cultural understandings. But as my thinking progressed, it became clear that deeper strategies were needed to address emerging challenges. Today's high school students graduate in a world that is fundamentally different from the one in which we grew up. We're increasingly living in a globalized society that has an entirely new and difficult set of challenges.

The future is here. It's multiethnic, multicultural, and multilingual. But are students ready for it? Vivien Stewart (2007)

While there are multiple education models that can be examined to investigate these global challenges, in this chapter, I will focus on a project titled *Our Shared Forests* (OSF) that embodies various components that open doors to global insight and can empower youth to better understand and care for the environment.

Our Shared Forests: Background and Overview

Linking Local Education to Global Learning and Conservation

Our Shared Forests is a migratory-bird partnership involving Ecuador and Georgia. It is implemented through integrated conservation, bird monitoring, and environmental education. In Ecuador, OSF targets research-based habitat conservation throughout the Choco-Andean Corridor of Northwestern Ecuador, deemed one of Earth's top five biodiversity hot spots by Conservation International. The OSF program aims at creating awareness about ten bird species that migrate between the two regions and a myriad of associated social, ecological, and political issues.

With funding initially from the US Fish and Wildlife Service (USFWS), OSF was designed to become socially, environmentally, and financially sustainable. It is a binational partnership between the Ecuadorian NGO Fundación Maquipucuna, the University of Georgia's State Botanical Garden, and the APROCANE associations of farmers and landowners in Northwestern Ecuador. Overall, OSF brings light to the importance of conserving existing habitats and reestablishing fragmented habitats of neotropical migratory birds. Neotropical migratory birds spend their winters in North America and their summers in Central or South America. The habitats of these birds are increasingly fragmented as trees are cut down for timber, development, and agriculture.

In its educational component, OSF provides tools and training for parents, teachers, and youth leaders. In Georgia schools, these programs guide 2nd–8th grade students in activities that encourage critical thinking and foster an understanding of the people, plants, and animals in their communities. Students develop understandings of bird habitats on their school sites as they investigate migratory birds. The project uses a multidisciplinary approach that blends scientific information, conservation priority setting, habitat restoration, and education. As an intended consequence of the learning strategies and tools, learners grapple with global environmental issues (forest health, migratory birds, loss of biodiversity, monoculture crop production, pollinator decline), cultural issues (poverty, cultural identity, coffee and cacao production), and sustainable development issues (cottage industries, shade-grown crops, fair trade, organic produce). Although political boundaries divide our world through invisible state and national lines, birds fly freely from one continent to another, ocean currents have no regard for coastlines, and airborne pollutants such as acid rain are not limited to end-of-pipe effluents.

The Our Shared Forests Project Development Model

The Our Shared Forests program provides an interesting example for how education programs can be developed and delivered. Each stakeholder in the OSF program has different research questions and goals, yet these are linked with a common vision of high-quality global education for students and land protection for wildlife and people in Ecuador and Georgia.

Key questions for the OSF program development team	
Education	How can we hook students' interest in learning about and conserving their local environment while investigating related global environments on other continents?
Research	What are the optimal conditions for producing shade-grown, bird-friendly, organic coffee in the highlands of Ecuador and cacao in the lowlands of Ecuador?
Conservation	How can a resource of global significance, such as the biodiversity of the Chocó-Andean region of Ecuador, be conserved from encroaching land development and habitat fragmentation while still providing economic opportunities for local populations?

Increasingly, funding agencies such as the USFWS require such collaborations; the education partner and component gives voice to the research and conservation activities, and the research and conservation component provides "real-world" content and contact with scientists for the education program. The OSF collaboration opened global gateways of knowledge and conservation and inspired students to explore beyond their national borders.

Components of the OSF Environmental Forest Education Program

The OSF program provides standards-based instructional units, resources for family science nights, opportunities for educational fundraising with "green" coffee, and teacher and student exchanges (both real and virtual). OSF curricular units guide students to value the importance of habitats in both North and South America as they learn about neotropical migratory birds. Teachers introduce students to the forest in their own "backyard" and its similarities and differences to the forests of Ecuador, with particular focus on ten bird species that migrate between Georgia and Ecuador, including the summer tanager and the Blackburnian warbler.

Children learn that in April, summer tanagers leave their winter homes in tropical forests just north of Quito, Ecuador, and wing their way to nesting grounds in Georgia's hardwood-pine forests. Each fall, these small red songbirds, weighing no more than a DVD, make the return trip, mindless of political borders. Travel between the Americas is not easy for these beautiful creatures. The flight is between two and 3,000 miles, and the birds require fuel in the form of food. There are storms to contend with, and power lines, and predators to dodge. The birds navigate by internal compasses and make the trip year after year. Learners also discover that protecting habitat along the flyway is important for the birds but also for the people in the countries where the birds live.

When the birds arrive in Ecuador, they depend upon forests to reproduce and survive. Since their habitat is increasingly depleted to make way for oil pipelines, agriculture, and other pressures from an increasing number of humans, conservation initiatives and local education programs are vital. The OSF curricula introduce these land threats as well as sustainable land-use practices with shade-grown coffee and cacao. As part of the USFWS grant, researchers investigated optimal growing conditions for these two important economic crops; they also considered shade-tolerant fruit trees as understory plants of the Ecuadorian coffee plantations, which could provide suitable food for the birds.

This approach to education links multiple concepts and stakeholders in the learning process, including research, education, and action for the environment. It also involves children from two different cultures, as well as North American bird-watchers and Ecuadorian farmers. It explains how the local economics of coffee and cacao are connected to global markets, with effects extending to the citizens of Georgia, and it hooks student interest by introducing them to species they can see locally, on their school grounds and in their backyards.

Beyond the Textbook: *Learning in the Outdoors*

> If we want children to flourish, to become truly empowered, then let us allow them to love the Earth before we ask them to save it. (David Sobel)

Children today can find out about anything on the planet as they surf the Internet – but many don't know what kind of trees are in front of their homes, and many cannot correctly name three common birds in their neighborhoods. They can watch live events on TV but are increasingly oblivious to the life going on outside their windows. Kids are often just not connecting with nature – in any way.

The term ecophobia was coined to describe a fear of the natural world and environmental issues. David Sobel, in *Beyond Ecophobia* (1996), explains that "what is emerging is a strange kind of schizophrenia. Children are disconnected from the world outside their doors and connected with endangered animals and ecosystems through electronic media" (p. 4). Sobel goes on to explain that children are being exposed to unsettling environmental issues at an early age, but are not first being given the opportunity to develop close personal connections with nature.

These matters were taken into consideration in the OSF program, where children are given opportunities to develop connections with nature right on their school site, an underutilized yet readily available resource. Examples of school-site activities include observing and identifying birds, surveying biodiversity of the bird habitat, recording data in journals, investigating feeding behavior through inquiry experiments, planting bird-friendly vegetation, mapping school-site vegetation, and playing bird migration games.

Increasingly it is recognized that learning need not be confined to the walls of a school. In fact, "researchers who study learning are increasingly questioning the assumption that learning happens only in the classroom. Their evidence strongly suggests that most of what the general public knows about science is picked up outside school, through things such as television programs, websites, magazine articles, and visits to zoos and museums – and even through hobbies such as gardening and bird watching. This process of science education is patchy, ad hoc, and at the mercy of individual whim, all of which make it much more difficult to measure than what is considered formal instruction. But it is also pervasive, cumulative, and often much more effective at getting people excited about science – and an individual's realization that he or she can work things out unaided promotes a profoundly motivating sense of empowerment.

As children spend time observing and investigating school-site plants and animals, they develop an understanding of the needs of these organisms. From this knowledge may grow a desire to improve the health of their school-site habitat for the birds, insects, butterflies, and other organisms that share their site. As the students become increasingly curious about these creatures, they discover that some of the local birds migrate. But where to? Hence, children become interested in the forests that their birds share on other continents. And they also become interested in the people who live there, who observe their birds – possibly the very same birds they observe on their school sites! From these interests emerges a desire to meet diverse children from faraway places.

Beyond the Textbook: *Service Learning*

From the desire to further investigate their migratory birds and to meet children in faraway places, the young learners are motivated to action. This action, which we call service learning, has resulted in groups of learners participating in green, shade-grown, bird-friendly, coffee fundraisers. Funds have been used to support various projects, including developing bird habitats on the school site and buying digital cameras to send to an Ecuadorian village school who share their birds.

While a village school in Ecuador may not have the funds to purchase a digital camera, they have been happy to accept the invitation to partner with a school in Georgia. Once both schools have digital cameras, students begin sharing photos of their birds and other features of their local ecosystems. These digital-photo exchanges inevitably grow to include photos of the children, their homes, their food, celebrations, pets, and more. And foreign language education comes into play, too, as Spanish e-mails are translated into English and vice versa.

OUR SHARED FOREST

Learners progress from:

⇩

CONTENT KNOWLEDGE

⇩

UNDERSTANDINGS

⇩

'GREEN' FUNDRAISING

⇩

SERVICE LEARNING

⇩

GLOBAL UNDERSTANDINGS

In the service-learning component, students apply their newly acquired knowledge about the needs of school-site organisms to real-life needs on their school site. This opens the doors to further global learning. The chart below depicts how issues that children investigate on their school site can lead to fundraising and school-site projects that improve or restore the local habitats.

Issues	Related service-learning ideas
Lack of food for birds	Construct bird habitat; install feeders
Lack of cover for birds	Plant trees
Soil erosion	Plant ground covers
Lack of birds	Plant bird-friendly vegetation to attract birds
Quality of habitat in "shared" habitat in S. America	Develop partnership with school in Ecuador
A lack of knowledge about the needs of birds	Educate the school community about the needs of local bird populations

In addition to addressing an environmental need on the school site, such service-learning activities can help improve students' communication and cooperative skills, motivation, citizenship, and awareness of community and global issues. Service-learning initiatives support the philosophy that schools should share part of the responsibility for our larger society.

Grow Programs and Ideas with Strong Partnerships

Strong partnerships grow strong programs and good ideas. As we internationalize our schools, who should we invite to join us in these ventures? Three partners that were important to the OSF program are described below.

Science Centers as Partners

With funds from the USFW grant, we developed eight OSF science night kits and leveraged these resources to establish a network of OSF "hub" sites in Georgia. Most states have a statewide environmental education association. In Georgia, this association is called the Environmental Education Alliance of Georgia. We worked through this organization to locate science centers (such as nature centers, zoos, or botanical gardens) to serve as the OSF hub sites. In addition to loaning the science night kits to local schools, the hubs sponsor OSF educator workshops and promote the educational coffee fundraisers. This is a win-win situation: the science centers get access to a high-quality education program they can offer their constituents, and schools receive access to high-quality programs that bring more families and communities members into their schools. Further, the overall goals of the OSF program are being met as the project is implemented statewide.

A Coffee Wholesale Business as a Partner

How can we most effectively involve businesses to support our global education efforts? In the OSF program, we partnered with 1000 Faces Coffee (www.1000facescoffee.com), a local coffee roasting company that is a direct distributor of bird-friendly coffee produced by farmers in the Choco-Andean Corridor of Ecuador. We developed presentations and other instructional resources about the coffee-production process, and the company posted these resources, along with information about staging school coffee fundraisers, on their website. Employees from the company attend some of the science nights and help educate families about coffee and cacao terms, including bird-friendly, fair trade, shade-grown, and sustainability.

The OSF coffee fundraisers provide schools with funding opportunities by providing families with excellent coffee. Students market the coffee with knowledge of its historical origins, where it was grown, who grew it, and its relationship to our native songbirds. We were not surprised to discover that many parents were happy to support the sale of coffee that was cultivated without artificial fertilizers or pesticides and whose profits directly benefit the farmers who grow it. This activity replaced in part the more traditional fundraising events that involved cookie dough and wrapping paper. The sale of this coffee is not only a great way to raise funds as part of a service-learning project – it also benefits the wildlife of Georgia and Ecuador, as well as the coffee-farming families.

Parents as Partners

Parents are a logical and common partner in learning, but we often miss opportunities to meaningfully involve them. In the OSF program, we partnered with our statewide Parent-Teacher Association (PTA). PTA is a perfect partner for (1) the OSF green coffee fundraisers, (2) establishing partnerships with schools in Ecuador, and (3) promoting and sponsoring science nights. PTA leaders typically select their annual fundraisers early in the school year. As an official partner with PTA, we are invited to present at their statewide conference each summer. Hence, we inform the PTA presidents of the OSF resources available to their schools at the beginning of each school year.

The OSF science nights provide a venue for bringing families and additional local collaborators together to celebrate and experience science. A science night is an evening program of activities in which students and their parents work together on meaningful, age-appropriate science activities. The program uses readily available, low-cost materials. The OSF science night kits were developed to encourage the entire school community to become engaged in "doing science." A science night "passport" guides family members on a (virtual) migration trip from Georgia to South America. Again, this model demonstrates that science should not be limited to textbook learning but can be experienced by the whole family in a fun, relaxed atmosphere in an evening or on a weekend.

In summary, partnerships and collaborations greatly enhance our ability to internationalize our schools. Encouraging businesses, science centers, parents, and other community organizations to participate meaningfully in our schools greatly increases our capacity to prepare learners for the world of tomorrow.

How Can We Support Generation R and Their Teachers?

> Unless someone like you cares a whole awful lot, nothing is going to get better. It's not. (Dr. Seuss, *The Lorax*)

Dr. Suess is one of my heroes; he has inspired generations of youth to care for the environment. In one of his many beloved books, *The Lorax* (1971), he hooks young children's heart, inspires love for nature, and in some cases moves youth to action. He and a myriad of other great thinkers poetically present the problems on earth. How can we help teachers prepare Generation R to solve global environmental problems? How can we help teachers motivate their learners to care, a whole awful lot?

- What are the implications from the OSF project and other successful EE projects to Generation R?

- What needs and trends do we, as educators and policy makers, need to be mindful of as we march into uncharted territories?
- How do we turn our knowledge and understandings into action plans?

There are no suitable recipe-book answers. But I will share my observations and research as a veteran science educator, a mother, and "wanderer" on planet Earth.

Implications for Policy Makers

The Changing International Playing Field

Significant trends have challenged, and continue to challenge, America's educational systems in the international arena. Other countries have invested heavily in secondary and higher education – so it's not just that American education has lagged but that many other countries have caught up. The impact of globalization has far-reaching impacts on all of our educational systems. In his book *The World is Flat* (2005), Thomas Friedman explains that he arrived at his central metaphor after hearing a software executive in India explain that the world's economy was being leveled because there were no more barriers to entry. Due to the communications revolution, an entrepreneur in India has the same access to global production facilities and markets as a US counterpart. Friedman quotes Bill Gates, founder of Microsoft, as saying that 30 years ago, if you had the choice of being born a genius in Mumbai or Shanghai or an average person in Poughkeepsie, you would have chosen the latter because your chances of living a prosperous and fulfilled life were much greater. "Now," Gates says, "I would rather be a genius born in China than an average guy born in Poughkeepsie." What a shift in the global playing field of opportunity for young people!

Addressing the Needs of Classroom Teachers

As part of my collaboration with scientists, educators, and coffee farmers in Ecuador, I have traveled to this country multiple times. In 2009, I went there again with a group of 20 Georgia science teachers and witnessed the depth of personal and professional growth that travel to another culture and environment evokes. Teacher comments included:

- *The experience strengthened my understanding that we are a global community and truly depend on other environments and countries. I can only hope to make my students more aware of the vital connections and dependencies on the environment. I can't wait to teach my unit. I now have the life experience and passion to share it with my students.*

- *This has been an extraordinary experience that I will never forget. Seeing how others live is a life changing experience.*
- *The course provided an unparalleled opportunity to experience many aspects of biology and sociology that can be translated into classroom experiences for students.*

These teachers returned highly motivated to tackle the challenges in their classrooms and communities and with a desire to globalize their teaching practices. More recently, I co-instructed a five-day environmental education workshop that was based outside at the State Botanical Garden of Georgia. On the final day of the workshop, participants were asked to recall some highlights. One teacher stated, "being in the botanical garden and on the trails renewed my spirit and reminded me how exciting it is to be outdoors." Another teacher mentioned how thrilling it was to see a snail in the woods. In both cases, teachers benefited greatly from professional development opportunities; they learned by being immersed in nature as well as in a different culture and were motivated to share similar experiences with their learners.

