Citation: Peters, S. and Wals, A.E.J. (2013) Learning and Knowing in Pursuit of Sustainability:
Concepts and Tools for Trans-Disciplinary Environmental Research.
In: Krasny, M. and Dillon, J. (Eds.) Trading Zones in Environmental Education: Creating Transdisciplinary Dialogue,
New York: Peter Lang, p. 79-104.

Chapter 4

Learning and Knowing in Pursuit of Sustainability: Concepts and Tools for Transdisciplinary Environmental Research

Scott Peters and Arjen E. J. Wals

Unsustainability is rapidly becoming a key focus in research and education across the planet. Facilitating and pursuing sustainability is not simply or only a scientific and technical project; it has complex ethical, philosophical, and political dimensions. As such, it requires an embrace of epistemological pluralism that engages multiple ways of knowing, and multiple forms of knowledge. While ways of knowing that produce scientific and technical knowledge remain necessary, they need to be integrated with ways of knowing that produce what Aristotle called phronesis: a form of practical wisdom that can guide us in what should be done and how to act—in a moral, ethical, and political rather than technical and instrumental sense. Our purpose here is to provide a set of concepts and tools practitioners of transdisciplinary research can use to co-produce both scientific knowledge and phronesis. Practical theory building is highlighted as a tool that is helpful in designing sustainability-oriented education and research. We conclude by briefly noting several challenges and opportunities for academic professionals and students who

seek to practice a publicly engaged form of transdisciplinary environmental research that embraces epistemological pluralism.

We use the concept of transdisciplinary environmental research rather than transdisciplinary environmental education research (TDEE) deliberately to indicate that transdisciplinary environmental research that pursues sustainability inevitably will need to have an education and/or learning component as it requires reflexivity, co-creation, communication, and dialogic interaction between multiple societal actors. In this sense, all transdisciplinary environmental research is a form of TDEE. We like to think that this chapter itself is a product of transdisciplinary work as it interweaves Scott's grounding in political and educational philosophy, democratic theory, and narrative forms of inquiry with Arjen's grounding in environmental education, social learning, and critical pedagogy.

Introduction

> We are drowning in information while starving for wisdom.—E.O. Wilson (1998, 300)

In an essay about philosophies of science and democratic ideals, Sandra Harding (2000, 131) made the following point:

> Cultures' different locations in nature's order and their different interests in their environments will lead them to ask different questions and to develop different repositories of knowledge about nature's order. Since a culture's preoccupation with one set of environmental issues can lead it to ignore others, bodies of systematic knowledge are always accompanied by bodies of systematic ignorance: the two are always coproduced.

Harding's point raises an important question for academic professionals and students who seek to contribute to the work of developing and improving programs, initiatives, and practices of environmental research and education. How can environmental researchers and educators illuminate and address the problem in their particular cultural contexts of the production of bodies of systematic ignorance? Transdisciplinary environmental research appears to offer a promising means of answering this question. In its idealized form, practitioners of transdisciplinary research embrace epistemological pluralism (Miller et al. 2008). They intentionally interweave different ways of knowing in all

phases of a research project, including the naming of research problems, questions, and goals, the selection of theoretical and conceptual frameworks, the selection of methods, the gathering and analysis of data, and the communication of findings. A transdisciplinary approach is promising as it recognizes not only that the production of bodies of systematic knowledge and ignorance go together, but also that they are closely related to the ways of knowing that particular cultures choose to utilize or ignore, or to legitimize or marginalize. Theoretically at least, by choosing to utilize and legitimize many different ways of knowing, bodies of systematic ignorance can be reduced.

To make this point less abstract, consider the urgent problem of unsustainability, which is arguably the most important focus of attention across the planet in environmental research and education (Wals 2010). Facilitating and pursuing sustainability is not just a scientific and technical project (Röling and Wagemakers 1998). It has complex ethical, philosophical, and political dimensions. As such, it requires an embrace of epistemological pluralism that engages multiple ways of knowing, and multiple forms of knowledge. While ways of knowing that produce scientific and technical knowledge remain necessary, they need to be integrated with ways of knowing that produce what Aristotle called phronesis. Roughly defined, phronesis is ethically practical knowledge that is indispensable for the work of making context-specific value judgments about ends and means. Put another way, phronesis is a form of practical wisdom; it is knowledge about what should be done and how to act in particular circumstances—in a moral, ethical, and political rather than technical and instrumental sense (Dunne 1993; Flyvbjerg 2001; Flyvbjerg, Landman, and Schram 2012). While wisdom can be understood in individual terms as something that arises out of personal contemplation and reflection, we think of it here mainly in social terms as something that is produced in and through deliberative forms of public work.

Many nations invest billions in the production, dissemination, and application of scientific and technical knowledge and information. Investments in the social production of wisdom are far smaller and weaker (Maxwell 2007). While we may well still be lacking when it comes to scientific information and knowledge—our ignorance of the natural and biological world is, after all, still quite large—we are much more lacking when it comes to wisdom. Considering Harding's point in the context of sustainability, our lack of wisdom about what we should rather than can

do to facilitate sustainability is produced. It constitutes a body of systematic ignorance that is produced from the priorities, methods, and dynamics of our educational and political systems, and by the workings of power.

Given the inherently political and power-laden nature of this situation, can environmental researchers and educators do anything to reduce such systematic bodies of ignorance and develop what we might call "sustainability wisdom"? We think so. Our purpose in this chapter is to provide a set of concepts and tools that practitioners of transdisciplinary environmental research can use to facilitate the development of sustainability wisdom by co-producing both scientific knowledge and phronesis. What we provide reflects our own embrace of two normative positions about higher education. First, we believe higher education should adopt a position and identity that is engaged in rather than detached from the public work of democracy. Democracy here refers to the process and means by which individuals and groups develop and exercise power in neighborhood, community, and other settings as they seek to understand and address technical and social problems. Through the public work of democracy, participants stand for and strengthen key normative ideals and values, and promote, consider, deliberate about, negotiate, and take action to pursue their self-interests, their common interests, and larger public interests (Mathews 1999; Boyte 2004). Second, we affirm and support the civic role for academic professionals that C. Wright Mills identified in his classic book *The Sociological Imagination*. Mills (1959, 191–192) wrote that the "educational and political role of social science in a democracy is to help cultivate and sustain publics and individuals that are able to develop, to live with, and to act upon adequate definitions of personal and social realities." While the performance of such a role within and beyond the social sciences includes the production, dissemination, and application of scientific knowledge and theory, it also includes the facilitation of learning and the production of knowledge about what should as well as can be done to address social and environmental issues and problems (Fischer 2000; Peters 2010).

