Weaving Traditional Ecological Knowledge into Biological Education: A Call to Action

ROBIN WALL KIMMERER

As scientists and educators, we train our students to thoroughly examine all the available evidence and to consider alternative explanations for biological phenomena. In peer review, we critically assess whether the author has carefully cited the appropriate primary sources. And yet, in our biology curricula, we are perhaps unknowingly ignoring an entire body of knowledge that has potential significance to contemporary science and policy: traditional ecological knowledge (TEK).

Indigenous peoples are the stewards of fully 4 percent of the land area of the United States and represent some 700 distinct communities possessing detailed knowledge of the biota of their homelands. Native American land holdings in North America collectively contain more wildlands than all of the national parks and nature conservancy areas in North America (Nabhan 2000). Globally, indigenous peoples inhabit areas with some of the highest remaining biodiversity on the planet (Durning 1992) and are actively engaged as partners in biodiversity conservation (Weber et al. 2000). Issues of sustainable development, resource management, and ecological restoration all include Native American stakeholders. Federal agencies are required to consult with tribes on a government-to-government basis on a host of scientific and natural resource policies. Thus, college biology graduates have a high probability of encountering issues involving indigenous cultures and TEK. However, the majority of scientific professionals and educators have little understanding of the value of TEK or its cultural context.

Traditional ecological knowledge is increasingly being sought by academics, agency scientists, and policymakers as a potential source of ideas for emerging models of ecosystem management, conservation biology, and ecological restoration. It has been recognized as complementary and equivalent to scientific knowledge (Colorado and Collins 1987, Corsiglia and Snively 1995, Salmon 1996, Richards 1997, UNEP 1998, Berkes et al. 2000). Indeed, the United Nations Convention on Biodiversity calls for recognition, protection, and utilization of TEK. Researchers in pharmaceutical laboratories and in agricultural experiment stations worldwide are beginning to recognize the knowledge of indigenous peoples in scientific research. New directions in applied biology that have direct parallels and precedents in traditional knowledge include ecosystem management, medicine, pharmacology, agroecology, wildlife, fisheries, and animal behavior. Biological research is moving to explore these approaches, yet acknowledgment or understanding of traditional ecological knowledge is rare in the scientific community. Most college ecology courses begin a history of the discipline with 19th-century Europe, neglecting the highly sophisticated precedents in indigenous knowledge systems. My goal in this article is to present the case that exposure to TEK has a legitimate role in the education of the next generation of biologists, environmental scientists, and natural resource managers. Traditional ecological knowledge has value not only for the wealth of biological information it contains but for the cultural framework of respect, reciprocity, and responsibility in which it is embedded (Kimmerer 1998, Pierotti and Wildcat 2000).

What is traditional ecological knowledge?

Traditional ecological knowledge refers to the knowledge, practice, and belief concerning the relationship of living beings to one another and to the physical environment, which

Robin Wall Kimmerer (Citizen Potawatomi) (e-mail: rkimmer@esf.edu), a plant ecologist, is an associate professor of environmental and forest biology at the College of Environmental Science and Forestry, State University of New York, Syracuse, NY 13210. She has an active research program in the ecology and restoration of plants of cultural significance to native peoples.

is held by peoples in relatively nontechnological societies with a direct dependence upon local resources (Berkes 1993). Traditional ecological knowledge is not unique to Native American culture but exists all over the world, independent of ethnicity. It is born of long intimacy and attentiveness to a homeland and can arise wherever people are materially and spiritually integrated with their landscape (Kimmerer 2000). TEK is rational and reliable knowledge that has been developed through generations of intimate contact by native peoples with their lands (Mauro and Hardison 2000). TEK is being recognized as having equal status with scientific knowledge (UNEP 1998) and has been termed the "intellectual twin to science" (DeLoria 1995). This long intellectual tradition exists in parallel to Western science, yet has been historically marginalized by the scientific community (Salmon 1996).

Traditional knowledge has much in common with scientific ecological knowledge (SEK), which is not surprising since both traditions derive from the same source: systematic observations of nature. Both knowledge systems yield detailed empirical information of natural phenomena and relationships among ecosystem components. Both SEK and TEK have predictive power, and in both intellectual traditions, observations are interpreted within a particular cultural context.