A growing body of scientific evidence identifies strong correlations between experiences in nature and children's ability to learn. The term "nature deficit disorder" was coined by Richard Louv in his book, *Last Child in the Woods: Saving our Children from Nature Deficit Disorder* (2006). He (and others) describes what happens to young people who become disconnected from their natural world, and he provides strong evidence to back up his ideas. Louv links a lack of nature to some of the most disturbing childhood trends, including rises in obesity, attention disorders, and depression. Our children are part of a vast experiment – the first generation to be raised without meaningful contact with the natural world.

Those of us who identify ourselves as naturalists, conservationists, or environmentalists probably have had some transcendent experience in nature – often early in life, perhaps while playing in a leaf pile, or in a field, or another outdoor area. David Sobel (1996) states it well, "What's important is that children have an opportunity to bond with the natural world, to learn to love it, before being asked to heal its wounds" (p. 9). Richard Louv (2006) notes, "immersion in the natural environment cuts to the chase, exposes the young directly and immediately to the very elements from which humans evolved: earth, water, air and other living kin, large and small. Without that experience we forget our place; we forget that larger fabric on which our lives depend (p. 7). If well-known Harvard ecologist E. O. Wilson's (1984) "biophilia" hypothesis is correct – that humans are hardwired to get their hands wet and their feet muddy in the natural world – then a child's love of nature is more than a childhood pastime: rather, it is essential to their motivation to learn about the environment and to serve as stewards of Earth.

A central question that we must ask address, then, is this: What support and tools do public teachers need to prepare their learners to be wise decision-makers about the global environment within this ever-changing global field? We need to provide venues for rich, meaningful, professional development for teachers as well as opportunities for their learners, to encourage venture into nature. In the OSF program, children investigate and care for birds on their site. Every school site is a place that provides life support for wildlife and humans. At some schools, children may begin by observing and viewing organisms that live in cracks in school pavement or by observing and measuring plants growing up on fences. It is, in any case, a start. As children are outside, a butterfly, flower, or other “teachable moment” may catch their interest, and a seed is planted for loving nature, investigating science and more.

We need to provide opportunities for teachers to get outside, learn how their school-site ecosystem works, and discover how to make the school site an exciting extension of their classroom. We need to open the doors of our schools to a larger nature that ignites children’s love and interest in the nature. As the saying goes, “we cannot love what we do not know.” As the doors to the schools are opened, teachers are empowered and indeed have a moral obligation, to plant hardy seeds of environmental understandings.

Many communities have thriving school and community gardens that afford opportunities for children to develop firsthand relationships with nature. Many schools have daily after-school programs to serve the child-care needs for working parents. After-school leaders are often hungry for activities to conduct with their learners. Let’s provide support for a multitude of opportunities for teachers to get their children outdoors, through existing and new venues.

Building Capacity for Business Partnerships in Our Schools

While many very meaningful business partnerships exist in today’s schools, there is room for growth and improvement. When my children were attending public schools in Georgia, typical business-school partnerships included local pizza and ice cream establishments who partnered with schools by providing rewards (pizza and ice cream) for children or food for special events such as fall festival. While this is a great way for local businesses to support schools, additional school partnerships are needed. We need to encourage businesses to share their business expertise and philosophies with our children. One example from the OSF project includes having a local coffee business working with students on coffee fundraisers and providing education to learners on topics related to the rationale for producing and marketing fair-trade, organic products. While excellent business-school partnerships can be highlighted, many more such partnerships are needed.

It is becoming commonly accepted that knowledge about the rest of the world is no longer a luxury; it is a necessity. Toward this end, we must envision the business, public policy, and philanthropy communities working together to prepare students to succeed. They must also work together on lofty tasks such as developing a corps of teachers skilled in international education, modernizing our nation’s high schools, and promoting the use of new technologies and distance learning across the board.

First and foremost, schools are preparing students to be caring knowledgeable citizens with skills to thoughtfully tackle the challenges of the future. Clearly, schools prepare youth for jobs of the future, and businesses are a source of funding and their places of work provide opportunities for students to become employed.

Partnering with Nonformal Science Education Centers

I have worked in out-of-school science education centers for much of my professional teaching career. The term "nonformal" has been applied to institutions such as nature centers, zoos, botanical gardens, and museums. The term "formal" teaching institutions refers to our public and private schools. The nonformal institutions tap rich resources and link learners with the scientific community while extending the walls of the schools into the community. Such collaborations might be viewed as transferring some of the responsibility (burden?) of teaching from the shoulders of the teachers to a broader community of support. And international programming is increasingly vital to the missions of these nonformal institutions, just as it is to our public schools.

The OSF program at the State Botanical Garden of Georgia is an example of such programming. Such institutions often have programs that link children directly to scientists who conduct international research. The National Science Foundation has recognized the value of these kinds of educational networks and has help financially support effort to link schools to out-of-school intuitions for many years; many other funding organizations have helped, as well. For example, funding for the OSF program was provided by the US Fish and Wildlife Service. Policy makers can encourage the development of such partnerships and can seek opportunities to enhance funding to strengthen them whenever possible.

Summary

> We need to develop a new definition of education for success in the early twenty-first century. This conclusion has been drawn before, but the urgency with which we must act has never been more acute. Our economic strength, national security, the health of our democratic institutions and cultural vitality all depend upon appropriately training the next generation of leaders. Hundreds of local schools in the U.S. have already revamped their teaching and learning processes to accommodate these new demands through means such as international magnet programs, new language programs and integrating international education into the range of subject areas, from social studies and literature to math and science. The task now is to extend international education to all primary and secondary schools. (Stephanie Bell-Rose, Goldman Sachs Foundation and Vishakha Desai, Asia Society 2002)

As we prepare Generation R to take on the multiple challenges facing our society, knowledge about the rest of the world is no longer a luxury: it is a necessity. Let's step up to challenge with grace and expediency.

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Part V
Responsibility with Decisions, Policymaking, and Legislation

Chapter 26
Frankenstein, Monsters, and Science Education: The Need for Broad-Based Educational Policy

Bradley D. Rowe

Amid the hype and paranoia about the failure of American schools, there is an energizing optimism in education these days. Many believe that our present moment is ripe for imagining and implementing a better education for youth. Along with the other contributors of this book, I am one of these believers. Yet it has also become clear that we cannot (and should not) rely on narrow policies to introduce the type of broad-based and comprehensive educational changes we need for youth in contemporary society. Despite much rhetoric for change during the 2008 presidential campaign, the current President does not differ much from his predecessors concerning the *purposes* of education: the main goal of education is, and has been, to help individuals secure employment so America will remain competitive in the global economy. In this chapter, I challenge this popular way of thinking about education by illustrating the problematic aspects of an education policy predominantly devised to meet this goal. This chapter is not about any particular policy problem *in* education, but the problem *of* education – namely, that it is becoming increasingly narrow, more technical, and reduced to the status of job training.

I hope to show that expanding the dominant paradigms of educational research and policy is important for thinking about not just how education *can* be improved but also why education *should* be improved. On the heels of No Child Left Behind and at the onset of Race to the Top, what is lacking in many research and policy circles is a set of basic questions concerning what education is for and what sort of persons education should cultivate. Although such questions tend to go overlooked for the sake of practical convenience, I contend that they are at the heart of all areas of education.

In joining J. Myron Atkin (2007), I will discuss how revitalizing longstanding modes of human understanding by incorporating the wisdom of the humanities (e.g., philosophy, history, the classics, and literature) provides valuable insights in

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thinking about education, particularly with respect to science education. As a case in point, I will take Mary Shelley's novel *Frankenstein* (1831) and use it to: (1) highlight the problems and dangers of implementing narrow education reforms, and (2) explore why a more comprehensive direction in science education is needed. Ultimately, my hope is that readers will come away from this chapter with a renewed appreciation for the many purposes of education, and perhaps a richer, more comprehensive understanding about the possibilities of policy in science education.

Policy in Education

Educational policy is a very large tent. It is well beyond the scope of this chapter to adequately describe this nuanced and expansive field. Educational policy can encompass a breadth of issues and areas, including, but certainly not limited to: assessment, accountability, student achievement, teacher quality and development, curriculum, funding, equal access, and school choice. Additionally, all of these areas can be explored at the early childhood, middle, secondary, and post-secondary levels. Policy can be developed, decided, and carried out in a number of ways – through legislation, a judicial decision, curricula reform, a board of education, a business-school contract, or a code of conduct. Thus, it can be problematic to paint "educational policy" with a broad brush by over-generalizing it as one thing. However, while there are many variations in the field, it is the commonalities that are the focus of this section.

A policy, in the most general sense, is a plan of action for solving a specific problem or achieving a stated goal. While this may seem fairly simple, how exactly policy occurs in education is much more complicated. Educational policy is always a political endeavor because it always involves decision-making about the problems and goals of communities (Stone 2002). Whether large or small, a community must decide on strategies regarding the what, when, and how of education. Any choices concerning the strategic allocation of goods, services, or recourses requires group thinking and group action. As difficult as it may be to accept for those who want immediate or clear-cut solutions, policy is laden with human interests and values, because policy happens within human communities (Stone 2002). And values and interests are not always clearly defined or even understood by those engaged in the political process; in fact, they are usually implicit, complex, and socially shared.

Decision-making in communities involves dynamic power relationships between many groups and individuals. In public education, a range of actors and coalitions are involved in decisions that affect their communities, including teachers, administrators, parents, state and local boards of education, legislatures, committees, lobbyists, unions, and other school and district authorities. Each brings their own values, agendas, and often different goals to the policy table. In the networks of education policy, conflict of interest is the norm, not the exception. Competing interests take time to unravel, trade-offs must be made, and plans of action will invariably satisfy one party while disappointing another. Thus, policymakers must be malleable and allow their reforms to remain open for revision and adaptation. Getting something accomplished, then, is a matter of open dialogue, cooperation, negotiation, and reconciliation – all the necessary components to political life.

One major challenge in education is that policies are debated and devised by those who hold limited terms and tend to hold limited – sometimes even whimsical – interests. For better or worse, short-term solutions frequently take priority over long-term reform. Stakeholders want to get things done, even when political expediency conflicts with consequential change. As President Obama himself acknowledged after the sweeping defeat of Democrats nationwide in the 2010 midterm elections: "We were in such a hurry to get things done that we didn't change how things got done" (White House 2010b). As I will discuss later, being too concerned with quick-fix tactics in education can greatly limit more meaningful possibilities and horizons. It is not that the technical strategies are not important: In fact, they are central in education policy. However, if we become too consumed with questions of relevancy and applicability, then our understanding of human education and its purposes is severely lacking (Hostetler 2010).

It should be clear by now that, although we may wish it to be the case, policy is not a straightforward or even rational process (Stone 2002). If it was, then it would be as simple as identifying an educational problem, pinpointing a solution, and then implementing practical applications to solve the problem. But since policy making does not happen in this simplistic fashion, complexity emerges with the very first step of identifying the problem. For a community to identify something as a "problem" that needs fixing, value judgments must be employed. That is why the editors of this book have collected the perspectives, knowledge, and experiences – the stuff that informs human values – of a variety of authors, students, teachers, parents, youth activists, and other education and policy actors. We feel that much more is needed than a report or research study to guide thinking and action in educational policy as it is concerned with science education. While many of us will draw on particular reports or research studies, as a collective, we have come together to share our values about what it means to educate ecologically and socially responsible citizens. We are not just concerned with *how* policy is to be implemented or simply with *what works*. We are also concerned with *why* policy should be implemented. And a conversation about why policy should be implemented entails asking questions about the goals of education.

Goals of Contemporary Public Education

> There was a time when educators became famous for providing reasons for learning; now they become famous for inventing a method. –Neil Postman (1996, p. 26)

Many well-intended folks in education believe that if there is more scientifically-based research conducted on, for example, teaching methods, student achievement, or classroom management, then many of the problems in schools can be addressed and solved. The problem with this way of thinking is that it misses the forest for the trees. In this case, the trees are the technical approaches to education research and policy that are mainly concerned with what works in carrying out change, and the forest is the broader moral discussion regarding the reasons why we want change and what we are implementing change for – that is, the goals of education. David Labaree (1997) accurately puts the problem this way:

> Goal setting is a political, and not a technical, problem. It is resolved through a process of making choices and not through a process of scientific investigation. The answer lies in values (what kind of schools do we want) and interests (who supports which educational values) rather than apolitical logic. Before we launch yet another research center (to determine 'what works' in the classroom) or propose another organizational change (such as school choice or a national curriculum) we need to engage in a public debate about the desirability of alternative social outcomes of schooling (pp. 40–41).

The purpose of this section is to do just that: Engage the main goals of education in our present moment.

Labaree identifies what he sees as the three main goals for American schools: (1) democratic equality, (2) social efficiency, and (3) social mobility. Education for the goal of democratic equality stipulates that teaching students about and for citizenship and democratic participation are essential purposes to schooling. The goal of social efficiency focuses on education's role in helping students acquire employment so that they may do their part in contributing to the collective economic well-being of the society. Both of these goals, Labaree points out, are for the public good. The social mobility goal is different. It is highly individualistic, competitive, and posits schools as functionaries in preparing students to move up the social ladder. For Labaree, the social mobility goal poses the greatest threat to public schooling, as it essentially turns public education into a private commodity in which schools are, first and foremost, places where market choice, status, and wealth undermine the civic goals in education. I agree with Labaree, but it seems to me that the two goals of social mobility and social efficiency have morphed. In the current gloomy economy, the social efficiency goal of education is dominating the political–educational landscape, which I believe has created an even more dangerous situation for the public and civic purposes of education.

Labaree discusses how social efficiency is not a new goal in education; it has long been an aim for American schools to help train productive employees so that society runs more efficiently. In fact, we are now at the point where this aim has become so deeply entrenched in the collective consciousness of Americans that it is taken for granted as a, if not *the*, main purpose of education. This is a big problem and warrants criticisms for at least two main reasons.

First, critical points of view should be brought to the fore since President Obama – arguably the most prominent national figure within the past 40 years for social, political, and cultural change – does not challenge the same old story of schools serving primarily economic purposes. Second, and more importantly, there are very real dangers to the education of citizens in a democratic society when education is presented and packaged as specialized job training for a particular occupation. When *public* education is conceived and carried out chiefly as preparation for the *private* job sector, it predominantly serves the interests of the marketplace, industry, and corporations, not the interests of the public. Private values such as money-making, competition, materialism, production, and consumption are triumphing over public values such as good citizenship, community activism, equality, and justice. Anyone who believes that becoming a good citizen is something that needs to be learned in schools, and that civic learning necessitates a deep understanding and appreciation of democratic public values, has very good reason to turn a critical eye toward the type of reform initiatives the President has put in place.

The Race to the Top program is President Obama's signature contribution in education reform. It is a massive federal grant program instituted as part of the American Recovery and Reinvestment Act of 2009, a historic piece of legislation engineered to "stimulate the economy, support job creation, and invest in critical sectors, including education" (DOE 2009, p. 2). Race to the Top rewards the states that propose and carry out effective educational reform plans, as defined and prioritized by the "powers at be" at the U.S. Department of Education and the White House. The social efficiency goals of the program overshadow all other purposes of education. For example, the first of four "core education reform areas" is "adopting standards and assessments that prepare students to succeed in college and the workplace and to compete in the global economy" (DOE 2009, p. 2). As such, state officials and policy reformers are in a frenzy to implement new standards, raise test scores, and institute rigorous accountability measures and more assessments in order to meet the Department of Education's demands for funding. Consequently, in meeting the Department's demands for funding means that states must meet the Administration's education goals. Since states had to clearly lay out exactly how their policies would honor the core aim of social efficiency, and since social efficiency is so widely taken for granted as a purpose of education at the state and federal levels, policies are being put in place throughout the country that reinforce this goal. As clearly stated in Race to the Top, successful states "will offer models for others to follow and will spread the best reform ideas across their States, and across the country" (DOE 2009, p. 2).