As a means of grounding our ideas and arguments, we begin with a specific scenario or case about a complex environmental dispute. We then reflect on higher education's ability to play meaningful and generative roles in such cases. In doing so, we ask what kinds of challenges such cases pose for higher education, and what kinds of learning and ways of

organizing and supporting learning they require. We then introduce and discuss the reflexive work of practical theory building as a tool for designing environmental education and research initiatives, and for improving their effectiveness and trustworthiness. We conclude by noting several challenges and opportunities for academic professionals and students who seek to practice a publicly engaged form of transdisciplinary environmental research that embraces epistemological pluralism.

Grounding Scenario: The Marcellus Shale

Underlying much of several states in the northeastern region of the United States—including Pennsylvania, New York, Ohio, and West Virginia—lies the Marcellus Shale. Geologists and scientists have long known that this geological formation contains a massive store of natural gas. It is currently estimated to contain as much as 363 trillion cubic feet (roughly 10.3 cubic meters) of natural gas—enough to supply the gas needs of the entire United States for 15 years (Soeder and Kappel 2009)[1].

It has only been since the turn of the millennium that the gas industry has developed and tested technologies—namely, hydrofracking and horizontal drilling—that can be used to extract natural gas from the Marcellus Shale in ways that are profitable (but only under specific regulatory circumstances). These technologies are now being used in every state included in the Marcellus Shale, with one exception: New York State. State government in New York has placed a temporary moratorium on the granting of permits for wells that use hydrofracking and horizontal drilling technologies until the state's Department of Environmental Conservation completes an environmental review. Meanwhile, citizens and industry groups have engaged in vigorous lobbying, protest, and propaganda campaigns for and against the use of the new gas-drilling technologies.

While there are, of course, many different views and positions in the debate over the use of the new technologies, the extreme views and positions have received the most attention. The extreme position on the pro-drilling side is to demand an immediate granting of permits for the use of the new technologies. Advocates of this position argue that the technologies have been proven to be safe in other states. They emphasize the potential economic benefit of gas drilling and the environmental benefits of natural gas compared with coal. They place a high degree of

trust in the gas industry and its technologies and methods. The extreme position on the antidrilling side is to demand an outright ban of the technologies in New York and elsewhere. Advocates of this position argue that the new technologies have been proven to be unsafe in other states. They emphasize the fact that the hydrofracking process uses millions of gallons of water in each well that is dug, along with an unknown mix of chemicals. (The reason why the chemicals are unknown is because the gas industry was granted an exemption from the Clean Water Act during the George W. Bush administration.) They argue that the technologies are too risky to be permitted because they endanger groundwater and drinking supplies, and the health of living things (including people).

Advocates of the two opposing sides of the gas-drilling issue have developed and exercised different levels and kinds of knowledge and power. They have articulated and advocated for conflicting values, interests, and ends. They have expressed conflicting views of what constitutes the "public" interest, and how it can and should be advanced. And in making their cases, both sides have skillfully engaged in what Fischer (2000) refers to as "the politics of counter-expertise." They have recruited their own scientists and conducted their own studies. They have even produced their own documentary films to support their interests, views, and claims, including Gasland (2010), a documentary produced by an antidrilling activist, which was shown on HBO and subsequently nominated for an Academy Award.

Despite (or perhaps because of) the efforts of the pro- and antidrilling advocates, many people remain unsure about what should be done. And for good reason. The effects of the use of the new gas-drilling technologies are uncertain. In fact, the whole scenario involves a high degree of technical, social, cultural, economic, and environmental uncertainty and complexity. There are conflicting and competing views not only about what the "facts" are and how to interpret them, but also about which interests, values, and ideals are at stake, and which are more and which less important.

The Marcellus Shale case (and other cases like it that relate to sustainability) offers rich and urgently pressing argument for environmental education and transdisciplinary environmental research. Faculty, staff, and students in colleges and universities can—and we think, should—be engaged with others beyond the campus in efforts to understand and address the issues and problems it involves. Indeed, they

already are engaged. For example, many faculty, staff, and students from Cornell University are presently working with their colleagues from other colleges and universities—as well as with legislators, government officials, the media, and members of the public—to conduct research, provide information, and organize and facilitate opportunities for discussion about the Marcellus Shale situation. What we refer to as practical theory building can be a useful tool in such work. Before we introduce that tool, we think it would be helpful to reflect on the ways that the task of dealing with unsustainability challenges in the twenty-first century carries serious implications for concepts, practices, structures, and systems of leaning and knowing.

Reorienting Higher Education in the Face of (Un)Sustainability

Although the scales and levels of intensity might differ, it can be argued that all sustainability challenges involving multiple stakeholders—including those related to food security, biodiversity, and climate change—are characterized by complexity, uncertainty, and contestation, and multiple causation, interactions, and feedback loops (Folke et al. 1998; Folke 2006; Gunderson and Holling 2002; Davidson-Hunt and Berkes 2003). These characteristics diminish and limit the effectiveness of old mechanisms, coordination points, problem-solving strategies, modes of scientific inquiry, and forms of teaching and learning. Yet, dominant structures in governance, policy making, and science and education are still essentially based on fragmentation and "management and control thinking," rather than on connectivity and "chaos and complexity thinking" (Axelrod and Cohen 2000; Gunderson and Holling 2002). In this chapter we are particularly interested in the implications of this observation for higher education, as the sector can no longer occupy the role it played in the industrial society.

Ulrich Beck has long argued that during the twentieth century we transitioned from an industrial to what he calls a "risk" society (Beck 1992, 2008). Whereas industrial society was mainly about material growth and the distribution of "goods," society today is mainly about the distribution of "bads" such as environmental disasters, hunger, contaminated drinking water, floods, droughts, oil spills, and so on. Oftentimes, these risks are distributed discriminately (i.e., consistently

affecting those who are less fortunate). But as many of these "bads" are now of a global nature (e.g., runaway climate change), the risks associated with them tend to be distributed more and more indiscriminately. Whether you are rich or poor, there is no escaping them, although money does help, at least temporarily, in escaping or reducing the consequences. Industrial growth fuelled by unbridled consumerism is beginning to turn against us, because it is yielding more and more risks.

The emerging risk society will show a shift from acquiring material wealth to safeguarding against risks. In addition, trends such as globalization and individualization have an enormous impact on the complexity of society, resulting in increased insecurity and unpredictability. What is typical of the risk society is that this insecurity and unpredictability stem from unintentional and often unforeseen changes to ecosystems. Society is constantly in motion, and citizens are facing problems and challenges for which there are no ready-made solutions available. Past solutions no longer offer guarantees of adequate results, either now or in the future. For higher education to play a meaningful role in the risk society, with its sustainability challenges, a major reorientation of teaching, learning, research, and university-community relationships will be required (Corcoran and Wals 2004; Jones et al. 2010; Martens et al. 2010).