Traditional knowledge encompasses a wide range of biological information, which overlaps significantly with the content of a mainstream course in ecology or conservation biology. The scope of traditional ecological knowledge includes detailed empirical knowledge of population biology, resource assessment and monitoring, successional dynamics, patterns of fluctuation in climate and resources, species interactions, ethnotaxonomy, sustainable harvesting, and adaptive management and manipulation of disturbance regimes (Berkes 1999). Case histories of the utility of TEK in conservation biology span a range of biomes from the tundra to the tropical rainforest (Williams and Baines 1993, Berkes et al 1995, Fernandez-Gimenez 2000, Gadgil et al 2000). Should not our students learn to access and evaluate this valuable source of long-term ecological information?

Traditional ecological knowledge differs from scientific ecological knowledge in a number of important ways. TEK observations tend to be qualitative, and they create a diachronic database, that is, a record of observations from a single locale over a long time period. The National Science Foundation, in its support of the Long-Term Ecological Research program, has validated the importance of such continuous data. In TEK, the observers tend to be the resource users themselves, for example, hunters, fishers, and gatherers whose harvesting success is inextricably linked to the quality and reliability of their ecological observations. In contrast, scientific observations made by a small group of professionals tend to be quantitative and often represent synchronic data or simultaneous observations from a wide range of sites, which frequently lack the long-term perspective of TEK. Additional differences between scientific knowledge and traditional knowledge are described in Berkes (1993).

The amazing red corn is Tarahumara maiz rojo. Photograph: Native Seeds/SEARCH, Tucson.

Some of 60 different chili varieties richly diverse in color, shape, size, and heat grown at the Conservation Farm in Patagonia, Arizona. Photograph: Native Seeds/SEARCH, Tucson.

Western science is conducted in an academic culture in which nature is viewed strictly objectively. In this aspect, TEK diverges significantly from Western science (Pierotti and Wildcat 2000). TEK is much more than the empirical information concerning ecological relationships. Unlike SEK, traditional knowledge is woven into and is inseparable from the social and spiritual context of the culture. Traditional knowledge can rival Western science as a body of empirical information, but traditional knowledge may also extend its explanatory power beyond the strictly empirical, where science cannot go. TEK is laden with associated values, while the scientific community prides itself on data that are "value free." TEK includes an ethic of reciprocal respect and obligations between humans and the nonhuman world. In indigenous science, nature is subject, not object. Such holistic ways of understanding the environment offer alternatives to the dominant consumptive values of Western societies (Berkes 1999, Hunn 1999). Embraced as an equal partner to the power of Western science, TEK offers not only important biological insights but a cultural framework for environmental problem solving that incorporates human values.

Gadgil and colleagues (1993, p. 151) wrote, "Modern scientific knowledge, with its accompanying worldview of human beings apart from and above the natural world, has been extraordinarily successful in furthering human understanding and manipulation of simpler systems. However, neither this worldview nor scientific knowledge has been particularly successful when confronted with complex ecological systems.... It is in this context that traditional ecological knowledge is of significance."

Why include traditional ecological knowledge in biological education?

A basic tenet of biology is that diversity is the raw material of evolution. Without adequate diversity, adaptation to changing environments is not possible, and extinction ensues. Similarly, intellectual diversity fuels the evolution of cultures and their ability to adapt to a changing world. The adoption of a single mode of thinking based on a materialistic view of nature has contributed to serious environmental degradation. The complex issues of environmental sustainability require a diversity of intellectual approaches and can benefit from a thoughtful consideration and incorporation of traditional ecological knowledge.

Traditional knowledge represents an intellectual tradition of generating, validating, and interpreting information about relationships in the natural world. As such, it is of intrinsic value to scientists. However, this extensive body of knowledge has great applied value as well. An extensive review of the applications of TEK is beyond the scope of this paper. The recent collections by Berkes (1999) and Ford and Martinez (2000) provide an excellent introduction. However, the following overview offers a glimpse of the depth and breadth of TEK and how it may be incorporated productively into Western science education.