The social efficiency goal takes on even more authority in Obama's vision of higher education, as the *main* purpose of education is to ready students for jobs in the global economy. The hopeful expectation that President Obama would propose a higher education different from his conservative predecessors that focused on the aims of democratic participation and civic virtue has eroded. In depressive economic times, in a speech on education to students at the University of Texas, the President made it clear why he was taking the time out of his schedule to give a speech on education, using the justification that "Education is *the* economic issue of our time." The President's remarks were dominated with the following phrases: "lead the world," "out-compete," "growth sectors of our economy," "prepare our graduates to succeed in this economy," "lead the global economy in this century," "workers compete," and "make sure American remains number one" (White House 2010a). Of course, there were his usual warm and optimistic overtones, but on a campus to the youth that elected him for political and social change, nothing substantive was said about education cultivating an engaged citizenry, justice, democracy, or peace. And certainly there was nothing mentioned about a more holistic education for deep understanding, human flourishing, art, beauty, love, or any of the other vast possibilities of education.

On rare occasion, Obama uses language that is far from politically astute, giving education a more transcendent purpose. In fact, the President's most bold and humane ideas regarding education can be found in his talks to younger school-age children. In a back-to-school speech to elementary, middle, and high school students in Philadelphia, the President affirmed that education is about more than just "getting a good job" and should give "each and every one of us the chance to fulfill our promise, and to be the best version of ourselves we can be" (White House 2010c). He goes on to discuss the role education plays in building mutual respect and character, and the importance of children embracing the wonders and diversity of human life.

While the President may feel in his heart that education is about more than getting a job, his rhetoric continually returns to the ultra-competitiveness of social efficiency. In the same talk, he says, "The farther you go in school, the farther you go in life. And at a time when other countries are competing with us like never before, when students around the world…are working harder than ever, and doing better than ever, your success in school is not just going to determine your success, it's going to determine America's success in the 21st century" (White House 2010c). While the social efficiency goal is not the only goal for this Administration, it is by far the most celebrated and valued, and thus occupies the prevailing role in both rhetoric and formal programs.

These criticisms do not mean that education should not serve as a way for youth to acquire gainful work, for education does and should do this. But as cultural critic Neil Postman (1996) eloquently puts it, when the goal of social efficiency (what he calls the God of Economic Utility) is "elevated to the status of a metaphysical imperative, we are being told that we have reached the end of our wits – even worse, the limit of our wisdom" (p. 36). Farmer, poet, and essayist Wendell Berry (1990) expresses a similar sentiment, when he wrote the following during the Reagan administration: "It seems that we have been reduced almost to a state of absolute economics, in which people and all other creatures and things may be considered purely as economic 'units,' or integers of production" (p. 130). I am troubled that Postman and Berry are terribly accurate here. When youth think of their educational experience, as well as their sense of self, others, and the world, around earning capital, competing, and consuming, *then earning a living becomes the very same thing as living a human life*. Human beings are economic beings for sure, but we are also moral, spiritual, artistic, and philosophical beings – and these aspects need to be as much a part of education as the economic. To incorporate a multitude of humanist perspectives and experiences, we must do a much better job in rethinking and challenging the knowledge claims that ground what actually goes on in schools and classrooms on a daily basis.

Education Research and Policy

Despite what we scholars might wish, educational policy is frequently divorced from educational research (Potter 2010). Schools do not need academic scholarship to implement a policy. For example, a local board of education can identify a problem, address it with a vote, and carry out a plan of action – all without policy research influencing or guiding its decision. However, educational research is increasingly becoming a decisive factor in education policy networks, especially at the federal level (Orland 2009). And there is an unfortunate trend in the relationship between education research and policy.

The type of educational research that is considered rigorous enough to influence policy is overwhelmingly scientific – that is, research of educational phenomena driven by scientific methods (Orland 2009). I deem this trend *unfortunate* because if policymakers and legislatures are genuinely interested in understanding and addressing the nuanced questions concerning what we are educating for and who we are educating, then there is not a broad enough spectrum of human perspectives in scientific educational research (Bullough 2006; Hostetler 2010). As discussed earlier, educational policy is about competing interests within communities; it involves human values and a never-ending culture of political persuasion and bargaining. Thus, it is doubtful that the single-handed scientific pursuit of educational problems alone will suffice if we want to enrich the lived experiences of youth and future generations through a holistic educational experience (more on this soon).

For those who submit to the view that empirically based scientific research will best influence policy, the knowledge and wisdom of the humanities are seen as less valuable – or altogether irrelevant. The conjecture here is that research perspectives that are not scientific or experimental are not applicable to the real world of schools and classrooms. One reason for this view is a mistaken belief that the theoretical disciplines like philosophy do not employ the evidence-based practices that will produce objective knowledge, which in turn, can be straightforwardly applied to practical solutions. I think this is a misguided way to approach education research and policy – a narrow view of education that makes policy research dry and unmoving, and makes policy discussion and debate uninteresting, and often inaccessible, for teachers, parents, students, and the general public.

I criticize this trend toward the scientific because I strongly believe that empirical research should not *monopolize* impacts on policy decisions. And I am not alone in this criticism. In one of the most influential and highly acclaimed books on public policy, *Policy Paradox: The Art of Political Decision Making* (2002), Deborah Stone writes, "What communities decide about when they make policy is meaning, not matter. And science cannot settle questions of meaning" (p. 379). Similarly, J. Myron Atkin (2007) affirms, "Scholarly styles rooted in science are inadequate intellectual tools for reaching decisions that center on identifying just what schools and teachers *should* strive to accomplish" (p. 67; italics original). The reason that Atkin emphasizes *should* is because science alone does not provide the whole picture with respect to what we ought or ought not to do – that is, how human beings should act. Science is the study of what is, not the way the things ought to be. Works of literature and philosophy, on the other hand, go beyond describing the material conditions of *what is*; they explore human ethics and values about how we ought to act, how we ought not to act, and what *should* be. Simply put, no matter how rigorous, precise, or objective, scientific inquiry in education – and of its many contextualized relationships, processes, and problems – does not *sufficiently* capture the essence of education's subjects: human persons.

Given the multi-faceted, value-laden nature of education and educational institutions, there should be a robust effort on the part of researchers and policymakers to harmonize empirical research with the vast wealth of moral knowledge of the scholarly disciplines within the humanities. Atkin remarks on the significance of integrating the humanist and scientific perspectives:

> [M]oral and value questions will always be at the core of educational decision making. The heart of the matter centers on what students *should* be learning and doing. Education research is about past, present, and future. The advancement of the public interest cannot be based solely on traditional conceptions of science alone… Both scientific and humanistic perspectives have a bearing on many of the issues that face those responsible for the education of children. The task of a scholarly community intent on increasing its own relevance may be to learn how to utilize both of these ways of knowing in a manner that capitalizes on the strengths of each perspective in the service of improving what goes on in schools (pp. 70, 84; italics original).

Without other modes of human understanding to adjoin the experimental and scientific, we are not equipped to deal with the contextualized moral relationships incumbent in educating human beings. The challenge is getting policymakers and policy participants thinking down this path.

A focus on human values can be a taboo for many policymakers: they frequently tend to be more comfortable with quantifiable data to inform their proposals. Yet it is critical to remember that, in some shape or form, ideas and values play a significant role in research and policy, even if they go ignored or devalued. Stone explores just how closely values and ideas are wedded with policy, going as far as affirming that "the essence of policy making" is the "struggle of ideas" (p. 11). She continues:

> Ideas are the medium of exchange and a mode of influence even more powerful than money and votes and guns. Shared meanings motivate people to action and meld individual striving into collective action. Ideas are at the center of all political conflict… Political fights are conducted with money, with rules, with votes, and with favors, to be sure, but they are conducted above all with words and ideas (pp. 11, 34).

Ideas alone cannot guide policy; they need to be transformed into directives, rules, guidelines, etc. However, the practical world of policy should not be divorced from the conceptual and moral world of ideas and values, as the latter should inform and enrich the former. Educational researchers should strive for some genuine deliberation on how these two worlds can come together to best serve the greater purpose of improving policy in education and schools.

In the next section, I want to examine how the empirically based, overly technical path that we are on, in virtually every realm and on virtually every level of education, leads to disastrous implications for the comprehensive and holistic education of human beings. I now want to look outside of the "relevant research" and turn to the wisdom of Mary Shelley to inform how we should, and should not, think about education in our time.

***Frankenstein*: Why the Humanities Matter**

Mary Shelley was not an educational researcher or policymaker. Nevertheless, as a nineteenth century romantic writer, she offers what I believe to be the most provocative and imaginative case for the humanities in education. Generally speaking, Shelley helps us better understand education when it is conceived as merely a means for a narrow functional end. More specifically, her gothic tale gives us a good idea about what *not* to do in implementing educational policy, especially in the areas of science and science education. Shelley ponders many questions germane to our current discussion: What is education for? What happens when ethical questions are separated from scientific and technical ones? Taking readers' imaginations to the absolute brink with her provocative prose and eerie depictions, Shelley dramatizes the questions that speak to the dangers and purposes of education.

Most of us are familiar with the story of *Frankenstein*, but two things need to be said about the book before I move on. First, readers should remember that the character Frankenstein is not the monster in the novel. The monster has no name; he is the invention of Victor Frankenstein, the human scientist. Second, Victor Frankenstein has been popularized through movies as a "mad scientist" who irresponsibly uses science to do God's work of creating life. But rarely do we inquire into what made this scientist mad or why he was so irresponsible. I believe we need to look at the scientist's education to do so. Therefore, this section explores the inadequate education of Victor Frankenstein.

Shelley devises two very different educations: one for Victor and another for Victor's scientific invention, the Creature. While the Creature's education is also insufficient (McWhir 1990), I focus on Victor's education because it is the direction that education is increasingly taking now, the direction of narrow technical training. Victor attended some of the finest European institutions, where he studied the sciences, mainly chemistry, anatomy, and physiology. Victor always had "a fervent longing to penetrate the secrets of nature," desiring to break away from tradition and the old ways of doing science (p. 41). For Victor, areas of study outside of science were dismissed as irrelevant or altogether ignored in his education. Victor was predominantly focused on what works and was never really challenged to contemplate the broader moral questions and ideas concerning value and meaning. His education did not afford him enough exposure to philosophy, ethics, literature, or the arts to balance and complement the training he received in the sciences. Practical and technical, Victor's education was overwhelmingly about how to bestow "animation upon lifeless matter" (p. 53). And when he cashed-in on his education and began to invent life, careful reasoning and deliberation on the possible unintended and dangerous consequences of science could not be drawn on, only an obsession with the functional and practical questions of *how* and *what works*.

The pivotal scene in *Frankenstein* is when the Creature first opens his eyes in the laboratory and is immediately misjudged by Victor as a threat, as a demonic other. Seeing his invention as an ugly wretch, Victor is disgusted, panics, and flees for no good reason, forsaking and marginalizing his creation with a superficial frail reaction. The Creature had only been living for seconds and had done nothing wrong; he was just not pleasant to look at. Frankenstein's reaction was unscientific and irresponsible because his education never allowed him to respond as a well-rounded educated human person should: with an open mind and welcoming heart.

Shelley's story should not be viewed as an anti-science tale. The book is much more nuanced, presenting an argument for an education broad enough to bring the powers of knowledge, science, and technology under human control. Yes, Frankenstein infused life into an inanimate body – but what was it that turned this life into a monster? Readers should not blame science for the tragic result of Victor's work, which is an uncontrollable monster wreaking havoc and terror by murdering innocents. *Science alone does not invent rampaging monsters; uneducated humans who lack understanding do*. Responsibility, then, should be placed on the overly technical education of Dr. Frankenstein, which closely resembles the procedural specialists of our time, trained in dismissing the social, political, and moral dimensions of their work.

As we learn from Shelley, the monster was at first innocent, even yearning to be loved by humanity. But Victor never knew this until it was too late, because his education was too functional: it insufficiently prepared him to cope with his creation and ill-prepared him to relate with the Creature humanely and intelligently. Dr. Frankenstein created a deformed creature, and nothing more. Victor's initial desire for scientific discovery, coupled with his training, resulted in a hubristic failure to take responsibility for the monster he invented. It was human culture (the Creature was rejected by other human beings in the story), coupled with miseducation and misunderstanding, that transformed the Creature into a murdering monster.

Monsters in Training

Education is essential because, as Shelley teaches us, we should not run away from our creations, problems, and obligations like Victor Frankenstein did. Only through a comprehensive education that involves literature, philosophy, ethics, the classics, and art can we learn how to not be servile to these technological and scientific monsters of our making. "We must educate our scientists," writes philosopher-scientist Bernard Rollin (1995), "so as to assure ourselves that the moral and social implications of what scientists do are as much a part of their mind-set as are the technical" (p. 32). In a similar vein, I argue that science educators should teach and learn for a similar state of mind. Given the preeminent role of the sciences and the science-related fields in today's most popular and well-funded reform areas in education, an ethical–philosophical disposition concerned with larger moral and social consequences of science is perhaps needed more than ever. For example, through Race to the Top, the Administration expanded the role of the sciences in schools and universities by greatly extending support and funding for an STEM (Science, Technology, Engineering, and Mathematics) education. As follows, many states have put STEM education reform plans at the top of their lists and have made these fields a top priority for areas of new policy implementation.

A healthy critical reflection is possible within the constraints of the science education community, but it might be difficult. As Rollin suggests, "Total immersion in an area tends to be inimical to reflection on that area" (p. 11). A moral-social reflective mind-set requires an open-mindedness to other disciplines that have critical reflection at their core, such as philosophy and literature. Do current policies a curricula in science education engender such reflection? Is an STEM education today training a culture of technicians, like Victor Frankenstein, predominantly concerned with the functional *how*, neglecting their moral and social obligations to ask *why*?

While universities, schools, think-tanks, and research organizations may be getting more stimulus money from the current Administration, it is education that could be suffering a devastating blow. There is a large, unfortunate tendency to conflate education and labor-force training. "Folks need a college degree." Then, the very next line of a speech that President Obama gave at the University of Texas, he said, "They need workforce training" (White House 2010a). There is an important difference, however, between *education* and *training*. As Rollin (1995) writes, "We do not educate scientists or physicians to be virtuous citizens, we train them in a technocratic way" (p. 31). Training is a very particular preparation and instruction. It is more mechanical, requires less critical reflection, and is more about doing than knowing and understanding, just like Victor Frankenstein's education. While useful for learning how to perform a specific skill-set – like how to re-animate a patchwork of corpses – training, when it stands alone, is adverse to education, which includes learning broadly about oneself, others, and the world. Education involves a cultivation of the faculties of reason, reflection, and imagination. Certainly, the workforce training that is so zealously and routinely endorsed in the leading reform areas cannot produce the open-minded, warm-hearted human beings who, unlike Victor Frankenstein, would try to understand ugly creatures. In a time when education is misconstrued by the consenting majority as merely job training, how many monster-inventors are being manufactured and trained in the laboratories that are present-day schools and universities? We need more comprehensive *education* policies and curricular reforms so this generation of STEMs do not turn out to be the Victor Frankensteins of our time.

Education should aim at cultivating the best person possible, in every case, regardless of who is the President: we all need to be "the best version of ourselves." No school policy could ever capture such a broad aim. The point is that, in the hustle and bustle of making policy, we should never lose sight of the transformative and awesome powers of education: It can fundamentally change individuals, communities, and societies. Yet to continue on the narrow path of training we are going down is the path to inventing havoc-wreaking monsters.

Concluding Remarks: Moving Forward with Love

For those concerned about the comprehensive and holistic education of human persons, educational research, policy, and practice should promote broader understanding of the purposes of education – and this may or may not involve social efficiency or world economic supremacy. Education involves something much broader, something deeper and more significant. Many timeless works of humanities teach us about the role of love in human lives. Love – that most fundamental yet elusive of ideals – needs to assume a role in our discussions of the purposes and aims of education. Youth will not learn to love anything or anyone when they are *trained* to believe that learning is a mere instrument to competiveness, to monetary gain, to business and consumptive practices.

To end, educational reforms might accelerate the economy, improve earnings, and help America regain its global competitiveness. New polices in education might make us better employees, skilled technicians, and more efficient information seekers and consumers. But all the while, we risk becoming worse human beings, more materialistic, self-interested, and indifferent. We risk becoming inferior teachers and learners, bad artists, worse thinkers and writers. But most troubling, we risk that Generation R will never learn to love misunderstood, deformed creatures.