Today's universities appear to be caught between two trends: one that is hegemonic, and another that is emerging but still marginal. The hegemonic trend builds upon the industrial society model of fragmentation, prescription, management, control, and accountability, while the marginal trend is based on integration, self-determination, agency, learning, and reflexivity (Unterhalter and Carpentier 2010). The latter appears to represent an orientation towards the emerging risk society referred to earlier. In many universities both trends can be found, but usually one far outweighs the other. In Table 1 we have juxtaposed the two trends, for debate's sake, with the realization that these distinctions are neat on paper but inevitably messy in the everyday world of academia: science as commodity and science as community.

Table 1. Juxtaposing Two Stereotypical Conceptualizations of Science in the Context of Higher Education

	Science as Commodity	Science as Community
Research orientation	Science for impact factors Strong emphasis on publication, targets to be met by publishing in ISI journals, preferably those with a high impact factor	Science for impact Strong emphasis on societal relevance, targets to be met by positive feedback by extended peers that include those who are to benefit from the research
Educational orientation	Efficiency Students are viewed from an economic perspective as clients input, throughput, and output, who need to get their diplomas within the time allocated at minimal costs Instrumental—transfer of predetermined and relatively fixed outcomes	Authenticity Students are viewed from a human-development perspective as citizens who want to develop themselves and want to engage in meaningful learning around authentic issues Emancipatory—high degrees of self-determination, space for transformation and co-created and emergent outcomes
Business orientation	Focus on continuous growth The university wants or is forced (as governments withdraw public money) to get more money out of the market. Faculty get acquisition targets and "billable days" targets. Rapid growth of private universities and the disappearance of public ones.	Focus on dynamic quality The university invests in community relations and community outreach, seeking to become indispensable and an integral part of the community, which in return is willing to support the university.
Epistemological orientation Type of knowledge generated	Empirical rationalism Finding an objective truth. Establishing causality. Single truth exists and can be known. Maximize predictability, management, and control. Minimize uncertainty. Scientific and technical knowledge that can (in some but not all instances) be generalized across contexts to inform attempts by various social actors to predict, control, and/or intervene for specific instrumental ends.	Socio constructivism Co-creation of knowledge, intersubjectively validated. Pluralist. Not one single "truth" but many, subject to interpretation. Uncertainty as a given. Facts and values are inseparable. Not only scientific and technical knowledge, but also phronesis: ethically practical knowledge that is indispensable for the work of making context-specific value judgments about ends and means.

Without rejecting the "science as commodity" perspective outright, as it may still provide some answers in the quest for sustainability, we are particularly interested in the emergent conceptualization of "science as community," as we believe it holds promise in addressing sustainability issues in a risk society. It reflects and includes transdisciplinary research's embrace of epistemological pluralism. And it appears more prepared to deal with some key characteristics of sustainability issues, including:

- indeterminacy (the impossibility of knowing in advance what the best course of action is);
- value-ladenness (the crucial position of values in affecting behaviors, lifestyles, and systems);
- controversy (the lack of and impossibility of full agreement or consensus among all stakeholders);
- uncertainty (not being able to predict the exact or even near-exact impact of a chosen strategy or action); and
- complexity (the messy interactions between a whole range of variables operating at different intertwined scales).

Let us take the epistemological orientation in Table 1 to illustrate these characteristics. Accepting that it is an illusion to think that we will ever be able to achieve zero uncertainty or even get close to that will be quite problematic for some, if not many, people working in (research) universities, as well as many members of the public who think that universities can produce settled knowledge. This is so because it implies that more science, information, and knowledge might not necessarily lead to less uncertainty. It may actually lead to more uncertainty, as new complexities and questions arise. The alternative to minimizing uncertainty and maximizing predictability is quite radical, as it requires a mindset that accepts living with uncertainty: seeing it as a given, something that cannot be conquered, only transferred (Borchers 2005). Bearing in mind these distinguishing features of sustainability, it appears to make sense to develop a "precautionary reflexivity" (Wals 2010) that can steer clear of the inaction, paralysis, and apathy that often results from the prevailing "wait and see until we have all the facts" attitude among many citizens, including scientists. Such an attitude suggests that as long as there is disagreement among scientists and policy makers about what is happening to the planet and about what needs to be done, we have no reason to break with our existing routines and can return to

business as usual. In their edited volume on education and climate change, Kagawa and Selby (2010, 243) write: "As a fundamental contribution to climate change [prevention and adaptation], it seems that educational spaces should build a culture of learning awash with uncertainty and in which uncertainty provokes transformative yet precautionary commitment rather than paralysis." Similar pleas can be read in the work of social ecologists focusing on learning in "managing" complex adaptive and resilience-seeking systems (e.g., Berkes et al. 2003; Berkes 2009; Armitage et al. 2003), and in the work of scholars in the field of environmental education (e.g., Krasny et al. 2010).

Likewise, a shift in the contextual orientation of science towards one that better aligns with the science as community perspective described in Table 1 implies that rather than prescribing and transferring particular knowledge, understanding, and behavior (to the extent this is even possible), it may be more fruitful to create learning environments and to facilitate learning processes that will strengthen citizens' "dynamic" qualities (Posch 1991). Such qualities are those that would help people cope with uncertainty, poorly defined situations, and conflicting (or at least diverging) norms, values, interests, and constructions of reality (de Haan 2010; Martens et al. 2010). Such qualities require, among other things, better listening, empathy, and Gestaltswitching, which is the ability to look at an issue from multiple perspectives (Wals and Blewitt 2010; Barth et al. 2007; de Haan 2006, 2010). Posch (1991, 12) writes: "Professional, public and private life has become increasingly complex, with divergent and even contradictory demands on the individual [who lives] within an increasingly pluralistic value system. Above all, it is necessary to look beyond everyday normalities and to search for ethically acceptable options for responsible action." The science as community perspective calls for an emancipatory approach that recognizes that the dynamics of our current world are such that all citizens—including scientists and scholars—need to become engaged in an active dialogue to establish co-owned objectives, shared meanings, and a joint, self-determined plan of action to make changes that they themselves consider desirable, and that contribute to a more sustainable society as a whole (Wals and Jickling 2002). Finally, the educational orientation within the science as community perspective also requires a critical awareness with respect to one's own frames and those used by others. Such awareness can help us understand specific value judgments about ends and means, while preventing

people's own frames or ways of seeing from producing obscuring insights (cf. Harding's systematic ignorance).