Traditional ecological knowledge can be a source of new biological insights and potential models for conservation biology and sustainable development. The World Conservation Union (IUCN) recognizes the practical significance of TEK to contemporary sciences such as ecology, conservation biology, pharmaceutical botany, forestry, and fish and wildlife sciences. An IUCN report (IUCN 1986) lists the following arenas in which TEK can prove useful to science and environmental applications: new biological insights, resource management, conservation education, reserve design and management, development planning, environmental assessment, and commodity development. TEK also has strong potential for informing the science of ecological restoration (Martinez 1994, Kimmerer 2000). Ford (2001) suggests that TEK plays a vital role in ecological monitoring by providing early warning signs of ecosystem change.

Traditional ecological knowledge is not restricted to the biology of subsistence activities but includes detailed observations of population ecology and species interactions, which arise from long-term association with a particular flora and fauna. These kinds of observations can be extremely valuable in validating scientific hypotheses and suggesting new research directions. For example, Nakashima (1993) compares the extent of information about Hudson Bay eider collected by wildlife biologists with the traditional knowledge of eider gathered by Inuit hunters. The Inuit knowledge had been dismissed as unreliable "Eskimo reports." After interviews with Inuit hunters, it became apparent that the knowledge of Inuit hunters far exceeded that of the wildlife biologists. Traditional knowledge of the Inuit contained information new to science on range, winter behavior, mortality, and demography of the eider. TEK has been shown to provide accurate and reliable species information, and therefore effective management, in a growing number of cases, including fisheries (Berkes 1977), caribou age structure (Mander 1991), census of bowhead whales (Huntington et al. 1999), forest fungi (Richards 1997), wolves (Stephenson 1982), and food plants (Anderson 1996, Turner et al. 2000).

Knowledge of species interactions may be documented in sources unfamiliar to scientists, but valid nonetheless. Nabhan (1997) presents a translation of an ancient O'Odham song, which describes, in detail, the behavior of a hawk moth feeding on *Datura metaloides.* Centuries after its first description, this same interaction was analyzed by professional biologists (Grant and Grant 1965), who were perhaps unaware of the precedent in the oral tradition. Indigenous languages can encode significant information concerning species interactions. Nabhan (2000) suggests that biological information embedded in indigenous languages may be valuable in conservation biology. Songs, poems, and stories that exist in the oral tradition may be of great value in validating and expanding scientific understanding. The scientific richness of the oral tradition forces scientists to confront assumptions concerning the validity of this traditional information, which has typically been marginalized by scientists. The wealth of ecological information in native languages, many of which are nearly extinct, supports the link between conservation of biodiversity and conservation of cultural diversity (Maffi 1999).

Exploration of traditional ecological knowledge offers not only a host of new biological insights but also opportunities for cross-validation of scientific hypotheses. Indigenous observations can offer concrete evidence for contemporary interpretations of patterns in nature. Deloria (1995) documents that the oral tradition of many tribes contains accurate information on past geologic events, such as floods, tsunamis, and earthquakes, that can validate contemporary hypotheses. There are well-documented instances where TEK offers significant predictions of natural patterns well in advance of scientific explanations, for example, the prediction of El Niño events by Andean peoples (Orlove et al. 2000).

Examination of traditional ecological knowledge explicitly brings multicultural perspectives into the core of the science curriculum, where they have generally been absent. As educators have come to understand the growing importance of cultural diversity in academia, development of cross-cultural competence is being integrated into university curricula all over the country. In general, such integration takes place outside the mainstream science curriculum, usually in the humanities and social sciences. The lack of integration of cross-cultural competence with science implies to our students that cross-cultural perspectives have little application to the sciences. Exposure to traditional knowledge in biology classes offers an opportunity to bring much-needed multicultural perspectives directly into the science curriculum. As educators, it is our responsibility to prepare ourselves and our students to participate productively in a complex, multicultural scientific community.

Western science also takes place in a cultural context, of which students and practitioners of science are often unaware. The exercise of examining environmental relations from a cross-cultural perspective not only deepens awareness of another culture but also provides mainstream students with insights into the cultural assumptions underlying their own intellectual tradition of Western science and technology.