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Chapter 27
School Policy in Science Education

Promoting a More Humanistic Approach to the Teaching and Learning of Science

George E. DeBoer

The premise of this volume is that the next generation of Americans—dubbed Generation R (for Responsibility)—will face personal, environmental, and social challenges different from any we have faced before. Citizens of responsibility will have to be more attuned to personal health, environmental sustainability, and community building through collaborative action, and the science education they receive will be holistic, integrated, and attuned to the relationship between humans and the physical world. Measures of school effectiveness will need to capture this holistic spirit. Finally, schools must start now to get ready for this next generation of learners. In this chapter I review the extent to which past and current policies in science education are preparing us for this transformation to an integrated, holistic, and more humanistic approach to science education and the creation of indicators of school achievement to match that focus.

Progressive Versus Traditional Ideals

The themes of this volume have their origins deep in U.S. educational history. Progressive educators created programs focused on responsible citizenship and the relationship between individuals and their natural environments. Programs in nature study and environmental education were common throughout the first half of the twentieth century. In the 1970s, Rodger Bybee wrote extensively about transformations taking place in post-industrial America and the coming "ecological society."

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He identified four human-centered objectives that science educators should keep in mind when preparing students for the cultural changes taking place:

- Fulfill basic human needs and facilitate personal development;
- Maintain and improve the physical and human environment;
- Conserve and efficiently use our natural resources; and
- Develop greater community at the local, regional, national, and global levels (Bybee 1993, p. 44).

Consistent with these objectives, scientific literacy became a major theme of science educators during the 1970s and 1980s. A policy statement from the National Science Teachers Association (NSTA) in 1971 argued that scientific literacy was the most important goal of science education for the 1970s. A decade later, NSTA reconfirmed its commitment to scientific literacy in the policy statement "Science-Technology-Society: Science Education for the 1980s" (NSTA 1982).

Progressive ideals have not always been at the forefront of educational thinking. History shows an ongoing tension between traditionalist and progressive worldviews. A change in direction tends to occur when the pendulum swings farther to one side than educational leaders and the general public are comfortable with. John Dewey, in his 1938 *Experience and Education*, describes the essential differences between progressives and traditionalists. It was also the theme of *A History of Ideas in Science Education* (DeBoer 1991), and it was an issue of pointed debate in the science education community during the 1980s (Yager 1985).

Key periods when the focus has been on disciplinary rigor include the 1890s, when the Committee of Ten of the National Education Association (1894) promoted an academic curriculum for all students, whether bound for college or the world of work (similar to today's focus on preparing students to be "college and career ready"); again in the 1950s and 1960s, when the NSF-sponsored curriculum reform movement upgraded and updated the content of science curriculum materials and placed greater emphasis on the science disciplines, largely disconnected from their technological applications or societal relevance; and, finally, the past quarter century of standards-based accountability, which began with the publication of *A Nation at Risk* (U.S. Department of Education 1983). During these periods, the dominant themes have been the traditional values of rigor, standard setting, and accountability, with a strong focus on disciplinary content.

Of course, there are always traditionalists and there are always progressives. There are always school communities that give students opportunities to pursue their personal interests, that emphasize collaborative group work, or that require students to perform community service. In the same way, there are always schools that focus largely on academic content, college preparation, opportunities for acceleration through the curriculum, and raising test scores. And some schools do both. But, in the society at large, at any point in time, one or the other is more highly valued, and this enables policymakers who share those values to influence state and national education policy and to affect how local, state, and federal dollars are spent.

A Merging of Progressive and Traditional Approaches

The NSF-funded reforms of the 1950s and 1960s had improved the teaching of science in many ways, but it was widely recognized that the new curriculum materials failed to connect science to the everyday lives of students or to larger societal issues (Hurd 1970). The Science-Technology-Society (STS) movement that followed brought social relevance back into the curriculum, but to some critics STS placed too little emphasis on science content. During the 1990s, there was reason to believe that the swings between progressive and traditional approaches might be moderating. National organisations concerned about science education reform took the lead in promoting a new synthesis. For example, *Science for All Americans,* a vision of science literacy for all, published in 1989 by the American Association for the Advancement of Science (AAAS) recognized the importance of science content as well as the social and personal relevance of science. *Science for All Americans* included the principles and methods of science and the way humans intersect with science and the scientific enterprise. A number of influential standards-setting documents taking that approach soon followed (AAAS 1993; NRC 1996).

Science for All Americans

Science for All Americans begins by affirming the importance of science for all:

> Education has no higher purpose than preparing people to lead personally fulfilling and responsible lives. For its part, science education—meaning education in science, mathematics, and technology—should help students to develop the understandings and habits of mind they need to become compassionate human beings able to think for themselves and to face life head on. It should equip them also to participate thoughtfully with fellow citizens in building and protecting a society that is open, decent, and vital (p. xiii).

This inspirational statement of purpose is followed by a set of principles to guide the selection of content for the curriculum. Affirmations of high purpose are important, but alone they do not answer the question of what students should learn. The authors of *Science for All Americans* recognized that not everything that is worthwhile to teach can be included in the curriculum. To guide the process of deciding what to include and what to leave out, they agreed to the following basic criteria:

Utility. Will the proposed content—knowledge or skills—significantly enhance the graduate's long-term employment prospects? Will it be useful in making personal decisions?

Social Responsibility. Is the proposed content likely to help citizens participate intelligently in making social and political decisions on matters involving science and technology?

The Intrinsic Value of Knowledge. Does the proposed content present aspects of science, mathematics, and technology that are so important in human history or so pervasive in our culture that a general education would be incomplete without them?

Philosophical value. Does the proposed content contribute to the ability of people to ponder the enduring questions of human meaning such as life and death, perception and reality, the individual good versus the collective welfare, certainty and doubt?

Childhood Enrichment. Will the proposed content enhance childhood (a time of life that is important in its own right and not solely for what it may lead to in later life)? (pp. xix–xx).

To help readers appreciate that the primary emphasis was not on the traditional disciplines (as it had been during the reforms of the 1950s and 1960s), but rather on a broad and integrated study of the natural, social, and designed worlds, the chapter headings in *Science for All Americans* deliberately use descriptive language. Chapter titles include: The Physical Setting, The Living Environment, The Human Organism, Common Themes, Habits of Mind, the Designed World, the Mathematical World, and Historical Perspectives. Common themes, including systems, models, constancy and change, and scale, were chosen to represent ways of thinking that are relevant not only to science, mathematics, and technology but also to areas of inquiry such as business and finance, education, law, government, and politics. *Science for All Americans* does not reduce the emphasis on science content, but rather it acknowledges that the primary responsibility of schools is to teach the science that is most important for the development of the functional intelligence of youth.

A central theme of *Science for All Americans* is the integration of ideas. For example, throughout the chapters on the living environment and the physical setting, connections are made whenever possible and appropriate. The importance of such connections is stated early in the introduction to the volume: "By emphasizing and explaining the dependency of living things on each other and on the physical environment, science fosters the kind of intelligent respect for nature that should inform decisions on the uses of technology; without that respect, we are in danger of recklessly destroying our life-support system" (p. xiv). In the education that is envisioned, connections would be made by teachers and curriculum developers across content areas whenever those connections would lead to a deeper and more integrated understanding of the living environment, the physical setting, and their relationship to human society.

The chapter on Human Society begins:

> Human behavior is affected both by genetic inheritance and by experience. The ways in which people develop are shaped by social experience and circumstances within the context of their inherited genetic potential. The scientific question is just how experience and hereditary potential interact in producing human behavior (AAAS 1989, p. 89).

There are frequent references to the connection between humans and science throughout the volume. Regarding science as innovation: "Science is a blend of logic and imagination. [It]…is as creative as writing poetry, composing music, or designing skyscrapers" (p. 5). Regarding bias: "Scientists' nationality, sex, ethnic origin, age, [or] political convictions…may incline them to look for or emphasize one kind of evidence or interpretation" (p. 7). Science as a complex social activity: "Scientific work involves many individuals doing many different kinds of work and goes on to some degree in all nations of the world. Men and women of all ethnic and national backgrounds participate in science and its applications (p. 8). On scientific ethics: "Most scientists conduct themselves according to the ethical norms of science.... Sometimes, however, the pressure to get credit for being the first to publish an idea or observation leads some scientists to withhold information or even to falsify their findings. Such a violation of the very nature of science impedes science. When discovered, it is strongly condemned by the scientific community and the agencies that fund research" (p. 10).

The human connection is also evident in the discussion of the nature of technology and engineering:

> …the human presence, which is evident almost everywhere on the earth, has had a greater impact than sheer numbers alone would indicate. We have developed the capacity to dominate most plant and animal species—far more than any other species can—and the ability to shape the future rather than merely respond to it (p. 32).

Science for All Americans features a number of key historical episodes, which connect the advances in knowledge and technological development to the lives of individuals responsible for those discoveries and innovations, and to the social conditions of the time. The historical episodes provide concrete examples of how scientific knowledge develops, and it does so in the context of what the society at large and the scientific establishment is prepared to accept at any point in time. Episodes include the Copernican revolution, the Newtonian world, Einstein's theories of special and general relativity, Lyell's ideas of deep time, Wegener's theory of plate tectonics, Lavoisier's chemistry, Marie Curie's discovery of radioactivity, the Darwinian revolution, Pasteur and the germ theory of disease, and the harnessing of power during the Industrial Revolution. Inclusion of these historical themes in the school curriculum can be justified on the basis of their cultural importance alone, but the episodes also are compelling examples of how science is conducted in the context of human society.

Benchmarks for Science Literacy

Soon after the publication of *Science for All Americans*, its broad vision of science literacy was operationalized in terms of learning goals for each of four grade bands in *Benchmarks for Science Literacy* (AAAS 1993). *Benchmark* statements that address the human element in the context of the relationship between science, technology, and society include:

By the end of 2nd grade, students should know that

People, alone or in groups, are always inventing new ways to solve problems and get work done. The tools and ways of doing things that people have invented affect all aspects of life.

By the end of 5th grade, students should know that

Technologies often have drawbacks as well as benefits. A technology that helps some people or organisms may hurt others—either deliberately (as weapons can) or inadvertently (as pesticides can).

By the end of 8th grade, students should know that

Technology is largely responsible for the great revolutions in agriculture, manufacturing, sanitation and medicine, warfare, transportation, information processing, and communications that have radically changed how people live and work.

By the end of 12th grade, students should know that

Social and economic forces strongly influence which technologies will be developed and used. Which will prevail is affected by many factors, such as personal values, consumer acceptance, patent laws, the availability of risk capital, the federal budget, local and national regulations, media attention, economic competition, and tax incentives.

What is important about these statements is that they transform the vision of science literacy described in *Science for All Americans* into concrete learning goals that are meant to guide instruction and assessment.

Atlas of Science Literacy

Another resource to facilitate implementation of the vision of science literacy in *Science for All Americans* and *Benchmarks for Science Literacy* is the *Atlas of Science Literacy* (AAAS 2001, 2007), which maps the connections between the science ideas in *Benchmarks*. Each map of the *Atlas* includes conceptual themes that can be followed from primary school through high school. Each map shows connections between ideas that are on the same map and from other topics on different maps. The *Atlas* has proven to be a highly valuable resource for curriculum developers and school personnel to create a coherent and integrated curriculum throughout a student's K-12 education.

National Science Education Standards (NSES)

Just as *Science for All Americans* and *Benchmarks* included the human element in their content recommendations for school science, so did the National Research Council's 1996 *National Science Education Standards* (NSES). For each of three grade bands, NSES includes a section on Science in Personal and Social Perspectives, and a section on the History and Nature of Science. Science in Personal and Social Perspectives includes issues of personal health, human populations, the impacts of humans on their environments, and the positive and negative impacts of human inventions. The History and Nature of Science Section focuses on science as a human endeavor. The treatment of each of these themes becomes progressively more sophisticated as students move through the grade bands.

Federal Legislation and the Development of State Science Standards

The policy documents of the 1990s included significant human elements in their description of the science that students should learn. This is evident in the emphasis on human health, human society, the nature of the human organism, the nature of the scientific enterprise as a human activity, the relationship between social values and the worlds that humans design, and episodes in the history of science showing the relationship between individual discoveries and broad cultural values.

But the implementation of those ideas over the past 25 years has been limited at best. The vision of reform—which included a broad interpretation of what constitutes science (encompassing technology and engineering, mathematics, the social sciences, and the natural sciences), as well as a clear and detailed specification of what students should learn in each of those areas—was soon overtaken by the standards-based accountability movement. It was not intended to be that way. *Benchmarks for Science Literacy* was not written to be a list of accountability standards, but rather a practical guide for making the vision of reform a reality (DeBoer 2006). But policy statements from the federal government in the early 1990s began calling for public accountability. In 1991, President George H. W. Bush released *AMERICA 2000: An Education Strategy* (U.S. Department of Education 1991), a 15-point accountability package that called for national content standards in each of five core subject areas, national tests, and public reporting of results.

Even though national content standards and tests never become legislated policy, in 1994 President Clinton signed the *Improving America's Schools Act* (IASA), which laid the foundation for what later was to become the *No Child Left Behind Act of* 2001 (NCLB). By the mid-1990s, the focus of policymakers had shifted from national standards to a system of state-level accountability. Proposals also shifted from requiring content standards in each of five core content areas (including science) to requiring content standards in just mathematics and language arts. Under IASA, each state had to develop challenging content standards in mathematics and language arts as well as performance standards for assessing those content standards at three grade spans. IASA also devised the concept of "adequate yearly progress" (AYP), which were benchmark measures that schools had to meet each year or face punitive consequences, such as having to offer supplemental services, school choice options, or replacing the existing staff.

Although it was not until 2007 under NCLB that states were required to develop content standards in science and to assess students against those standards, many states had begun the process of developing state standards and assessments in the early 1990s, when it looked like the federal government might be successful in putting such a requirement in place. Most states took the work that AAAS and the National Research Council had done, and over the next two decades adapted it to create accountability standards and assessments to measure student performance in their own states. In doing so, the idea of benchmarks and standards as visionary statements of what students should know and be able to do to be science literate was changed into a view of science content standards as part of the public accountability movement.

Looking Forward

Even though we have been in a period of standards-based accountability for the past 25 years and continue to move forward with the development of a new standards document in science (National Research Council 2012), there are signs that there may be some movement away from a rigid standards-based approach, which could foreshadow a return to a more progressive and humanistic attitude toward education. For example, in response to mounting criticism of the *No Child Left Behind Act of* 2001 *(NCLB)*, the Obama administration introduced a proposal for its reauthorization that would expand the range of what can be included in a school's accountability system, and it focuses on growth models rather than on student performance measured at just one point in time.

A Blueprint for the Reauthorization of ESEA

In March, 2010, the U.S. Department of Education published *A Blueprint for Reform*, the Obama administration's proposal for the reauthorization of the Elementary and Secondary Education Act of 1965 (in its current form known as NCLB). Although the *Blueprint* continues to emphasize standards-setting and incentives for meeting those standards in much the same way that the previous two incarnations of ESEA did, the *Blueprint* also shows signs of supporting a broader view of education. It is difficult to know at this time what the final bill will look like because passage depends on the thinking of members of Congress at the time the bill is debated, but given that the House of Representatives is currently controlled by Republicans and the Senate is controlled by Democrats, we know that any bill that is passed will have to have bipartisan support. This means that it is unlikely that all of what is in the administration's blueprint will be included in the final bill; but given the discontent with NCLB, it is also likely that there will be significant changes.

High standards. As already mentioned, the *Blueprint* retains NCLB's focus on high standards and a challenging curriculum for all. That goal is now expressed in terms of all students' becoming college and career ready by 2020, and it would be accomplished by having each school create a challenging high school curriculum, accelerated learning opportunities, and pathways that lead to college readiness. Under the proposal, states would continue to implement statewide science standards and aligned assessments in specific grade spans, and they would be able to choose to include those science assessments—as well as assessments in other subjects, such as history—in their accountability system. The proposal would also provide competitive grants to support states in strengthening their STEM programs and by providing substantial support to high-need districts in implementing high-quality instruction in mathematics, science, technology, and engineering.