Learning in a Risk Society

The science as community perspective requires forms of education and learning that are more responsive to the risk society with its sustainability challenges. A whole range of associated forms of learning, some old, some new, are emerging that appear particularly congruent with science as community and the emancipatory perspective outlined above. Examples include: transdisciplinary learning (e.g., Klein 2000; Sommerville and Rapport 2000), transformative learning (e.g., Cranton 2006; Mezirow and Taylor 2009), cross-boundary learning (e.g., Levin 2004), anticipatory learning (e.g., Tschakert and Dietrich 2010), action learning (e.g., Marquardt 1999; Cho and Marshall Egan 2009), and social learning (e.g., Pahl-Wostl and Hare 2004; Keen et al. 2005; Wals 2007) These forms or rather models of learning show a high family resemblance in that they all:

- view learning as more than merely knowledge-based;
- maintain that the quality of interaction with others and with the environment in which learning takes place are crucial;
- focus on existentially relevant or "real" issues that affect and engage learners;
- view learning as inevitably transdisciplinary, "transperspectival," and transboundary in that it cannot be captured by a single discipline or by a single perspective;
- see indeterminacy as a central feature of the learning process in that it is not and cannot be known exactly what will be learned ahead of time, and that learning goals are likely to shift as learning progresses.

The above characteristics suggest that "hybridity" and synergy between multiple actors are needed. They also imply the blurring of nowadays obsolete concepts such as formal, nonformal, and informal education. Opportunities for this type of learning expand with an increased permeability between disciplines, generations, cultures, sectors, and so on. The hybridity and associated boundary crossing that are needed in all these emerging forms of learning are likely to generate uncomfortable dissonance and frictions as

taken-for-granted perspectives, values, and interests come to the surface and are confronted with those of others.

A Learning Ecology

George Siemens speaks of a "learning ecology" to emphasize that connectivity between people is influenced and can be strengthened by a number of interrelated factors that together form a learning configuration (Siemens 2005). Figure 1 shows how a learning ecology is a networked, facilitated, and mediated configuration of multiple modes of learning revolving around a change or transformation challenge. The learning taking place is influenced by the filters that learners bring to the configurations (values, perspectives, and beliefs), the conduits that facilitate learning (language, media, and technology), the various dimensions of learning (from learning about something to learning to transform something), and the different layers of learning concepts (from data to wisdom).

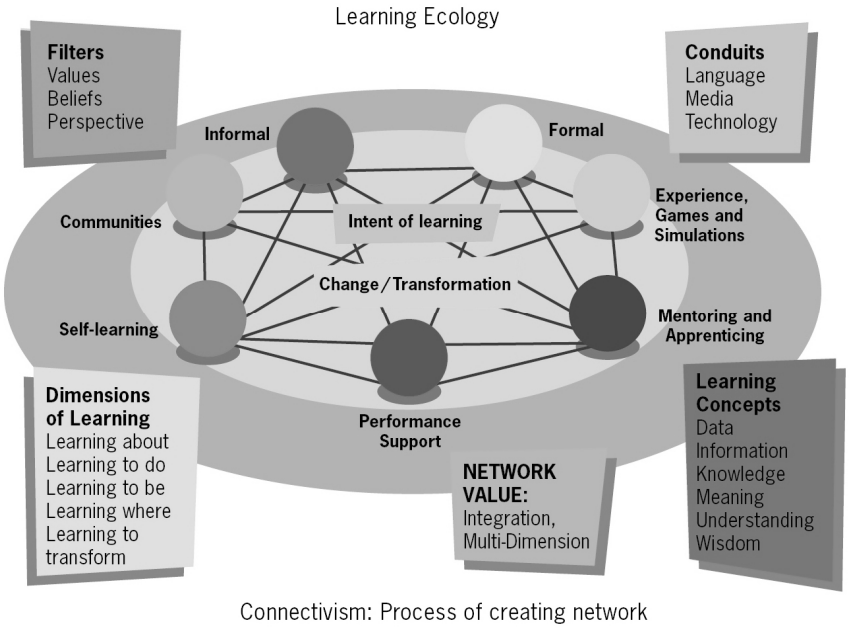

Figure 1. George Siemens's Learning Ecology. Source: Siemens 2005.

Siemens's model emphasizes connectivism, which refers to boundary crossing between different vantage points in a web of generative relationships that go far beyond the confines of a school building or a university. In line with our earlier observation, it can be argued that learning in the context of sustainability requires "hybridity": generative combinations of actors representing different vantage points but facing similar challenges. Through this hybridity and connectivity, new spaces might open up that will allow for transformative learning to take place (Mezirow and Taylor 2009), including space for alternative paths of development and space for new ways of thinking, valuing, and doing. In essence, these ideas are simply new ways of naming the best forms of publicly engaged education and scholarship that have long been practiced by some (but decidedly not all) academic professionals and students in many institutions. (See Peters et al. (2005) and Peters (2010) for elaborations and examples of forms of publicly engaged education and scholarship as they exist in land-grant colleges and universities in the United States.)

Practical Theory Building

How then, practically, might students, academic professionals, and their public partners design and implement transdisciplinary environmental research initiatives that incorporate ideas about learning and knowing that are compatible with a science as community perspective? In this section, we offer a tool that can be used for this purpose. Inspired by Kurt Lewin (1946), we call this tool practical theory building[2].

In brief, a practical theory has three closely related components (see Figure 2):

- an understanding of "the way things are," and why and how they came to be the way they are;
- a view of "the way things should be," given the values and ideals we embrace, the ends we think are worth striving for, and the interests we want to advance; and
- a strategy that identifies what we can and should do to move from the way things are to the way things should be.

In relation to these components, practical theory building involves three distinct kinds of work:

The work of determining what is. This includes naming, framing, and setting problems; identifying, observing, and documenting physical, social, cultural, and political realities, phenomena, and behaviors; identifying and documenting views, opinions, and needs; and identifying and articulating ideals, values, and interests.

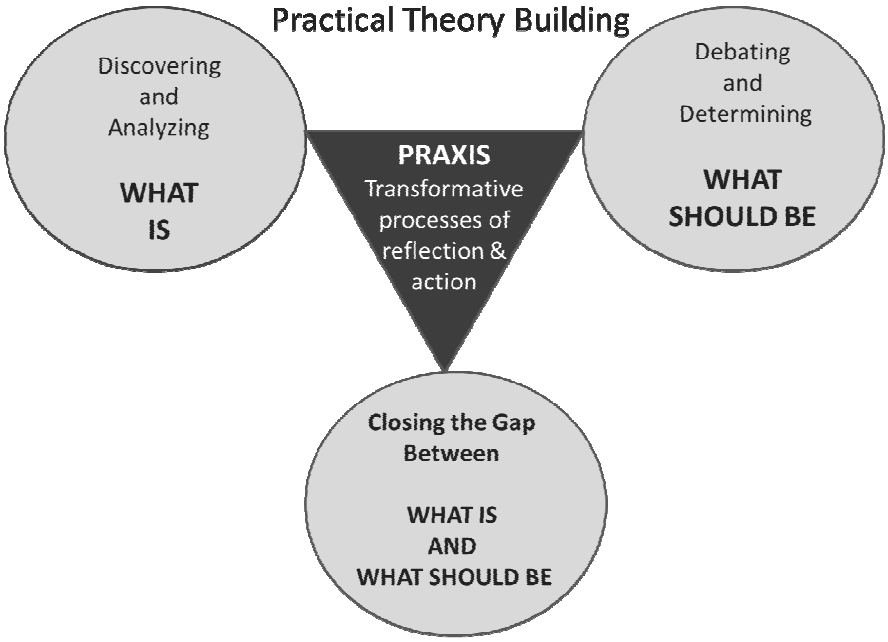

Figure 2. The process of practical theory building

The work of determining what should be, and what can and should be done to close the gap between what is and what should be. This includes public deliberation and debate; the production of public judgment; the running of experiments; and the development and testing of action plans, strategies, and tools.