Recognition of traditional ecological knowledge increases opportunities for productive partnerships between Western scientists and indigenous people. Understanding of traditional knowledge can foster creative collaborations between indigenous and local peoples and tribal governments and Western environmental scientists, nongovernment organizations (Weber et al. 2000), policymakers, and natural resource managers. Many case histories document such cooperation, such as the biocultural restoration work of the Indigenous Peoples Restoration Network, the Intertribal Bison Cooperative, wolf restoration in Nez Perce territory (Robbins 1997), and Peoples Biodiversity Registers Program (Gadgil et al. 2000). Nabhan (2000) proposes partnerships with indigenous peoples to integrate their extensive knowledge bases for endangered species recovery efforts.

Incorporation of traditional ecological knowledge into the curriculum can increase the participation of Native American students and practitioners in the scientific community. Native Americans are the most underrepresented group in the American scientific community and are "barely a presence in science," according to a report of the National Science Foundation (Levy 1992). A 1991 study found a "consistent and nearly complete absence of American Indian faculty members in science and engineering" (Levy 1992). Native American students encounter serious challenges in the alien culture of a mainstream academic community. In many cases, the culture of science is perceived as unwelcoming, exclusionary, and hostile to traditional ways of knowing. Scholars of Native American education emphasize that educational programs must resonate with cultural values (Cajete 1994). Incorporation of TEK into science curricula not only broadens the horizons of students from the dominant culture but also can validate and encourage the inclusion of native students.

Traditional ecological knowledge integrates scientific and cultural concerns in a holistic manner. In a commentary on scientific education, Aldo Leopold lamented the division between training in science and the humanities (Kessler and Booth 1998). He argued that both were essential as guides to environmental conservation. Complex scientific questions benefit from a diversity of problem-solving approaches, and traditional reductionist science often falls short in explaining dynamic, multidimensional systems and human interactions with nature (Bekoff 2000). The need for integrative thinking was pointed out in the plenary session of the year 2000 meeting of the American Institute of Biological Sciences, in which eight of America's most prominent biologists identified the challenges that lie ahead for science. Nearly all the presenters identified the integration of social and cultural concerns as a major new direction for scientists. Edward O. Wilson noted that the widely perceived "fault line" between natural sciences and humanities is, in fact, no division at all, "just a broad domain of poorly understood material phenomena awaiting cooperative investigation from both sides" (Ben-Ari 2000). In order to make science more attractive to students and to increase our success in analyzing complex systems, Bekoff (2000) calls for "holistic, heart-driven" science that is "impregnated with spirit and compassion" and "acknowledges the full spectrum of human–nature interrelationships."

Traditional ecological knowledge, as an intellectual partner to Western science, offers a model for just such integration. In indigenous epistemology, a thing is understood only when it is understood with all aspects of human experience, that is, the mind, body, emotion, and spirit (Cajete 1994). Western scientific education gives privileged status to objective information only and specifically excludes emotional and spiritual dimensions. Traditional knowledge recognizes the different strengths of multiple understandings and explicitly incorporates the cultural experience of the observer into interpretation of the natural world. TEK is highly rational, empirical, and pragmatic, while simultaneously integrating cultural values and moral perspectives. With its worldview of respect, responsibility, and reciprocity with nature, TEK does not compete with science or detract from its power but extends the scope of science into human interactions with the natural world.

How can traditional ecological knowledge be incorporated into mainstream biology education?

There are various approaches by which traditional knowledge can be incorporated into mainstream science teaching, as exemplified by the small but growing number of course offerings at universities and tribal colleges. Approaches include entire courses dedicated to TEK, individual exercises in lab and classroom, or incorporation of examples into the lecture materials of existing courses, such as general biology and ecology.

University courses with an anthropological focus may include traditional ecological knowledge and can be valuable in interpreting the cultural context of TEK. However, the number of science majors in such classes is generally low. Thus, if biology students are to be exposed to TEK, it should be in the context of their training as scientists, rather than a peripheral, elective offering.