A Well-Rounded Education. One of the criticisms of NCLB was that it placed too much emphasis on students' test scores in mathematics and English language arts at the expense of other school subjects. The administration's proposal advocates "a well-rounded education" to include not just literacy and mathematics but also science, technology, engineering, history, civics, foreign languages, the arts, financial literacy, environmental education, and other subjects. To help more students in high-need schools receive a well-rounded education, the proposal would provide competitive grants to states, high-need districts, and nonprofit partners to strengthen the teaching and learning of these subjects. The proposal also promotes accelerated learning opportunities in all these areas to more students to make postsecondary success more attainable.

Education as a shared responsibility. The proposal also envisions education as a shared responsibility between "families, communities, and schools working in partnership to deliver services and supports that address the full range of student needs" (p. 1). The proposal recommends the development of community partnerships to provide students with additional time and supports to succeed. This could involve expanding the school day or year, providing full-service community schools, or providing services before school, after school, or during the summer. All these programs would "focus on improving student academic achievement in core academic subjects, ranging from English language arts, mathematics, and science to history, the arts, and financial literacy, as part of a well-rounded education, and providing enrichment activities, which may include activities that improve mental and physical health, opportunities for experiential learning, and greater opportunities for families to actively and meaningfully engage in their children's education" (p. 32).

Assessment and accountability. Under the administration's proposal, states would be required to have data systems in place to measure student growth in language arts and mathematics. Data also would include graduation rates, college enrollment rates, and rates of college enrollment without need for remediation, all disaggregated by race, gender, ethnicity, disability status, English Learner status, and family income. One change from the current legislation is that states, districts, and schools would look not just at absolute performance and proficiency, but at individual student growth and school progress over time to guide local improvement and support strategies for schools. Improved assessments would be used to measure student growth and to help teachers adjust and focus their teaching. The expectation is that schools would be able to differentiate among teachers and principals on the basis of students' growth and use that data to monitor principal and teacher performance.

In summary, there are a number of hopeful signs coming from the administration's proposals for the reauthorization of the education legislation. If most of what is in the Obama administration's *Blueprint* becomes law, there will be additional opportunities to move the educational system in the direction that the authors of this volume are proposing for the preparation of Generation R. One particular improvement is the emphasis on growth models of student learning, and an acknowledgement that assessment is not just for purposes of accountability but also for diagnosing individual student learning problems and for improving teaching. Another is the emphasis on a well-rounded education and the important role the entire community plays in a child's education. Also acknowledged is the importance of science in the curriculum, with explicit mention of environmental education. When every word in a policy document like this is very carefully considered, it is not coincidental that environmental education is included. But, along with the hopeful signs, it is also true that there continues to be a very strong emphasis on accountability and academic preparation for college. How well the new legislation moves us toward the kind of education that will presumably be needed by Generation R is still to be determined, but the signs are encouraging that the legislative environment may make such movement possible.

Environmental Education Legislation

The *No Child Left Inside Act of* 2009 (NCLI) (H.R. 2054, S. 866) was introduced in the House of Representatives on Earth Day, April 22, 2009 by Rep. John Sarbanes, Democrat from Maryland and in the Senate by Sen. Jack Reed, Democrat from Rhode Island. The bill would amend the Elementary and Secondary Education Act of 1965 (ESEA) by including certain environmental education provisions into that reauthorized legislation. Because ESEA was not considered in the last Congress, NCLI must be reintroduced in the current Congress. NCLI would authorize funds for states to implement environmental literacy programs and teacher professional development. To be eligible for funding, a state would be required to have in place a pre-kindergarten to grade 12 environmental literacy plan that would ensure that elementary and secondary students are environmentally literate. Many states have developed such plans over the past several years, partly in anticipation of future federal funding. But it is still uncertain if the provisions of NCLI will become part of the reauthorized ESEA. However, as noted above, it is encouraging that the administration's proposal for reauthorization includes explicit reference to environmental education. If the provisions of NCLI are included in the federal education legislation, it would provide an enormous boost to environmental education.

A Framework for K-12 Science Education Standards

Something else to watch on the policy front as we look toward the future is the development of a new science education standards document. In 2012, the National Research Council of the National Academies released a conceptual framework, which Achieve, Inc. then used to write the *Next Generation Science Standards* (Achieve, Inc. 2013). The hope is that even though the administration's *Blueprint* for reauthorization of federal education legislation makes the inclusion of science optional in the states' accountability programs, the new standards will be adopted by many, if not most, of the states. In addition, states will likely be required to continue to test students in science even if they do not use the science results in their federally mandated accountability programs. The point is that the NRC's framework and the new standards should have a significant influence on what is taught in science for at least the next decade and probably longer.

Much like *Benchmarks for Science Literacy* and the *National Science Education Standards*, the *Framework for K-12 Science Education* gives significant attention to the relationship between humans and science. The framework is organized around three dimensions: Dimension 1 addresses specific core disciplinary ideas; Dimension 2 includes cross-cutting themes that have applicability across the science disciplines; and Dimension 3 describes science and engineering practices. The human element is present in each of these dimensions. Under core disciplinary ideas are included among other things the relationship between humans and biodiversity, the balance between humans and earth systems, and the relationship between humans and technology. Under cross-cutting themes are the historical, social, cultural, and ethical aspects of science, engineering, and technology. And under science and engineering practices are ideas about how scientists and engineers work, including their engagement in creative model building, communication and discourse, and the critical evaluation of evidence and conclusions.

What is encouraging is that the framework and standards writers have followed the lead of all the others who have preceded them in the writing of national standards documents and assessment frameworks, by paying attention to the relationship between humans and science. The important thing now is that the new standards, curriculum materials, and assessments that follow also address this human element.

Competency Models for Assessment

It is not just in the United States where a shift in attitude regarding standards-based accountability is occurring. In Europe, a number of countries are beginning to describe expectations for students at a larger grain size than in the past, giving teachers more flexibility in what and how to teach and how to assess students. In Scotland, for example, a recent initiative by the Scottish government acknowledged that the curriculum of the compulsory school has been "over-specified" and that schools need more flexibility (Bryce 2007). In the Netherlands, an Exploratory Committee on Chemical Education concluded that the exam requirements for chemistry are "a constraining straitjacket." The committee noted that practical assignments and personal research received too little attention and that the required testing made it impossible for teachers to include "extramural activities such as an introductory visit to a university, a school for vocational education, a laboratory, or a company" (The Exploratory Committee on Chemical Education 2003, cited in Driessen 2007, p. 233). And in England, according to Millar (2007), revisions of the National Curriculum that came into effect in 2006 "greatly reduced the amount of detail in the specification of content" (p. 89).

Related to this has been the decision of the Program for International Student Assessment (PISA) to describe student outcomes in terms of what are referred to as "competency models" (Weinert 2001). A competency model takes a holistic and integrated approach to science knowledge. Competencies include conceptual understanding in various areas of science, the ability to recognize personal and societal applications of relevant science ideas, and the disposition to use those ideas to explain relevant phenomena.

PISA used a competency model in its 2006 science framework. In the PISA assessment framework, science competencies are the abilities and motivations to use scientific knowledge in the solution of real-world problems. PISA identifies three competencies: the capacity to identify scientific issues, to explain phenomena scientifically, and to use scientific evidence in the context of real-world situations. On the 2006 PISA test, these three competencies were assessed in the context of problem-based scenarios having to do with health, natural resources, the environment, natural and human-induced hazards, and the frontiers of science and technology (OECD 2006, p. 36).

PISA reduced the emphasis on testing traditional curricular science knowledge, which some may find a drawback of the test, but others will see the advantages of its focus on the use of science knowledge in the real-world contexts that humans face everyday. And still others will want to see an even greater focus on socially relevant issues. Sadler and Zeidler (2009), for example, concluded that PISA items were "standard decontextualized process questions embedded in a brief, but unnecessary story" (p. 916). The authors found that the released items "seem quite removed from the SSI [socioscientific issues] movement" (p. 909). Although PISA is clearly not without its critics, PISA already has had a significant influence on science education policy in many countries (DeBoer 2011). It is possible that the approach they have taken of assessing *the use of knowledge* in important personal and social contexts may gain traction and shift the focus of science teaching and testing in the United States and elsewhere.

Summary

Although progressive theories of education run deep in American educational history, current approaches to science education provide only limited evidence that we are preparing for Generation R in the way that the authors of this volume envision. National science standards documents from the 1990s—both *Benchmarks for Science Literacy* (AAAS 1993) and *National Science Education Standards* (NRC 1996)—acknowledged that the human side of science should be included in the school curriculum, but most states have tended to focus almost solely on science content in their own science standards and assessments. Furthermore, federal education legislation (NCLB) has placed these state standards at the center of science education policy, so currently there is no realistic mechanism for implementing an alternative approach to science education on a wide-scale basis. A review of state science tests shows that most of them focus almost completely on science content and to a much lesser extent on the nature of science, but rarely on the history of science, environmental issues, the relationship between science and society, or meaningful real-world contexts.

Proposed revisions to federal education legislation mentioned earlier do suggest that there may be some changes forthcoming which could reduce the standards-based accountability emphasis that has led states to focus primarily on disciplinary content. Another hopeful sign is the continued efforts to update the environmental education legislation at the federal level, as well as environmental education efforts that are being made by individual states apart from any mandates at the national level. Still another hopeful sign is the direction that PISA has taken, in which scientific literacy is defined in terms of the ability to apply science knowledge in the context of problem-based scenarios having to do with health, natural resources, the environment, natural and human-induced hazards, and the frontiers of science and technology. Finally, the NRC's *Framework* and the *Next Generation Science Standards* retain much of the emphasis on the human element found in the AAAS's *Benchmarks for Science Literacy* and the NRC's *National Science Education Standards*.

A Final Caution

A review of educational history shows that approaches to science education that are offered in opposition to disciplinary science are often criticized for being intellectually soft. This was true throughout the twentieth century, and it is true today. Therefore, if alternative approaches are to be successfully received and implemented, it is important that whatever is offered has intellectual integrity. There are two things that can be done to support the intellectual integrity of efforts to educate Generation R as we move forward. The first is not to forget the importance of the science content. The NRC's *Framework* proposes that when it comes to instruction and assessment, cross-cutting themes and science and engineering practices should be crossed with the disciplinary ideas. This will be challenging to accomplish, but it is an important way to ensure that all three aspects of science receive the attention they deserve. It is also important to remember that we do, in fact, live in a standards-based age, and we need to keep in mind what this means for public accountability and for improving teaching and learning. Any vision of reform should be expressed in terms of substantive learning goals for students, and the accomplishment of those learning goals should be assessed with precision. Greater precision may not seem to mesh well with a "holistic" approach to science teaching, but focusing on the whole child should not mean that we cannot be clear about what our cognitive and social outcome goals are. And it does not mean that we cannot be thorough in gathering evidence about how well schools, teachers, and students are doing. With information about what students do and do not know, the results of assessment can be used to monitor student progress toward meeting those learning goals and can provide teachers with the information they need to modify their teaching and help students meet those learning goals.

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Chapter 28
Some Challenges in Planning Educational Programs for Generation R

J Myron Atkin

This book is premised on the view that each of us is shaped by the world into which we are born. In turn, we reshape that world. The concept is both mundane and profound. Of course we are creatures of time and place. Think about place: Bloomington or the Bronx? Amsterdam or Soweto? Tijuana or San Diego? Delhi or Auckland? Each of these places offers a different childhood, regardless of the size, wealth, and love of their families. And none of us can choose where to be born. Time, too: Born before or after World War II? Before or after Sputnik I? Before or after 9/11? During the recession of the late 2000s? It makes a difference, even about what is taught in school.

A quick, personal illustration: The formative years for a person born in 1927 were those of the Great Depression. There was little money in almost all families during the 1930s. Because of its scarcity, teachers began to teach saving. It wasn't a subject in the formal curriculum, just something that happened in the classroom. As 9- and 10-year-olds, we each opened accounts at the local bank. Nothing special about that – but we did it in and through the school. Each Monday we would bring our passbooks to class along with a nickel, or a dime, or a quarter, depending on what we could afford. (I don't remember anyone bringing a dollar bill.) The teacher collected the money. The updated passbooks were returned a few days later. At the end of the year, if we had accumulated $18.75, we received a United States Savings Bond redeemable in ten years for $25. The experience gave new meaning in school to the word "interest."

Decades later, I was anointed a member of the "Greatest Generation" because I served in the Navy during World War II. Never mind that the war ended before I completed boot camp – though I wasn't released from service for another year. (Good thing, too, for it gave me GI Bill benefits that fully covered my graduate education.) The concept of a generation, with a distinctive name for each

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succeeding group, has been in everyday usage for dozens of years. Witness Gilded Age, Jazz Age, and Beat Generation, for example.

The organizers of and contributors to this volume believe that examining in some depth the relationship between demographic realities and educational practice can deepen our conception of a desirable science education. Thus, we focus on the concept of a generation we call R, for Responsibility, and its possibilities and challenges in examining some implications for society, schools, teachers, students, and what happens in classrooms.

Moral Elements of Teaching and Responsibility

Central to this chapter and to many of those that precede it is the fact that teaching is a morally grounded activity. Matters of sustaining a livable environment for both our contemporaries and those yet to be born entail concrete, daily actions that transcend whatever may seem convenient personally at the moment. Yes, each of us must act in our own best interests – but not solely our own self-interest.

Teachers have always had a profound moral influence, even if unintended. Every state has a compulsory education law requiring that almost all children go to school. (About two per cent of children are home-schooled.) For most children, previous associations with authority figures outside the family have been incidental, sporadic, and brief (e.g., police officers, mail carriers, physicians and other health workers, checkout clerks, bank tellers). School attendance is very different. Every weekday of the school year, teachers set the substance and tone of what the child is expected to do. And an elementary-school teacher spends almost as much time with a child as do family and friends – and sometimes more. Particularly in the early years, the teacher is the one person, initially a complete stranger, who represents the authority of the outside world. What that person expects and how he or she comports himself or herself sends a powerful message about what the larger society expects of its children as they grow and mature.

The not-so-hidden curriculum extends beyond the learning of mathematics, writing, science, and the other school subjects. Undergirding the school-subject timetable is the teacher as a person and what she or he represents as a model of an adult human being. Is he or she helpful and respectful? Do all children get the attention they seem to deserve, or do there appear to be favorites? How transparent is the teacher about reasons for the decisions that are made? Is he or she consistent? Children often wrap up these moral qualities – and others, such as truthfulness, empathy, patience, and generosity – with their comments about whether or not a teacher is "fair" or "good."

For Generation R, the moral questions include not solely those that grow from the immediate context of personal interactions: they extend well into the future. Generation R was and will be born into a period in which their physical environment is changing, rapidly and dramatically. Sea levels are rising at an unprecedented rate. Severe weather exacerbates the resulting problems and challenges. Species are reaching extinction every week. As a result of these effects of planetary change, there are, and will continue to be, increasing political conflicts about allocation of resources: fossil fuels, clean air, potable water, and minerals essential for the technologies we depend on. Generation R, with stakes higher than those for preceding generations, must take actions that are in the best interests not only of themselves but also of generations that follow them – not solely for their own children, but of their children's children and their children's children's children. If not now, then when? If not me, then who?

The resulting moral predicaments, challenges, and questions are complex, profound, and difficult. How do we best use arable land? What restrictions, if any, do we place on industries that lower air quality? What are the environmental and health effects of shipping food thousands of miles from where it is grown to where it is consumed? These are just a few of the issues that already have erupted into contentious battles. Not least, how does each of us act, personally, to make best use of Earth's resources?

Coping with Moral Complexity

At one time, apparently, it was considered possible to address moral questions by logical analysis in the light of established principles of thought. Science majors at the City College of New York in the mid-1940s were required to take one philosophy course. (My major was chemistry). The course was "Formal Logic and the Scientific Method." So I learned about propositions, premises, syllogisms, and logical consequences. Even then I scratched my head wondering about the connection between such an approach to scientific inquiry and what little I knew about the actual work of scientists. I had read short, popular biographies of people such as Tycho Brahe, Pasteur, Koch, Galileo, and Darwin. Each of these brilliant scientists had distinctive personalities and employed much more than sheer logic.

I was still scratching several decades later when I stumbled onto a body of scholarship that seemed to provide more useful insight into issues that could not possibly be resolved by formal logic alone, but that have a strong scientific and/or technological component: issues like assuring a community's supply of clean water, or figuring out where to build a new subway line, or deciding on the location of a new landfill. Personal interests are always at stake, and not everyone shares the same preferences and predilections.