The work of determining, assessing, and interpreting what happened and why, and so what. This is done both during and after taking action and running experiments, and it can include both quantitative forms of measurement and qualitative and narrative forms of evaluation and interpretive meaning making.

If you are thinking this sounds a lot like action research (Greenwood and Levin 2007), you would be right. By definition, practical theory building

requires both research and action. It is not an academic exercise, to be done in detached ways by and for academics. To be effective, it must be done by diverse teams who commit to learning and theorizing in and through their active engagement in the world. And the teams who pursue it must constitute themselves as publics that work in public settings and for public purposes and audiences.

It is important to note that practical theory building is not an exotic or unusual activity. We all do it, albeit mostly intuitively. What we do not all do, however (and "we" includes those of us who work as scholars, scientists, and educators), is consciously, systematically, and transparently engage in practical theory building with our colleagues and external partners. And we do not typically do so in publicly engaged and transdisciplinary ways that invite and embrace deliberative decision making and epistemological pluralism.

To take all this out of the abstract, let us return for a brief moment to our grounding scenario and imagine how we would build and use a practical theory about the gas-drilling situation in the Marcellus Shale as part of an action research initiative. As we noted above, in New York State, legislators and agency staff in state government are faced with the task of determining whether they should grant permits for natural gas wells that will use hydrofracking and horizontal drilling technologies, and if so, under what conditions and with what kinds and levels of restrictions and oversights. Citizens as well as legislators and agency staff are faced with the task of understanding the potential effects these technologies might have, what is at stake (not only in terms of economics but also ecology, politics, values, culture, aesthetics), what other options might be available, and how a larger public interest as well as individual self-interests not only might but should be advanced.

In this scenario, we would begin our work by assembling a diverse team of partners within and beyond our universities. We would obviously want our team to include partners from the various sciences that have expertise about the technical aspects of gas drilling and its environmental impacts (e.g., hydrology, geology, and engineering). Given the political, economic, legal, ethical, and cultural dimensions of the situation, we would want to include scholars and educators with expertise in various fields from the arts and humanities, the social sciences, law, and planning and design. And we would also want our team to include community members who have various kinds of stakes in the situation, and various kinds of local knowledge.

Finally, we would need to recruit someone with skills in a kind of organizing that is both educational and developmental.

How big should our team be? Not too big as to make its functioning unwieldy. How diverse should it be? Diverse enough to be genuinely transdisciplinary, and to include enough different ways of knowing to counter the tendency to produce bodies of systematic ignorance.

Having assembled a diverse team, we would introduce the tool of practical theory building by co-designing with our partners ways to engage in the first two kinds of work it entails: the work of determining what is and what should be with respect to the gas-drilling situation, and the work of determining what can and should be done to close the gap between what is and what should be. During and after whatever actions we decide to take, we would co-design ways to engage in the work of determining, assessing, and interpreting what happened and why, and so what. And then we would begin the cycle all over again.

There are no universally valid bullet-pointed lists of steps to follow in the work of practical theory building. There are no "best practices." The work is and always must be improvisational, closely tuned to the realities and dynamics of specific contexts. As a tool to be embedded in action research initiatives, practical theory building should be understood as an ongoing routine or discipline rather than a blueprint or formula. Practical theory building engages people in collaborative forms of learning and knowing. It involves the ongoing discipline of articulating, questioning, refining, and testing the effectiveness of the ways people answer in specific settings the following general statement: Given what is and what should be, if we do these things, we'll get these results.

For academic professionals, students, and community members who might want to initiate or contribute to environmental research and education efforts in the gas-drilling scenario (or in other similar scenarios), practical theory building offers a distinctly different approach than business as usual. In the academy, business as usual is mainly classroom teaching and learning and/or disciplinary research for academic audiences. In communities, business as usual includes interest-group lobbying and advocacy, protests, and behind-closed-doors decision making. The development and practice of a routine of practical theory building in transdisciplinary and publicly engaged action research initiatives breaks out of these business-as-usual structures, systems, and habits.

Here, we want to stress something we think is extremely important. Approached in a way that engages people outside higher education as active knowers who can help create knowledge instead of passive "customers" or "taxpayers" to be informed, practical theory building can be used as a means of designing transdisciplinary environmental research initiatives that facilitate social learning and cultivate and sustain democratic publics in and through the research process. With respect to academic professionals, this can—and we think should—be done by avoiding partisan activism. It can do so by being open to critical reflection, and to evidence or values or ideas that might challenge particular beliefs, presumptions, and self- and common interests. However, this cannot be done without an embrace of interested public engagement over disinterested academic detachment. In essence, it charts out a third path that is less travelled in academic and public spheres. Such a path represents a different kind of politics that is more deliberative than activist, and that does not position academic professionals as disinterested experts or partisan activists, but rather as interested participants who contribute to social processes of learning and knowing as educators as well as scientists and scholars.

Earlier in this chapter we argued that transdisciplinary environmental research that pursues sustainability inevitably will need to have an education and/or learning component, as it requires reflexivity, co-creation, communication, and dialogic interaction between multiple societal actors. We somewhat provocatively stated that in this sense, all transdisciplinary environmental research is a form of environmental education. Here we would like to address the field of environmental education a little more specifically. Like academic professionals, environmental educators in nonuniversity settings are expected to play either disinterested or partisan activist roles. It is interesting to refer back to a heated debate in the field of environmental education that took place in the late 1990s when people representing conservative think tanks provided some strong criticism of the field of environmental education. These critics, led by Michael Sanera (Sanera and Shaw 1996), claimed that environmental education was alarmist, antibusiness, catastrophic, and unscientific. They also suggested that many educators are ill-prepared to present environmental topics to students in a manner that reflects the complexity of the issues involved. Greg Smith points out that much of the criticism at the time appeared to be aimed at diminishing legitimate concerns about issues such as global climate change and biodiversity loss by focusing on the alleged failure of environmental

educators to present conflicting scientific evidence, a failure linked to their avowed desire to turn their students into environmental activists (Smith 2000). The conservative voices were emphasizing that EE should focus on facts and not on fear, and that environmental educators should be educators, not indoctrinators; the response to this criticism was in part denial (e.g., we are objective educators, and we do not focus just on fear but also on love for nature, etc.) and in part "throwing the ball back" by arguing that these conservative voices had their own political agenda, which was to represent the interests of big business.