There are several good examples of science-based classes that explicitly focus on the contributions of TEK to environmental biology and natural resource management. Traditional knowledge is the centerpiece of a course at Oregon State University, "Ecosystem Science of Pacific Northwest Indians." The course represents a partnership between tribal members and OSU educators and is designed to compare Western scientific and Northwest Indian perspectives on ecosystem management.

At SUNY (State University of New York), I offer a course called "Land and Culture," which is designed for an audience of environmental biology majors. Using case studies, students compare the perspectives of indigenous communities with those of Western scientists on topical science and policy issues. Case studies have a high biological content and include wildlife biology, salmon restoration, conservation biology, agroecosystems, forest management, fire ecology, and ethnobotany. Students examine how cultural context influences research questions, interpretation of research results, and development of management alternatives. In a simulated public hearing, students are asked to represent the positions of multiple stakeholders, including indigenous communities and scientists. Reading and responding to primary documents from multiple perspectives gives students a hands-on appreciation for the complexities of interpreting science in a cross-cultural context. Throughout the course, students are provided with primary documents for each case study: reports, scientific papers, news stories, court cases, as well as information from non-Western, nonscientific perspectives.

Concepts of traditional ecological knowledge may also be readily interwoven with existing course offerings. For example, I designed a laboratory exercise for general botany that takes place in a Three Sisters garden planted for the class's use. The traditional Iroquois polyculture of corn, beans, and squash—the Three Sisters—provides an opportunity for students to learn basic botanical and ecological concepts in the context of a sophisticated agricultural system developed by the indigenous people of our region. Students compare yields of monoculture and polyculture plots, learn comparative plant morphology, concepts of symbiosis, nutrient cycling, and niche partitioning in the traditional garden. The garden serves as the manifestation of TEK and provides an opportunity to learn plant science in a cross-cultural context.

Tribal colleges can lead the way in integrating traditional ecological knowledge and scientific ecological knowledge. Tribal college faculty should be engaged as partners in an effort to design courses that incorporate TEK into university courses. For example, at Salish Kootenai College (SKC), Haskell Indian Nations University, Dine College, and other colleges, students routinely consider traditional knowledge in parallel with mainstream scientific knowledge. For example, in systematics lectures at SKC, an array of alternative taxonomic systems are presented for analysis by the class. Indigenous plant names are often descriptive of associated ecological interactions and offer valid alternative ways of categorizing biodiversity. Students can compare the origins and utility of the Linnaean system with indigenous classification schemes based on use, morphology, or habitat (Pat Hurley, [Salish Kootenai College], personal communication, April 2001). Through cross-cultural comparisons, students come to understand that all classification systems, Western and indigenous, are influenced by the observations available and respond to particular cultural needs. Consideration of alternative interpretations trains students to think critically rather than passively accept a familiar paradigm.

The opportunities to enrich our class presentations with TEK are rich and varied. I have found that students receive cross-cultural views with great enthusiasm. I routinely incorporate Native American stories and examples of traditional practices into biology lectures. The oral tradition of TEK offers a detailed prescription for "living in place" and includes both empirical and metaphorical elements. Many indigenous stories arose as vehicles for teaching and have great value in the classroom. In my experience, stories provide a memorable context that helps students retain information and integrate it with their own experience. The rich literature of published Native American stories provides a wealth of examples to draw upon. Traditional stories may also contain valuable biological insights. For example, Pierotti and Wildcat (2000) report on the relation between indigenous stories of Badger and Coyote hunting together and the empirical verification of cooperation between predators (Minta et al. 1992).

Traditional ecological knowledge incorporates the historical and contemporary role of human beings in shaping communities and landscapes. Most biology courses use local ecosystems as case studies for teaching biological concepts, and nearly every university in the country is located on the ancestral lands of indigenous peoples. The original inhabitants played a significant role in influencing the local biota and landscape pattern through manipulation of fire frequencies, hunting and fishing practices, and vegetation management (Anderson 1996). Interpreting the local landscape in light of traditional resource management practices is an excellent means of incorporating TEK into biology classes. Evaluation of traditional land use practices can be valuable in teaching concepts of successional dynamics, ecosystem management, and evolutionary biology.