I learned about Aristotle's concept of *phronesis*, usually translated as "practical wisdom." (Aristotle also shaped the field of formal logic, which is used today in certain aspects of mathematics and linguistics.) Phronesis is not a technique (Dunne 1993) nor is it the "scientific method" still enumerated in some high-school science textbooks. Rather, it is thought linked to action. It often involves discussion among a group of people, not solely people with different kinds of knowledge but also people with different perspectives, values, and interests. Knowing that a species is headed toward extinction does not mean that one also knows what to do about it. When action is to be taken, there usually are contending groups. Witness the contentiousness whenever the U. S. Fish and Wildlife Service adds an animal to the list of endangered species, as required by law. Many interests must be heard. Action is necessary.

I learned also about the uses of analogy and metaphor to enhance understanding of complex ideas and situations. Scholars such as Erasmus of Rotterdam (1466–1536) and Michel de Montaigne (1533–1592) incorporated stories in their writing to deepen understanding of the human condition. Stories are an integral part of the Abrahamic and Native American religions (and probably of the many religions I know nothing about). Case studies (stories, of course) are used today in preparing for professions such as medicine, law, clergy, management, and teaching. They are a prominent feature of the practice of politics, and are ubiquitous in human interaction.

Thanks to a chance encounter with a book by Martha Nussbaum (1986), I learned that Aristotle highlights the centrality of *deliberation,* which, he said, must complement methods like induction and deduction in deciding on a course of action. It is through deliberation that we try to accommodate competing beliefs and values, or decide how it might be done.

Aristotle claimed that phronesis comes only with experience and is characterized by prudence. Prudence, he asserted, comes only with experience. He claimed, in fact, that youth, lacking sufficient experience, are incapable of phronesis:

> Whereas young people become accomplished in geometry and mathematics, and wise within these limits, prudent young people do not seem to be found. The reason is that prudence is concerned with particulars as well as universals, and particulars become known from experience, but a young person lacks experience because some length of time is needed to produce it.[1]
>
> (Full disclosure: Not until the decade that roughly corresponded with my eligibility for senior fares on public transportation did I begin to feel comfortable with this feature of Aristotle's philosophy.)

Education to Improve the Environment

Global climate change frames a range of overlapping, contested issues that require both personal and community action: What do we need to do to accommodate to steadily rising sea levels? Or to extreme weather? Or about shortages of food and materials? How can we assure adequate water for planetary life? In every country, environmental education is coming to occupy a larger place in the curriculum. Fortunately, it has decades of precedents.

Let's look first at actual classrooms. Examples, actual cases, can inform our efforts to understand the kind of programs that might resonate with an emerging generation of young people who are inheriting a planet that is under extraordinary physical stress. Again, I'll start with my own classroom experience, this time as a teacher.

My first teaching position, in 1948, was to take responsibility for all the science classes (biology, chemistry, physics) in a small high school in Manhattan that was about to start its first year. The school was an extension of a Jewish day school that had been operating successfully at the elementary level for several years. As the only science teacher, I was asked to create the curriculum, design the wet lab, and choose the instructional materials. For biology, I chose a text (Bayles and Burnett 1946) that included genetics, evolution, and other topics emphasized in biology instruction at the time. It also had an unmistakable core theme: conservation.

There were several chapters and photographs in the textbook of dust storms of the early 1930s in places such as Eastern Colorado, Kansas, Nebraska, Oklahoma, and Texas. People could no longer make a living from the land. The disaster precipitated a major westward migration, particularly to southern California. John Steinbeck's *Grapes of Wrath,* and the film based on the book by John Ford and starring Henry Fonda, captured the tenor of the times.

What had happened? Farmers had turned the land upside down, literally. Native grasses were buried in order to grow wheat – which was then overplanted because wheat prices were high. These practices were followed by an unusually severe drought throughout the Plains and southern mountain states – terrain already a desert even under normal weather patterns. What needed to be done? Thus, I found myself teaching Jewish adolescents from Manhattan about restoring depleted soil through such techniques as crop rotation, contour farming, and the construction of windbreaks (e.g., trees, mounds, fences).

What about public policy related to topics in the course? The text emphasized the work of the Civilian Conservation Corps (CCC). It pointed out how young men by the hundreds of thousands went to work for a federal agency created to restore and protect the land. Between 1933 and 1945, the CCC had created jobs for more than two million young men between the ages of 18 and 24 who were on "relief" (the 1930s term for what is now called "welfare"). Additionally, the federal government created the Works Progress Administration (the WPA) that provided jobs to the unemployed to strengthen American infrastructure, like building roads and airports. During World War II, the country had dramatically expanded campaigns to recycle metals because they were needed to support the war effort. There were permanent drives to collect aluminum cans. Scarcity also led to fuel rationing, causing sharp reductions in the use of recreational trucks and automobiles.

In about 1950, new concerns about education began to enter the public consciousness, and attention to environmental issues receded. Matters of intellectual seriousness began to capture public attention. It was alleged that educational standards were declining, that the schools lacked sufficient rigor. The evidence? Teachers, particularly at elementary-school level (but not only they), had redirected the curriculum to studies of their own communities. Third-graders were taking field trips to nearby fire stations and public parks, for example, to learn how such entities served the local residents.

Critics asserted that school time should be devoted to the established subjects like history, reading, literature, written composition, mathematics, and geography. They said that teachers had been misdirected by the educational ideas of John Dewey, who focused far too much on students' proximate world in the early grades in the belief that they could learn also to read, write, and do mathematics and science in this context. "Integration", in the sense of connections among the separate subject-matter fields, was one of the watchwords of the progressives. Several distinguished university professors led the attacks, and they voiced their discontent loudly and effectively.[2] The debates about education quality and policy were at least as intense as they are today. It was a period that looked with suspicion on what was seen by some as non-traditional subject matter, like environmental studies.

Not so in Europe and Japan. Many countries in Europe had established programs that we today would call environmental education as early as the late nineteenth century. So, too, the United States; an American curricular reaction to urbanization is examined later in this chapter. Many of these programs were a consequence of every country's worries at the time about rapid urbanization and a longing for and idealization of rural life.

Now, let's fast forward to the 1960s. The Organization for Economic Cooperation and Development (OECD), a successor entity to the American Marshall Plan that assisted with European reconstruction, is a policy-oriented group of industrialized democracies headquartered in Paris. The United States, Australia, and Canada are members. In 1968, the OECD established its Center for Educational Research and Innovation (CERI), with considerable support from the United States. At a meeting of education ministers of the OECD countries in 1984, several of the countries (Austria, Belgium, Denmark, West Germany, Finland, Italy, the Netherlands, Norway, Portugal, Sweden, and Switzerland) were invited to develop case studies that reflected grass-roots efforts to help students from primary grades through secondary schools learn about environmental issues.

In 1991, CERI/OECD published a compilation of these school- based studies (Kelley-Lainé 1991). The Preface states that the case studies "could range from scientific, economic, to cultural subjects…and that an important criterion of choice of projects was that students had an important, if not the major role in defining the project and its objectives; that they took responsibility for carrying them out, and that the aim of their work was to bring about concrete changes in their environment…Young people need to experience the fact that they can contribute to their society through meaningful activities that are respected, and that they can actually influence the reality in which they live." (p. 7) One case at primary-school level is highlighted here. Several of the additional cases focused on secondary schools.

Thomasroith is a village of 800 people in the province of Upper Austria. Its primary school had two classes at the time of the study in 1986–1987, with a total of 45 students ages six to ten. The main objectives of the work described were: (a) to promote environmental awareness and personal initiatives on the part of the pupils, and (b) to improve the attitude and behavior of the pupils' parents and the village population toward the environment. The initiatives undertaken in the project fell into four categories, described in the OECD/CERI volume as: "i) effecting direct changes in the environment (e.g., laying out of a biotope in a private garden, participation in an anti-waste day by cleaning the bed of a stream, operation in the school of a container depot for waste recycling), ii) using personal contacts for influencing the local population (e.g., "Young environmentalists on the Go campaign ('Use burlap, Not plastics questionnaire'); flower campaign (distribution of flowers to the local population on the occasion of the International Environmental Protection Day), organization of parents' evening meetings on environmental activities, iii) exhibitions (e.g., construction of an 'environmental pillory' in front of the school, and iv) informing the local population (e.g., notes on environmental activity for the local newspaper)" (p. 39).

Karl Haas, Headmaster of the Thomasroith Primary School and author of the Austrian case study, provides additional detail. "As a result of an initiative completely planned by the pupils, Stefan Redtenbacher, 2nd form, is today able to present to the teachers his self-designed 8 m^2 biotope in the family garden, laid out after a great deal of painstaking work together with two classmates from the beginning of spring…Only the sealing foil had been contributed by Stefan's father. Acting as the guide, Stefan enthusiastically tells us which animals he had successfully transferred to his pond, and which animals had discovered this new living place on their own."

By means of a questionnaire developed in class, pupils in the 4th form examined the extent the local merchants were prepared to offer alternatives to plastic bags. In a conversation with the owner of Karl Kastinger's Bakery, a pupil recorded the following exchange:

Do you offer plastic bags to your customer?
Yes, we do.
Do you give them away free?
Yes.
What is the most common type of shopping bag your customers bring along? *Shopping baskets, leather bags.* Would you be prepared to offer your customers moderately priced environmentally sound burlap/cloth bags?
Yes.
Thank you for answering our questions.

All local merchants were basically prepared to offer their customers from then on not only plastic bags but also moderately priced cloth or burlap bags. The pupils then wrote a letter to the editor of the regional paper [asking] local shops for their commitment, and they expanded their inquiry to the district's capital Vöcklabruck, which is also a shopping area for many parents. Within two weeks the pupils had found out which shops in Vöcklabruck already offered their customers environmentally sound shopping bags. The eight shops received a handwritten letter of thanks. Haas continues, "The environmental pillory project grew out of a discussion in history class, "with the teacher trying to illustrate the meaning of 'pillory' with the question, 'Day by day we pillory deplorable environmental conditions, don't we?'" The pupils did not consider this to be figurative usage but took it quite literally, and a few days later agreement had been reached on the form and location of an environmental pillory. A wooden rack was constructed and put in front of the school to display things pupils found along the village roads, like empty cigarette packs and beer cans. Not surprisingly, the local newspaper picked up the story. The radio station noted that ever since the pillory went up, '…the pavements of Thomasroith have become considerably less littered. Who would like to discover his litter on the pupils' environmental pillory!' "

"Relevance," Pre and Post Sputnik

The U.S. Congress created the National Science Foundation in 1950 to support research and improve education. The first of its major grants to improve science education below the college level was awarded in 1955 to the Massachusetts Institute of Technology to support the Physical Science Study Committee (PSSC). Many of the scientists, including Jerrold Zacharias, the leader of the PSSC group, had been involved in the Manhattan Project. They designed the atom bomb and were American heroes. Now they wanted to work for the public good in peacetime. Having learned that a well- selected team of outstanding people could achieve extraordinary results, perhaps they could improve science education for coming generations. Zacharias recruited a group of esteemed physicists from many universities who began devoting their talents to designing a new course in physics for all those who would take the subject: would-be scientists and everyone else.

The physics typically taught in high school at the time had chapters on topics such as the four-stroke-cycle gasoline engine, principles of refrigeration, optics, and generation of electricity. The scholars from MIT and elsewhere who turned their attention to PSSC acknowledged that such topics might be interesting, but they hardly reflected the ideas that underlay modern physics as seen and practiced by the world's most outstanding physicists. Further, the existing texts were largely a compilation of conclusion; the course gave little attention to how those concepts had been conceived. The NSF grant to PSSC funded a project to explain the development of major science concepts and design the associated curriculum materials. The team produced a new textbook that dropped many topics previously studied in high school to emphasize concepts considered fundamental – and that also helped students understand how physicists think about the world. The selected topics included the nature of light itself (i.e., how it behaves as both wave and particle simultaneously) and the line of reasoning that led to the concept of the atom.

The PSSC effort served as a model for the NSF by setting the pattern for grants to improve education in the other science subjects taught in high school: identify scientists who are among the most respected by their peers and give them the resources to develop new courses. Chemists chose to replace the largely descriptive chemistry taught at the time with a course based on the foundational idea of the chemical bond. Biologists found it difficult to reach consensus about a single unifying conception, so three separate courses were developed. One centered on molecular biology, one on cellular biology, and one on ecology. All three stressed the key biological themes of the relationship between structure and function and the overarching concept of biological evolution that illustrates how all life is simultaneously both similar and different, that variations arose in past and are continuing in the present, and that these biological changes have been taking place over millions of years.

During this period, improving science education had become a major priority in American schools. Renowned scholars and researchers did more than criticize the quality of education below the university level: they shifted the direction of their own careers to help strengthen the education of students in elementary and secondary schools. The new attention to their subject affirmed for science teachers (like me) the importance of their work. The alliances between scientists and teachers also signified to the public that teaching is a noble vocation. The Sputnik launch in 1957 only increased American attention to and respect for the teaching of science.

Despite these auspicious curriculum developments, the new curricula did not usually address practical and local issues and challenges, except indirectly. That is, students might try to apply the basic chemistry, or biology, or physics they were learning to matters of pressing personal and community interest, but the first task was to learn fundamental science as identified by the people who were doing the basic research in the field. Environmental concerns were largely eclipsed in the initial NSF-supported projects.

There were exceptions. The ecological version of the BSCS texts (called the Green Version) addressed environmental niches in an evolutionary context, although there was little direct attention to the possibilities of humans doing much to change things in their own neighborhoods. In 1963, NSF supported the Engineering Concepts Curriculum Project (ECCP). This project featured concepts such as open and closed systems and feedback that could lend themselves to more localized studies, but not necessarily applied to matters of conservation and environmental protection.

One exception stands out all these years later: a chemistry curriculum project that received initial NSF funding in 1980. A grant was awarded to the American Chemistry Society (ACS) to develop a course for high schools. The text that was first developed, *Chemistry in the Community* (American Chemical Society 1985), begins with a fish kill in a fictional waterway. What was causing the fish to die? Succeeding chapters examine chemical changes in the lake and what might have caused them. Students became aware of the fact that methods of mitigation of an environmental problem can be controversial because there are different interests at stake. The recreational boater has one type of concern. The owner of the factory that discharges waste in the stream that feeds into the waterway has another. The farmer whose run-off adds contaminants to the lake is a third. At one point, the textbook suggests that the students role- play a discussion among interested parties to reach a decision about action that might be taken by the community at large.

It might be asked how this approach to high-school chemistry gained a place in the NSF curriculum-development portfolio. Preceding grants had gone primarily to support research by established scholar/researchers at the leading edge of their respective fields, almost always in the nation's premier universities. It was their vision of the frontiers of their subject that drove NSF in almost all its curriculum programs for secondary and elementary schools. (True, the NSF founding documents specified education as a major mission, but that aspect of its charge was interpreted in NSF's early years largely as support of doctoral students in the various science disciplines.)

The much-more-practical *ChemCom: chemistry in the community,* with its focus on a particular (fictional) locale and its serious attention to the importance of local knowledge, is an exception that invites explanation, or at least conjecture.

The reason, I believe, is that the American Chemical Society (ACS) is an organization whose membership includes a high percentage of chemists who work in government and industry. The professors who join tend not to view it as their primary professional society; they see their interests better served by more specialized societies serving fields of research and teaching like chemical geology, materials science, atmospheric chemistry, chemical engineering, pharmaceutical chemistry, and biochemistry. ACS saw the importance of reaching students at high school level to encourage interest in the entire field, which includes the kind of work one finds in the chemical industries. With that motivation, they decided to develop a curriculum that featured the relevance of chemistry to personal and social needs – hence "Chemistry in the Community" and its strong redirection to questions like those related to environmental protection. The principles of chemistry are taught in the context of practical, local problems.

Caring for the Environment: Stewardship

Environmental issues receive a considerable amount of public attention today. Every month there seem to be major incidents: extreme weather (heat, storms, and droughts), toxic waterways, oil spills, depleted supplies of fresh water, and atmospheric pollution. Young people watch this happening and recognize that the world they were born into is changing for the worse. In addition to the environmental problems, their families are worried about jobs, and mortgages, and spending more money than they have. Adults seem edgy, possibly including the teacher. These are scary times for everyone. Nevertheless, students – because of their age – also are primed to do something about their situation. They want to make things better. This state of affairs is saturated with moral issues, for children as well as adults.