We refer back to this debate to illustrate that not only is the role of scientists in society currently in question, but so too is the role of (environmental) educators. How should educators working in New York State, above the Marcellus Shale, handle a controversial issue such as this in public classrooms and/or community settings? What position do they take? How do they bring in and treat scientific evidence coming from different sides? Do they take a stance? Do they actively engage in such a complex and existentially relevant issue? Are they able and willing to draw distinctions between rhetoric and reality, and to reduce, using Sandra Harding's language, the systemic bodies of ignorance created around highly politicized issues such as these? Or should they stay away from issues such as these altogether, and stick to school board–approved textbooks in order to keep controversy out of the classroom?

We believe taking one side in the continuum between passive detachment and avoidance on the one hand ("playing it safe") and active involvement and engagement on the other ("taking a risk") will not be generative in taking education, learning, and research to a level where we can deal with issues such as these in a more satisfying, less polarizing way. This is where practical theory building offers a third way forward, as it assumes that learners—including teachers, researchers, policy makers, etc.—do not accept facts as an external given; rather, it requires self-confrontation and joint fact finding as a starting point for learning.

An important aspect of practical theory building, when it is approached in a public way that engages diverse participants inside and outside the academy, is its potential for establishing conditions in which there is ample space for alternative views that allow for generative dissonance to emerge. By "generative dissonance," we refer to dissonance or internal conflict that invites deeper thinking and self-confrontation both at the individual and at the collective level. It is the opposite of regressive dissonance, which blocks

deeper thinking and self-reflection and strengthens or freezes the view of frame one already has. In his interpretation of transformative learning, Mezirow also emphasizes dissonance when describing transformative learning as a process of "becoming critically aware of one's own tacit assumptions and expectations and those of others and assessing their relevance for making an interpretation" (2009, 4), which "enables us to recognize, reassess, and modify the structures of assumptions and expectations that frame our tacit points of view and influence our thinking, beliefs, attitudes and actions" (18). Confrontation with other assumptions and expectations offered by others can greatly help one become more aware of one's own way of seeing things.

Hence, practical theory building must involve frame awareness, frame deconstruction, and reframing (Kaufman and Smith 1999), whereby a frame refers to a particular lens or somewhat fixed way of viewing an issue. These are central steps in transformative social learning, and in public deliberation processes where people try to figure out not only what should be done about a particular problem, but also what the problem is and how to name it in the first place. People can become so stuck in their own frames—ideas, ways of seeing things, ways of looking at the world, ways of interpreting reality—that they may fail to see how those frames color their judgment and interactions, and how and why they may be different from others. Perhaps the essence and success of practical theory building, much like in social learning, lies in people's ability to transcend their individual frames so that they can reach common ground where they are able to find each other and create enough "chemistry" to feel empowered to work jointly on the challenges they come to share (Wals 2007).

Frame awareness is preconditional for deconstruction. Deconstruction, here, is the process of untangling relationships and becoming aware of one's own hidden assumptions, their ideological underpinnings, and the resulting tunnel vision they provide. When this process takes place in a collaborative setting, where dissonance is properly managed, cultivated, and utilized, participants become exposed to the deconstructed frames of others, begin to rethink their old ideas, and are challenged to jointly create new ones (Wals 2007). This process opens a door for the work of developing public judgment about what should be done about an issue or problem. In other words, it opens a door for the production of phronesis.

Conclusions

The concepts and tools we have offered in this chapter are in many ways deeply countercultural. They seriously challenge business as usual—not only in higher education and the academic profession, but also in other human systems such as government and industry. At the same time, we believe that they build upon and support several existing cultural practices and resources, as well as some emerging trends and dynamics within and beyond higher education. Although some will consider the glass half-empty, we believe the glass is half-full in terms of the current conditions and spaces for strengthening transdisciplinary environmental research. There are opportunities for academic professionals and students to use these conditions and spaces in transdisciplinary environmental research initiatives that engage a diverse range of participants drawn from within and beyond higher education.

Hence, what we offer is not utopian wishful thinking: The ideas and tools we express in this chapter are currently sprouting in networks, stakeholder alliances, and transition movements. Examples include the revival of university science shops as conceptualized in the 1970s (www.livingknowledge.org), the emergence of a number of new networks of community-engaged universities (e.g., Centro Boliviano de Estudios Multidisciplinarios, Commonwealth Universities Extension and Engagement Network, Imagining America, Campus Compact, Global Alliance of Community Engaged Research, Global Universities Network for Innovation, PASCAL International Observatory, Participatory Research in Asia, and the Talloires Network); the transition town movement in the United Kingdom and elsewhere; and, finally, the emergence of centers of expertise focusing on sustainability issues, such as the Regional Centres of Expertise (RCEs), in which universities are partners in a network of NGOs, civil society organizations, community groups, and schools (Mochizuki and Fadeeva 2008). In connection with such movements, initiatives, and networks, members of the academy are increasingly becoming engaged in public life and work. In doing so, they are tending to recognize the added value of epistemological pluralism, drawing from multiple ways of knowing and learning (see also: Blackmore 2007; Irwin 1995). Also in our own academic cultures, at both Cornell and Wageningen Universities, a call for societal relevance and public engagement that is strengthening a culture of learning and reflexivity is getting louder, possibly at the expense of what we might

call "a culture of knowledge production," which indeed also characterizes much of what goes on in our institutions.

Practicing transdisciplinary environmental research in ways that utilize the concepts and tools we have offered in this chapter involves more than the obvious challenge of figuring out how to break out of academia's narrow disciplinary silos. It includes five other closely related challenges. First, there is the challenge of figuring out how to build legitimacy and respect for qualitative and interpretive ways of knowing (such as narrative inquiry) that do not involve measuring things or establishing statistically significant relationships between variables. Second, there is the challenge of figuring out how to create legitimacy and respect for public engagement in the academic profession, not only as a means of "informing" or "serving" external audiences by extending and applying already existing scientific and technical knowledge, but also as a means of facilitating learning and knowing that generates new knowledge and theory, and builds and strengthens public relationships. Third, there is the challenge of figuring out how to create legitimacy and respect within higher education for the political project of cultivating and sustaining democratic publics, a project that is distinctly different from the more dominant but no less political project of prediction and control. Fourth, there is the challenge of figuring out how to create authority and space for the practice of a different kind of politics than is typically found within and beyond higher education—a politics that is productive as well as deliberative, that is citizen—rather than government-centred, and that embodies a developmental and participatory view of democracy as self-rule: the public work of a free people in everyday spaces and places. And last but certainly not least, there is the challenge of figuring out how to raise enough money and carve out enough time to conduct transdisciplinary research.