Native scholars and practitioners of traditional ecological knowledge are authoritative primary sources to bring TEK into the classroom as guest speakers. At Oregon State University, the course "Ecosystem Science of Northwest Indians" is cotaught by native scientists. At SUNY, College of Environmental Science and Forestry, we have been fortunate in bringing Native American leaders to campus through our Native American Visiting Scholars Program, funded by the US Department of Agriculture. Local Native American communities and tribal colleges may be of assistance in locating appropriate speakers. The American Indian Science and Engineering Society maintains a list of Native American scientists and educators and has chapters on many college campuses.

Other tribal resources include a wide array of intertribal scientific and natural resource management organizations whose publications provide excellent current cases in which Western and indigenous science are being integrated in practice. Such organizations include the Great Lakes Intertribal Fish and Wildlife Commission, Intertribal Bison Cooperative, Intertribal Timber Council, Columbia River Intertribal Fish Commission, and California Indian Basketweavers Association, among many others.

Protection and appropriate use of traditional ecological knowledge

Consistent with a call to introduce science students to the validity and value of traditional ecological knowledge, such education should be inseparable from a serious discussion of protection of traditional knowledge from exploitation. TEK represents the collective intellectual contributions of indigenous peoples, accumulated and systematized over millennia. The identity of the practitioners, informants, and the community should always be fully referenced and acknowledged with the same diligence that scientists apply to the contributions of their academic colleagues.

Protection of traditional ecological knowledge has often been framed in terms of intellectual property rights (Brush 1996, Posey 1996), which are intended to ensure equitable benefits from the use of TEK. However, the ethical question goes beyond appropriate monetary compensation for use of knowledge. Mauro and Hardison (2000) review policy initiatives that regulate access to TEK and institutionalize equal participation with indigenous peoples. Indigenous control over TEK is essential to cultural survival for the people who have generated and maintained this knowledge (Wavey 1993). Some tribes have designed educational and research guidelines to educate scientists interested in working with Native American communities to protect the rights of the indigenous peoples; an excellent example is the Akwesasne Task Force on the Environment (Akwesasne Task Force on the Environment 1996).

Misappropriation of traditional ecological knowledge can lead to adverse consequences, such as resource exploitation and misuse of knowledge. Professional guidelines for respectful use of TEK have been developed by a number of organizations (Mauro and Hardison 2000, Weber et al. 2000) and should be consulted. It is vital to respect the privileged, private nature of some kinds of ceremonial information, and use only the information disseminated in reliable sources. Permission of the community should be sought whenever possible.

TEK exists in a particular cultural and ecological context and should be presented in relation to that intellectual tradition. Respectful use of traditional ecological knowledge in education calls for thoughtful consideration of the cohesive, internally consistent worldview to which it belongs. It may be tempting to extract "data" from TEK and import it to the more familiar context of Western science. For example, the traditional use of fire could be taught simply as data on vegetation response to fire. There is clear merit in including such data. But we do a disservice to our students and to the intellectual tradition of TEK if we don't also consider the cultural framework of fire. In indigenous culture, wise application of fire represents not only ecological understanding of successional dynamics but also embodies the spiritual responsibility for participation in land stewardship.

I have found students to be hungry for an approach to understanding nature that includes both science and cultural values and spirituality. After almost every presentation linking traditional knowledge to science education, students come forward to express appreciation and to voice their frustration that their scientific curriculum allows no room for cultural concerns, even denies the validity of such concerns. A number of very capable students tell the story of abandoning their science education and a potential place in the scientific community, because of the perception that science prohibits the expression of personal connection to nature. At a time when our ecosystems are threatened by imbalance between humans and nature, we cannot afford to discourage such students from membership in the scientific community.

Stepping outside our own cultural and educational framework is exceedingly difficult—difficult, but worthwhile. As we seek to redefine our evolving relationship with nature, the knowledge systems of indigenous people can provide useful models. But the goal is not to appropriate the values of indigenous peoples. As an immigrant culture, Americans must start to engage in their own process of becoming indigenous to this place and regain their roles as members of the ecological community. If bringing traditional ecological knowledge to its rightful place in science education can move us toward that goal, then we will all be richer for the effort.

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