Children younger than five or six react sharply to the unequal distribution of things they want – crayons, pie, toys, or parental time. They even try to punish other children who seem to have too much. Ernst Fehr, an economist at the University of Zurich and a pioneer in the field of perceptions of inequity, has found that children are willing to accept some level of uneven distribution of something desirable, but within reason (Fehr and Schmidt 1999). They can become angry and resist aggressively if the gaps between them and others seem too great. Fehr, and others, raise the possibility that we may be hard-wired to share resources, and that humans may have surpassed other primates because we and not they tolerate moderate differences, but not extreme ones. Cooperation fosters group success. Fehr writes, "A minority of altruists can force a majority of selfish individuals to cooperate" (Fehr and Fischbacher 2003)

The impulse to care for Earth and its inhabitants, once acted upon, carries both a moral obligation and an emotional commitment. The two are symbiotic. This undercurrent surfaces in many of the organizations that today try to promote greater attention to environmental deterioration and its consequences. The U.S. Environmental Protection Agency uses the word *stewardship* when describing some of its activities in public statements. In England, stewardship is used to characterize a program for farmers whereby they receive government funds when they employ certain procedures and techniques that are known to sustain productive use of their land for future generations. Stewardship implies a sense of responsibility for the future. It is a moral act.

How can a sense of stewardship be fostered in school? Once more, by “going local.” Effective environmental studies in school usually require instruction about troubling conditions that are nearby and readily observed. What can we find out about this particular stream to figure out why large numbers of dead fish were seen there last month? Was it really more fish than usual? How can we be sure? Were air and water temperatures different this year than in the past, and might that make the difference? How can we find out? The water seems murkier. What do we mean by murky? Do we need to measure it? If so, how? Students need to collect data about this stream, and these fish – and perhaps about the recent and longer-term weather in this particular location, to list just a few categories.

Seminal features of project-based education with significant science content could be found broadly, and in some places deeply, in the United States to the end of the twentieth century. It is not entirely absent from schools today. Such programs are supported by many science museums that attempt to help students individually and in school groups to conduct genuine investigations. The George Lucas Educational Foundation maintains a lively and informative website and magazine for educators, *Edutopia*, which helps to keep alive the concept of an education in science that is not bounded by a textbook.

The Eight-Year Study

The kind of education suggested by these activities dates back to at least the 1920s in the United States. The Progressive Education Association (PEA) was founded in 1919 to promote what its members called student-centered education. The programs they developed were not unlike those that have been highlighted so far in this chapter. The difficulty, at least for the PEA, was that the high school curriculum was crafted along subject lines determined by the colleges and universities, though fewer than 20 % of the students went on to these institutions.

The PEA launched a study with the major goal of finding out how two different groups of students fared in colleges and universities. One group went to high schools that featured programs that engaged students in extensive projects of the type highlighted in this essay. The others went to schools whose curricula were shaped by textbooks designed to prepare them for college work. The question was: Would there be a difference between the two groups in terms of college success?

Thirty high schools from New England to California participated in the study. The attraction? They were assured that colleges and universities would accept the students who graduated. The colleges included Harvard, MIT, Princeton, Yale, Smith, Chicago, Ohio State, University of Tulsa, Michigan, Oklahoma, and Wisconsin. The study was conducted from 1933 to 1941.

It was found that those who learned by project methods, whereby they engaged in first-hand investigations supplemented by supporting reference works, did much better in college than those who learned from lecture-discussion supported by textbooks and conventional labs. This extraordinary, longitudinal research (called the Eight-Year Study (Aikin 1942)) was designed by Ralph Tyler, then of the University of Chicago and later Director of the Center for Advanced Study in the Behavioral Sciences. (He also made major contributions to the crafting of the Elementary and Secondary Act of 1965.) Tyler's study never captured the attention it deserved among policymakers and the general public. A likely reason is that it was published just as America was entering the Second World War.

Testing, Testing, Testing

The No Child Left Behind Act of 2002 is the most draconian legislation ever seen in American education. Schools that do not measure up in the specified subjects of reading and mathematics (science is coming!) can lose their federal funding. The judgment is based solely on student performance on standardized tests containing only multiple-choice or short-answer questions. The test, at the end of the school year, takes about 90 min for each subject. Furthermore, the law is at the federal level, passed by bipartisan action of the U. S. Congress and signed by the President. Teaching is now driven by externally developed tests to a degree never seen before in this country.

Much of this testing is a result of direct federal action (designed, of course, to "improve" the quality of American schools). It might be puzzling how the Congress got involved because education is constitutionally and traditionally a state-level responsibility. Since education is not stipulated in the Constitution as within the purview of the federal government, responsibility for providing it falls to the individual states. That's the Tenth Amendment.

Of course assessment is necessary. It also can assist learning and teaching. But before elaborating on this point, let's take a quick look at how Congress got involved in deciding what students should learn in school. The year 1917 saw the first breach of this constitutional divide of responsibility between states and the federal government. The Smith-Hughes Act that year provided federal funds for vocational and agricultural education in the various states. No legal challenge was raised. States received money they did not have before. What harm in accepting the funds for a worthy program?

Forty-three years later came the National Defense Education Act of 1958 that provided for the improvement of science, mathematics, and foreign-language education. This time there was a rationale for a federal role: Sputnik I symbolized a potential military threat to the nation. It is the federal responsibility to provide for defense, thus the name of the legislation. Twenty-two years later there was the Elementary and Secondary Education Act of 1965. The justification of the federal role this time was based on civil rights. The most poorly performing schools, notably those in the Nation's inner cities, were overwhelmingly non-white.

No one claims, with justification, that assessment is unnecessary in schools. One purpose is accountability. Public dollars are being spent. At another level, assessment provides a basis for making improvements. It happens that there is a form of assessment that serves both purposes. “Summative” assessments aim to give a picture of how much the student knows at the end of a year or a course. “Formative” assessments are usually continuing assessment at classroom level throughout the course of the school year. Their primary purpose is to help a student understand what he or she is expected to know and do now and by the end of the year. A teacher–student conversation about the gap between the student’s current understanding of a topic and what is a realistic and desirable level of accomplishment serves this purpose best. The conversation might be about how the student is contributing to a class project studying conservation measures in a nearby salt marsh. The student may be part of a subgroup trying to figure out how to learn about the variety of waterfowl in the marsh. The discussion can be broader and may include all members of the group of four students who are working together on their part of the project. It might be with the entire class about general issues associated with their project.

Whatever the format, an essential element of these assessments is to provide usable feedback. The discussion, or teacher comment, helps the student determine what to do to bridge the gap between current accomplishment and the goals that are expected. The discussion also helps the teacher understand what he or she can do to modify his or her teaching to help. This kind of assessment improves both learning and teaching.

This information about the results of formative assessment is not a secret. In 1998, Paul Black and Dylan Wiliam reported an analysis of more than 500 research studies which demonstrated that no other modification of teaching improves student learning as much as formative assessment that includes feedback to students to help them understand what they can do to improve their work (Black and Wiliam 1998). The paper has proved to be a touchstone for further work in the field both by them and other researchers who have followed in their footsteps, my work included (Atkin et al. 2005).

Perversely (some would say tragically), formative assessment has been hijacked by the companies that develop the standardized tests used for summative purposes. The testing companies (that enjoy a huge market for the end-of-year summative tests associated with NCLB) proceeded to develop abbreviated versions of the multiple-choice or short-answer questions administered at the end of the year. The mini-versions are administered several times a year. Thus there was an expanded market for the standardized tests.

Back to the Future?

A stock-market plunge in 1929 triggered the Great Depression. The depression was deepened by agricultural practices that amplified the resulting impact. Land was misused in broad expanses of the drought-prone American plains. Extraordinary dust storms and then the flooding of major mid-western rivers further made the soil unproductive. Millions of people migrated west, as others did before them, to start their lives anew in what they hoped would be better times. Environmental conservation rose to a national priority, and the schools responded accordingly.

Sixty years earlier, construction of the transcontinental railroad had “opened” the west, thus facilitating an earlier shift of the population. Deleterious effects on the land were certainly possible, and did occur. But corporate interests, particularly those of the railroads, became influential also as advocates of environmental protection. Their purpose was to enhance tourism, and they greatly speeded the establishment of national parks. The Great Northern Railway built public support for Glacier National Park and Mt. Rainier. The Northern Pacific helped with Yellowstone, and the Southern Pacific for Grand Canyon and Yosemite.

Before the railroads and with a vision not always apparent in national political leadership, Abraham Lincoln signed the Yosemite Grant Act in 1864 that protected the Yosemite Valley for public use. (The land was initially put under custody of the State of California.) Theodore Roosevelt, encouraged and assisted by John Muir, took the steps necessary to preserve huge tracts of federal land for public use. In 1903, he established Pelican Island in Florida as the Nation’s first National Wildlife Refuge. National parks and forests eventually were identified that extended to every state.

One could find, too, that conservation-type themes were becoming part of the school curriculum. Colleges of agriculture played a strong role because of their general concern about the quality of rural life. The Cornell University College of Agriculture provided the foundations for the Nature Study Movement in the teaching of elementary-school science. In the early Twentieth Century, leading biologists at the University like E. Laurence Palmer and Anna Botsford Comstock developed nature-study programs designed to help elementary-school children better understand and appreciate the rural places where they lived. Nature Study emphasized direct observation, as well as reading. The University launched the Cornell Rural School Leaflets that gave guidance to teachers about incorporating biology related to rural life in their curriculum. Teachers received further assistance from the network of county agents employed by the Cooperative Extension Service of the U.S. Department of Agriculture.

Our Most Serious Challenge

Perhaps the highest educational barrier for Generation R to surmount in trying to tame environmental degradation is a set of punitive policies crafted at federal and state levels during the first years of the twenty-first century and epitomized by the No Child Left Behind Act. There is a nationwide drive to “reform” the public schools. The language employed frames the issue. “Reform” hints at criminality and the urgent need to find corrective measures. This stance has ushered in a period of bi-partisan assault that has demonized the teaching profession itself. Teachers are portrayed as selfish and under-worked. The public is told that teachers are more interested in their own welfare than that of their students. In state after state, teacher salaries have been frozen. Pensions have been jeopardized for those nearing retirement and reduced for those just starting their careers. Laws have been passed to eliminate teachers' bargaining rights. Teachers, while seldom paid as much as others with the same levels of education, were respected figures in the community not so long ago. Now they are told that they need to be "reformed."

Thus, the global environmental crisis associated with Earth's warming coincides with the most serious attack on public education since the establishment of "common" schools – schools for all the people – in each state during the nineteenth century. All this is happening during a period of severe economic pressure and bitter political conflict. From this vantage, it is difficult to see how the crisis in education might be eased constructively. Presidents with a well-developed educational vision are rare. Many state governors and legislators, with whom the legal obligation resides to provide for education, seem to be part of the problem. A stressed public is preoccupied with its immediate economic challenges, in addition to perceived internal and external threats.

So we cycle back to the theme of this book. Generation R is alert to the serious situation its members have been born into. Like all youth of any generation, they are an energized and forward- looking group. And they want to act responsibly to restore the health of the planet. It is our nature to believe that something will happen to rescue us from ourselves. The fact that in the past very serious problems have somehow been resolved may be a comfort. But that seems a thin reed on which to build a bridge to a better future. Never before, it sometimes seems, have the American people placed so little value on the common good.

Even in the Civil War, by far the most wrenching and destructive event in American history, there was a sense of stewardship, a sense that the land must be preserved for future generations. Some of the Nation's most foresighted legislation was enacted in the midst of the War. The Land Grant Act of 1862 created affordable universities to advance "agriculture and the mechanic arts." The National Academy of Science was created in 1863 "to serve the nation." And in 1864, Lincoln signed the Yosemite Land Grant, an act of Congress that protected the Yosemite Valley for public use.

No, Generation R can't do the job alone. It needs support, and commensurate resources from its elders. People are beginning to grasp the fact that there are no simple or immediate solutions to environmental and political problems that have been festering for decades. In many respects it is already too late to redress the atmospheric changes that have led to global warming. The longer we delay, the more challenging the task.

Yet if the United States of America could find common purpose during and after the Civil War, by far the country's most destructive and traumatic experience to date, our situation may not be hopeless. Bitter enemies found common ground – and that was just within the Union leadership itself (Goodwin 2005). We had strong and articulate leadership from a president. Corporate interests aligned with public interests. Perhaps it can happen again.

Notes

1. Nicomachian Ethics 1142a.
2. See, especially: Bestor (1953).

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Chapter 29
Re-imaging the Goals of Science Education: What Role Should Assessment Play?

Maria S. Rivera Maulucci

Each of the authors in this text asks us to broaden our notions of the goals and purposes of education, in general, and science education, in particular, beyond the current focus on individual and collective achievement on high-stakes tests and preparing students to contribute to our twenty-first century economy. They paint a world with words wherein scientific literacy includes community engagement, civic responsibility, cultural studies, free-choice learning, socioscientific reasoning, environmental and expeditionary learning, earth smarts, digital literacy, knowledge building, and mindfulness. They imagine learning outcomes that include an engaged citizenry, ecojustice, democracy, critical civic literacy, peace, deep understanding, human flourishing, art, beauty, love, and so many other vast possibilities. Reading some of the success stories fuels a radical hope within me. If we can imagine it, we can build schools and educational programs around those ideals.

To me, there is nothing more beautiful than a child on the first day of school, with a smile on his/her face, and full of hope that the classroom will be a place of safety, of learning, of love. Yet, many children do not look forward to a year of learning. Our current system of schooling fails too many children. Business and community leaders have begun to advocate policies that threaten to dismantle the system of public education in our country. Schools are blamed for our nation's failures and simultaneously seen as the way to overcome them in the future. This paradox lies at the center of a deeply contested space that pits policymakers against teacher educators, parents against administrators, administrators against teachers, teachers against students, and the list goes on. Assessment policies play a fundamental role in this conflict because they set up a basic mismatch between what we imagine schools are for and the bottom line for how we measure their success. High-stakes measures exert tremendous pressure on schools, principals, and teachers, squeezing the room to imagine or re-imagine out of existence. Excellence becomes the

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exception rather than the rule, because too many stakeholders have lost a sense of radical hope.

The 1952 film, *Hans Christian Andersen,* starring Danny Kaye, provides a provocative critique of education that is eerily appropriate to where we are today. The film begins with a jaunty red kite flying high in the sky, a signal to the local children that they should meet Hans, the shoemaker, by the brook for stories. The schoolmaster vigorously rings his bell to call the children to school, but they gather by the brook instead. All the while, we hear the whimsical melody of the *Inchworm* song, original lyrics by Frank Loesser. The children are giggling and laughing, and looking at the kite, and their books and slates lie abandoned by a nearby tree stump. Hans wraps the string of the kite around some of the children's books as they ask him to tell them a story. The children sit with rapt attention as Hans sings the story about a king, who had no clothes. The children sing along in parts and it is clear that they love Hans and that Hans loves them.

Peter, an orphan boy that Hans took on as apprentice, runs up to warn Hans that the schoolmaster, the Burgermeister (Town leader), and the council are on the way. Hans says, "Oh Peter, don't worry so much on a beautiful day like this." When the men arrive, the schoolmaster objects to the way the children have left their books on the dirty ground and complains that the history of Denmark was used to tie the string of a dirty kite. Hans replies, "The history of any country can always use a bit of fresh air. Did you ever hear the story of the history book that took a vacation? It came back a much better history." The children laugh and the schoolmaster objects to the things Hans is filling the children's heads with. Hans says, "But there are different ways of learning." The schoolmaster tells Hans to attend to his shoes and let him attend to his schoolroom. Hans says, "But is the world made up of nothing else but shoes and schoolrooms?" He begins to tell another story, and just like the children, the Burgermeister and his council begin to lean in and listen. The schoolmaster interrupts saying, "What is this? Have we all lost our senses?" The Burgermeister tells the children to pick up their books and go to school.