Notes

[1] For a searchable database of scientific publications related to the Marcellus Shale, see http://www.bucknell.edu/script/environmentalcenter/marcellus.

[2] Kurt Lewin, a social psychologist who served on the faculties of both Cornell University and MIT, has been credited with saying: "Nothing is as practical as a good theory" (see Greenwood and Levin 2007, 18). The practical theory phrase was used as the title of an intellectual biography of Kurt Lewin, Alfred J. Marrow's *The Practical Theorist: The Life and Work of Kurt Lewin* (New York: Basic Books, 1969).

References

Axelrod, R., and M.D. Cohen. Harnessing Complexity: Organizational Implications of a Scientific Frontier. New York: Basic Books, 2000.

Barth, M., J. Godemann, M. Rieckmann, and U. Stoltenberg. "Developing Key Competencies for Sustainable Development in Higher Education." International Journal of Sustainability in Higher Education 8(4) (2007): 416–430.

Beck, U. Risk Society: Towards a New Modernity. New Delhi: Sage, 1992.

———. World at Risk. Cambridge, UK: Polity Press, 2008.

Berkes, F. "Evolution of Co-Management: Role of Knowledge Generation, Bridging Organizations and Social Learning." Journal of Environmental Management 90(5) (2009): 1–11.

Berkes, F., J. Colding, and C. Folke. Navigating Social-Ecological Systems: Building Resilience for Complexity and Change. Cambridge, UK: Cambridge University Press, 2003.

Borchers, J.G. "Accepting Uncertainty, Assessing Risk: Decision Quality in Managing Wildfire, Forest Resource Values, and New Technology." Forest Ecology and Management 211(1/2) (2005): 36–46.

Boyte, H.C. Everyday Politics: Reconnecting Citizens and Public Life. Philadelphia: University of Pennsylvania Press, 2004.

Blackmore, C. "What Kinds of Knowledge, Knowing and Learning are Required for Addressing Resource Dilemmas? A Theoretical Overview." Environmental Science and Policy 10(6) (2007): 512–525.

Cho, Y., and T. Marshall Egan. "Action Learning Research: A Systematic Review and Conceptual Framework." Human Resource Development Review 8(4) (2009): 431– 462.

Corcoran, P.B., and A.E.J. Wals. Higher Education and the Challenge of Sustainability: Problematics, Promise, and Practice. Dordrecht, Netherlands: Kluwer Academic Press, 2004.

Cranton, P. Understanding and Promoting Transformative Learning: A Guide for Educators of Adults. San Fransisco: Jossey-Bass, 2006.

Davidson-Hunt, I., and F. Berkes. "Learning as You Journey: Anishinaabe Perception of Social-Ecological Environments and Adaptive Learning." Conservation Ecology 8(1) (2003): 5.

De Haan, G. "The BLK '21' Programme in Germany: A 'Gestaltungskompetenz'-Based Model for Education for Sustainable Development." Environmental Education Research 12(1) (2006): 19–32.

———. "The Development of ESD-Related Competencies in Supportive Institutional Frameworks." International Review of Education 56(2/3) (2010): 315–328.

Dewey, J. Democracy and Education: An Introduction to the Philosophy of Education. New York: The Free Press, 1966. (1st ed., 1916.)

Dunne, J. Back to the Rough Ground: Practical Judgment and the Lure of Technique. Notre Dame, IN: University of Notre Dame Press, 1993.

Fischer, F. Citizens, Experts, and the Environment: The Politics of Local Knowledge. Durham, NC: Duke University Press, 2000.

Flyvbjerg, B. Making Social Science Matter: Why Social Inquiry Fails and How it Can Succeed Again. New York: Cambridge University Press, 2001.

Flyvbjerg, B., T. Landman, and S. Schram, eds. Real Social Science: Applied Phronesis. New York: Cambridge University Press, 2012.

Folke, C. "Resilience: The Emergence of a Perspective for Social-Ecological Systems Analyses." Global Environmental Change 16(3) (2006): 253–267.

Folke, C., F. Berkes, and J. Colding. "Ecological Practices and Social Mechanisms for Building Resilience and Sustainability." In Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience, edited by F. Berkes and C. Folke, 414–436. Cambridge, UK: Cambridge University Press, 1998.

Greenwood, D.J., and M. Levin. Introduction to Action Research: Social Research for Social Change. 2nd ed. Thousand Oaks, CA: Sage, 2007.

Gunderson, L.H., and C.S. Holling, eds. Panarchy. Washington, DC: Island Press, 2002.

Harding, S. "Should Philosophies of Science Encode Democratic Ideals?" In Science, Technology, and Democracy, edited by D.L. Kleinman, 121–138. Albany: State University of New York Press, 2000.

Irwin, A. Citizen Science: A Study of People, Expertise, and Sustainable Development. London: Routledge, 1995.

Jones, P., D. Selby, and S. Sterling, eds. Green Infusions: Embedding Sustainability across the Higher Education Curriculum. London: Earthscan, 2010.

Kagawa, F., and D. Selby, eds. Education and Climate Change: Living and Learning in Interesting Times. London: Routledge, 2010.

Kaufman, S., and J. Smith. "Framing and Reframing in Land Use Change Conflicts." Journal of Architectural and Planning Research 16(2) (1999): 164–180.

Keen, M., V.A. Brown, and R. Dyball. Social Learning in Environmental Management: Towards a Sustainable Future. London: Earthscan, 2005.

Klein, J. T. "Integration, Evaluation and Disciplinarily." In Transdisciplinarity: Recreating Integrated Knowledge, edited by M. Somerville and D. Rapport, 49–59. Oxford, UK: EOLSS Publishers, 2000.

Krasny, M., C. Lundholm, and R. Plummer. "Resilience in Social-Ecological Systems: The Role of Learning and Education." Environmental Education Research 16(5/6) (2010): 475–491.

Levin M. "Cross-Boundary Learning Systems—Integrating Universities, Corporations, and Governmental Institutions in Knowledge Generating Systems." Systemic Practice and Action Research 17(3) (2004): 151–159.

Lewin, K. "Action Research and Minority Problems." Journal of Social Issues 2 (1946): 34–46.

Martens, P., N. Roorda, and R. Cörvers. "Sustainability, Science and Higher Education: The Need for New Paradigms." Sustainability: The Journal of Record 3(5) (2010): 294–303.