A few minutes later, Hans approaches the schoolhouse and the children are reciting, "One and one are two, two and two are four, four and four are sixteen, sixteen and sixteen are thirty-two." Hans shakes his head. He passes by the schoolhouse door and a little boy smiles and waves to him. The schoolmaster turns and angrily shuts the door in Hans' face. In the meantime, Peter, who had gone ahead of Hans, has stopped in front of a marigold bush outside the schoolroom door. He tells Hans, "Look Hans! An inchworm! The first one of the year!" Hans sits next to the boy to look at the inchworm. He looks at the schoolhouse and shakes his head again. As the boy watches the inchworm in joy and wonder, Hans begins to sing, "Inch worm, inch worm, measuring the marigold, you and your arithmetic, you'll probably go far. Inchworm, inchworm, measuring the marigold, seems to me you'd stop and see how beautiful they are."

In this fairy tale, we are the inchworms! We are so busy measuring the marigolds, or the children, that we often do not stop to see how beautiful they are. Testing companies rake in vast sums of our educational dollars while we shun other ways of learning out of the belief that they do not help students achieve higher test scores. For example, in one school, the principal told teachers to eliminate the poetry unit because poetry was not tested. In my view, that was one school too many. How many other decisions like this get made in schools across our nation? How many schools sideline recess, the arts, school trips, social studies, and science to extend instructional time for tested subjects? Meanwhile, a world of wonder and other ways of learning await us inside and just outside the schoolroom door. The promise of No Child Left Behind remains unfulfilled and these are the emperor's new clothes that we are wearing.

Anthony's Story

My son, Anthony, recently completed the fifth grade in a "Blue Ribbon School of Excellence," located in a suburban public school district. The following excerpt from the program website describes the Blue Ribbon program:

> The National Blue Ribbon Schools Program honors public and private elementary, middle and high schools whose students achieve at very high levels or have made significant progress and helped close gaps in achievement, especially among disadvantaged and minority students. The program is part of a larger U.S. Department of Education effort to identify and disseminate knowledge about best school leadership and teaching practices.
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> The Blue Ribbon Schools Program sets a standard of excellence for all schools striving for the highest level of achievement. Each year since 1982, the U.S. Department of Education has sought out schools where students attain and maintain high academic goals. Using standards of excellence evidenced by student achievement measures and the characteristics known from research to exemplify school quality, the Department celebrates outstanding schools from states across the country (National Blue Ribbon Schools 2013).

In early June, I took him for a reading evaluation and he tested at a 3rd grade level for reading comprehension and a 4th grade level for word recognition. Read to in the womb, surrounded by books from a very young age, with two parents who value and support their children's education, one parent whose professional field is education, in a Blue Ribbon School with a fabulous school leader and dedicated teachers, my son still fell behind. All year long, I asked myself why he was falling behind. Why was he struggling so much? If a Blue Ribbon, suburban school cannot help all children succeed, why do we expect schools with less privileges and advantages to succeed with all children?

I have not told you the full story, because my son has an Individualized Education Plan (IEP). Over the years, various labels have been applied, "Child with Speech and Language Disability," "Pervasive Developmental Delays-Not Otherwise Specified (PDD-NOS)," and more recently, "Aspergers." While the various "diagnoses" have helped us to understand our son, develop strategies to work with him, and help him succeed, they by no means define who he is or what he can contribute to society now, or in the future. Here lies the crux of the matter. Do we stand by and allow his designation as a student with an IEP to become a self-fulfilling prophecy? As an example, to what extent does giving him extended time for tests produce a student who needs extended time for tests? Why are schools structured to sort and label students, and year-by-year limit the achievement of some students, while promoting and enhancing the achievement of others? Each time they pull him out of the regular classroom for Speech, which he needs, he misses instructional time. How can he make up the ground that he loses? With all the assessment schools are doing, why do we not have the information we need to help all students achieve? Why do I get a report from the state with a raw score, a level, and limited information about where his weaknesses might be or what we can do to help him improve? Why does this information arrive in late August or September, too late to do anything before the next school year? Finally, I have to ask the question, am I being unreasonable in my expectations for schools or for my son?

In fourth grade, Anthony's teacher attended Cub Scout Pack Night. My son had completed the requirements for almost all the academic belt loops and pins. Despite a lack of athleticism, my son also planned to complete all the sports awards. Anthony had a 3-in. binder full of the work he had done and pictures of him completing the activities. His teacher looked through the binder and was amazed. He had tears in his eyes as he said, "Wow! Now, I know what I can expect from him. This is incredible!" It was November, and he did not know what my son could do. In a later conversation he said, "You don't understand, you took a sow's ear and made a silk purse." My son has never been a sow's ear to me. He has been a gift from God, who teaches me every day what it means to persevere among many other lessons. Nevertheless, I realized that the teacher spoke from his experience with so many children whose parents did not or could not intervene in their child's academic trajectory. Although this teacher was one of the most loving and caring teachers my son had, somehow, in a class of 22 students, Anthony continued to fall behind. That summer, his state test scores showed a 10-point dip in the raw score for English Language Arts and a drop from a Level 3, "proficient," designation, to a Level 2, "Basic Standard," designation.

How did this happen? If you look closely at the subgroups that underperform in most school accountability measures, and you explore the underlying mechanisms by which the students come to underperform, you find a downward cycle of expectations. Each year, students achieve less than a year's worth of progress, causing teachers in subsequent years to move back the starting point and lower expectations for students' academic outcomes. Couple this with students who may have social, emotional, or learning difficulties, and you now have a recipe for disaster, as teachers focus more on whether the students are "doing school" appropriately, than whether they are making up the ground they have lost. As an example, in an Abell Foundation study of special education students and services in the Baltimore City Public School System, Kalman R. Hettleman (2004) reported that:

> IEP teams are not trained to recognize or apply research on the most effective instructional programs for students with learning difficulties. As a result, special educators vastly underestimate the academic potential of such students and violate IDEA and NCLB by failing to design and deliver appropriate instruction. Low expectations, particularly for low-income and low IQ students, are toxic self-fulfilling prophecies (p. 4) (Hettleman 2004).

Every time teachers accept less from students, they communicate explicitly and implicitly that the students cannot produce more. Furthermore, in many cases, the testing accommodations designed to level the playing field may serve to mask the actual extent of the achievement gap by inflating students' test scores.

At the same time, most school assessments are flawed. They seek to determine students' knowledge or skills within too narrow a range. That is why my son's teacher did not know that he had excellent (for his age) Internet research and computer skills. Nor did the teacher know that Anthony had a creative side, or that he loved nature, that he could read and interpret topographic maps, make long lists, play chess, plan train trips, navigate Metro North and the New York City subway system (on his own if we would let him!), or identify many different species of plants and birds. If we stop and consider what our assessments *do not* tell us about what students know or can do, how they feel, what interests them, or their goals for life or learning, we realize how limited they can be. Assessments leave more unknown, than known.

Anthony's story shows the ways in which equity and inequity inextricably intertwine with how we develop and use assessments in schools, both teachers' assessments and high-stakes assessments. When teachers' assessments focus on a narrow range of concepts and skills closely tied to the curriculum, they limit the possibilities for children's unique sets of knowledge and skills gained from social and cultural experiences in their families, communities, or home countries to be recognized, built upon, expanded, or celebrated. The curriculum narrows even further when state educational and accountability policies exert pressures on schools and teachers to make schoolwork and homework look like the tests in order to prepare students to perform well on the tests, as is the case in my son's Blue Ribbon school. In New York State, teacher and principal performance evaluations will now incorporate how well students do on state tests and the results will be reported in the newspapers. Nobody wants to be *that* teacher or *that* principal in *that* school. Accountability is important because achievement gaps persist even in schools, like my son's, that have taken up the gauntlet of teaching twenty-first century knowledge and skills. Yet, when accountability mechanisms run counter to efforts to reform teaching and learning, we essentially ask teachers and students to swim upstream. Anthony is lucky. He has parents and an extended family that can and do advocate for him and make sure that he has venues for self-expression and achievement outside of school. We spent the summer getting him ready for middle school with an intensive reading program, mathematics enrichment, language study, and plenty of merit badges now that he is Boy Scout. We also made the decision to place him in a private school where he would have smaller class sizes and be held to the same academic standards as the other students. After a year that has not been without struggles, he is poised to achieve straight A's. Yet, I do lose sleep at night worrying about the achievement problem and the many children we are leaving behind. Where is the hope?

Wrestling with the Enduring Problem of Equity in Science Education

When we turn our attention towards science, concerns about equity raise the serious question of science for all. As the chapters in this book make clear, how we answer the question of whether science happens for all depends on two components—how we define "science" and how we define "all." When we imagine science for all, do we mean traditional school science, scientists' science, everyday science, or children's science? Do we mean progressive, reform-based, constructivist, inquiry-based, critical, or social justice science? Do we mean western, indigenous, place-based, or culturally responsive science? Do we mean classroom-based, field-based, community-based, home-based, or museum-based science? Do we mean doing, watching, talking, arguing, reading, or writing science? Do we mean materials-rich, kit-based, or text-book science? When we imagine all, do we mean all students, all races, ethnicities, languages, cultures, and genders? Do we mean general and special education students? Do we include the potential scientists, other smart kids, outsiders, inside outsiders, and boundary crossers? (Costa 1995). Do we include those past the age of compulsory schooling, such as, teachers, parents, administrators, or community members?

In science education, the pipe-line model that has dominated our thinking about the problem of student persistence in science is deeply problematic. Consider the following physics equation for the flow rate through a pipeline:

$$Q = \frac{\pi r^4 (P_1 - P_2)}{8\eta L}$$

The flow rate (Q) through a pipe is directly proportional to the fourth power of the inside radius (r) of the pipe and the pressure difference between the ends (P_1–P_2), and inversely proportional to the viscosity (η) of the fluid and the length (L) of the pipe. Typically, we envision a leaky pipe as the cause of the numbers of students who do not persist in the science pipeline. We assume that we can just plug the leaks, thereby bypassing all the above factors that can affect flow rate. Middle school students are leaking out; therefore, we need to enhance science programs in middle schools. Girls are leaking out; therefore, we need compensatory science programs for girls. Yet, there are other factors to consider. One suggestion is that all we have to do is increase the size of the pipe and we can dramatically increase the number of science majors who go on to graduate school. Mathematically, doubling the size of the pipe would increase the flow rate by a factor of sixteen. We can apply more pressure, which is where high-stakes tests, graduation requirements, competition for grant funding, value-added teacher evaluations, and state accountability regimes weigh in. We could also try to shorten the length of the program, but that only seems to be popular when we speak of teacher education, certainly not for the preparation of scientists or engineers. What all these approaches have in common is a failure to recognize and adequately address issues of viscosity.

What is viscosity? Viscosity in liquids refers to internal friction due to cohesive forces between the molecules. Different fluids possess different amounts of viscosity. In the pipeline model, fluids with a lower viscosity will have a higher flow rate. Who are the students with lower viscosities that literally rise to the top? The literature clearly relates persistence in science to students' academic preparation, faculty support, quality high school and college science experiences, family support, and science support programs. Importantly, none of these factors are related to a student's individual characteristics, such as race, ethnicity, gender, socioeconomic status, or linguistic ability. However, students' access to these external factors highly correlates with race, ethnicity, gender, socioeconomic status, or linguistic ability. In practice, what this means is that if you are White and male, you are more likely to have all the supports in place to achieve and persist in science than if you are female, Black, or Latino/a. In addition to students' differential access to support, we also have widespread stereotypes and deficit models that purport to "explain" why we have so few women or Black and Latino/a scientists; they simply lack the drive or ability to succeed in science. We develop compensatory programs designed to "fix" students so that they can flow through the pipeline just like everyone else. Yet, few programs ameliorate the "stereotype threats" students from marginalized groups experience as they pass through the pipeline (Steele 2010). Thus, the inherent flaw in the pipeline model is that it does not take into account the ways in which our society stratifies children's access to persistence factors. It also does not account for the filters or sieves within the pipelines that allow some students to flow through while restricting the flow of others.

Clearly in re-imagining science education and the types of assessment that align with expanded goals for students, we must also excavate issues of equity. For example, how can we design and implement assessments for students' technological literacy without addressing the digital divide between the haves and have-nots. How do we promote place-based learning in schools where students are not safe in their communities? How do we help all students develop critical civic literacy when their agency to enact such literacy is constrained or afforded by how much purchasing power they possess? Where do we begin? Where is the hope?

If It Were Easy, Hope Would Not Be Necessary

Hope, in the Catholic tradition, is "the confident desire of obtaining a future good that is difficult to attain."[1] Our desire pushes us to seek and pursue that future good and to exert effort to attain it. Hope is the antidote to fear, which shies away from future evil, and it is the opposite of despair, or yielding to the notion that "human nature cannot co-operate with God's grace." Coupling these notions of hope with the word radical (Radical), which in chemistry refers to an atom, molecule, or ion that is likely to take part in a chemical reaction, or in medicine, refers to surgery carried out in extreme circumstances, or mathematics, a symbol used to indicate the root, makes it clear that in these extreme circumstances, we must take action, and we need a foundation of radical hope to re-imagine science education and assessment for Generation R, the generation that will need to take responsibility for the world as it is and the world as it can be. Our hope must be rooted in a belief in the basic goodness, dignity, and sacredness of each human life and the potential for each one of us to contribute to a better world. Aldo Leopold wrote:

> Acts of creation are ordinarily reserved for gods and poets, but humbler folk may circumvent this restriction if they know how. To plant a pine, for example, one need be neither god nor poet; one need only own a shovel. By virtue of this curious loophole in the rules, any clodhopper may say: Let there be a tree—and there will be one (p. 86) (Leopold 1966).

What acts of creation will we take responsibility for? A number of chapters in this book describe courageous acts of creation that can serve as models as we move forward. Yet, a word of caution is necessary. In our rush to replicate successful projects, what tends to get scaled up are the methodological approaches, such as service learning or place-based science and not the living, breathing, loving, and caring human beings that made it all possible in the first place. We need to be humble. A life or soul is not scalable.

Generation R Is Not Alone

This summer, my Dad and I took my two younger children, Anthony and Anna, snorkeling in Puerto Rico. We had been to a number of beaches during the week, and for both of them, a "good" beach was one where we would be sure to see "interesting fish." That day we saw angel fish, tangs, and other fish I cannot name, but the highlight was a long swim down the beach with a shoal of fish beside us and around us. As we swam with the shimmering shoal of fish, a deep sense of wonder filled me. I was so thankful for the privilege to witness one of the beauties of our Earth. Each time we would lose the shoal, either my Dad or I would point the way for us to find it again. As Atkin says in the previous chapter, Generation R is not alone and this fills me with radical hope.

Among so many other hopes and dreams, I want my children and their children's children to be able to swim at "good" beaches. Thus, Generation R is not alone because each of us must become a part of Generation R and play a role in securing a better now and a better future for us all. As we move ahead, I close with more questions than answers, but sometimes questions can be more important than answers. What should we prioritize as we re-imagine science education? How should our priorities shape science teacher education? Are high-stakes test scores still important? How do we use expanded indicators or measures of impact and at what levels? How do we reconcile prescription, advocacy, and freedom? How do we balance tensions of individual, local, national, and global relevance of our measurements? How do we take good ideas from one place and use them to make policy that works in other places? How do we develop assessments and policies that fully support the new types of science teaching and learning we imagine in and out of schools?

Note

1. Hardon (2000), See entries for “hope” (p. 257) and “despair” (p. 154).

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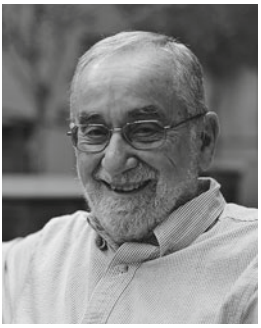

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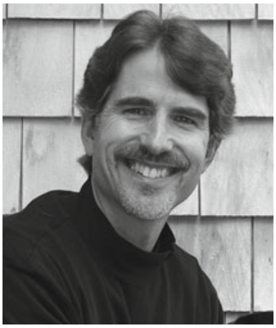

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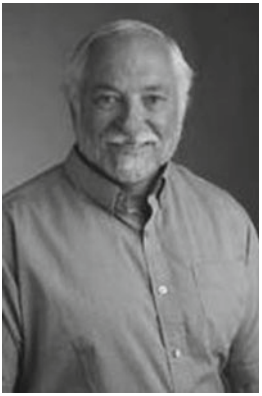

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