Marquardt, M.J. Action Learning in Action. Palo Alto, CA: Davies-Black, 1999.

Marrow, A.J. The Practical Theorist: The Life and Work of Kurt Lewin. New York: Basic Books, 1969.

Mathews, D. Politics for People: Finding a Responsible Public Voice. 2nd ed. Urbana: University of Illinois Press, 1999.

Maxwell, N. From Knowledge to Wisdom: A Revolution for Science and the Humanities. London: Pentire Press, 2007.

Mezirow, J. "An Overview on Transformative Learning." In Contemporary Theories of Learning. Learning Theorists . . . in their Own Words, edited by K. Illeris, 90–105. London: Routledge, 2009.

Mezirow, J., and E.W. Taylor, eds. Transformative Learning in Practice: Insights from Community, Workplace, and Higher Education. San Francisco: Jossey-Bass, 2009.

Miller, T.R., T.D. Baird, C.M. Littlefield, G. Kofinas, F. Chapin, III, and C.L. Redman. "Epistemological Pluralism: Reorganizing Interdisciplinary Research." Ecology and Society 13(2) (2008): 46.

Mills, C.W. The Sociological Imagination. New York: Oxford University Press, 1959.

Mochizuki, Y., and Z. Fadeeva. "Regional Centres of Expertise on Education for Sustainable Development (RCEs): An Overview." International Journal of Sustainability in Higher Education 9(4) (2008): 369–81.

Pahl-Wostl, C., and M. Hare. "Processes of Social Learning in Integrated Resources Management." Journal of Community and Applied Social Psychology 14(3) (2004): 193–206.

Peters, S.J. Democracy and Higher Education: Traditions and Stories of Civic Engagement. Lansing: Michigan State University Press, 2010.

Peters, S.J., N.R. Jordan, M. Adamek, and T.R. Alter, eds. Engaging Campus and Community: The Practice of Public Scholarship in the State and Land-Grant University System. Dayton, OH: Kettering Foundation Press, 2005.

Posch, P. "Environment and School Initiatives." In Environment, Schools and Active Learning, edited by K. Kelly-Laine and P. Posch, 13–18. Paris: OECD, 1991.

Röling, N.G., and M.A.E. Wagemakers, eds. Facilitating Sustainable Agriculture: Participatory Learning and Adaptive Management in Times of Environmental Uncertainty. New York: Cambridge University Press, 1998.

Sanera, M., and J. Shaw. Facts, Not Fear: A Parent's Guide to Teaching Children about the Environment. Washington, DC: Regnery, 1996.

Siemens, G. "Connectivism: Learning as Network-Creation." ASTD Learning News 10(1) (2005).

Smith, G.A. Defusing Environmental Education: An Evaluation of the Critique of the Environmental Education Movement. Milwaukee: Center for Education Research, Analysis, and Innovation, University of Wisconsin–Milwaukee, 2000. Accessed September 7, 2012. http://epsl.asu.edu/epru/documents/cerai-00-11.htm.

Soeder, D.J., and W.M. Kappel. "Water Resources and Natural Gas Production from the Marcellus Shale." U.S. Geological Survey Fact Sheet 2009–3032. Accessed March 6, 2009. http://pubs.usgs.gov/fs/2009/3032.

Somerville, M.A. and D.J. Rapport, editors (2000) Transdisciplinarity: reCreating Integrated Knowledge. Oxford: EOLSS Publishers Co. Ltd.

Tschakert, P., and K.A. Dietrich. "Anticipatory Learning for Climate Change Adaptation and Resilience." Ecology and Society 15(2) (2010): 11.

Unterhalter, E., and V. Carpentier. Global Inequalities and Higher Education: Whose Interests Are We Serving? New York: Palgrave Macmillan, 2010.

Wals, A.E.J. "Epilogue: Creating Networks of Conversations." In Social Learning Towards a Sustainable World, Edited by Arjen E.J. Wals, 497–507. Wageningen, Netherlands: Wageningen Academic Publishers, 2007.

Wals, A.E.J. "Message in a Bottle: Learning Our Way Out of Unsustainability." Address upon accepting a professorship and UNESCO chair in Social Learning and Sustainable Development, May 27, 2010, Wageningen University. Accessed September 7, 2012. http://groundswellinternational.org/2010/12/14/message-in-a-bottle-learning-our-way-out-of-unsustainability/.

Wals, A.E.J., and J. Blewitt. "Third Wave Sustainability in Higher Education: Some (Inter)national Trends and Developments." In Green Infusions: Embedding Sustainability

across the Higher Education Curriculum, edited by P. Jones, D. Selby, and S. Sterling, 55–74. London: Earthscan, 2010.

Wals, A.E.J., and F.V. Heymann. "Learning on the Edge: Exploring the Change Potential of Conflict in Social Learning for Sustainable Living." In Educating for a Culture of Social and Ecological Peace, edited by A. Wenden, 123–145. Albany: State University of New York Press, 2004.

Wals, A.E.J., and B. Jickling. "'Sustainability' in Higher Education, from Doublethink and Newspeak to Critical Thinking and Meaningful Learning." Higher Education Policy 15 (2002): 121–131.

Wals, A.E.J., N. van der Hoeven, and H. Blanken. The Acoustics of Social Learning: Designing Learning Processes that Contribute to a More Sustainable World. Utrecht/Wageningen, Netherlands: SenterNovem/Wageningen Academic Publishing, 2009.

Wilson, E.O. Consilience: The Unity of Knowledge. New York: Vintage Books, 1998.

Chapter 5

Inquiry, Models, and Complex Reasoning to Transform Learning in Environmental Education

Barbara A. Crawford and Rebecca Jordan

In this chapter, we bring together our different perspectives as a science education researcher and an ecological researcher to address the question, How can learners engage in environment-related investigations through the common lens of modeling as a practice? We begin by highlighting the conceptions of environmental, ecological, and scientific literacy, which also feature inquiry. We present two contrasting cases in which upper elementary and middle school students engaged in model-based reasoning. We posit that an understanding of models and modeling would position children and adults to have a better appreciation of the tools and products of an ecologist or environmental scientist. An emphasis on the process and nature of modeling could serve as a window into a learner's own thinking. We conclude with a broader consideration of cognitive theory and future research directions. The process of working across our two disciplines evolved as we first searched to find a common research focus. We discussed what it might mean to be transformative. Surprisingly, we discovered quite easily our common focus: one that is centered on models and modeling. We then evolved a two-part commentary, as each of us developed our own case illustrating the process and significance of models in the context of our own work. Finally, we worked towards finding a unified voice.

Achieving a scientifically literate citizenry presents a major challenge to environmental education. In this chapter we argue for merging evidence-